

Fish

Why Are Fish Important?

Fish are important natural resources that have ecological, economic, and cultural significance in Washington. Pacific salmon and trout are good indicators of a properly functioning aquatic ecosystem because they require cool, clean water, complex channel structures and substrates, and low levels of fine sediment (Bjorn and Reiser 1991). Pacific salmon are an important source for transporting marine nutrients from salt water across ecosystem boundaries to freshwater and terrestrial ecosystems (Cederholm and others 1999). Salmon and steelhead always have occupied a central position in the Pacific Northwest culture and economy. They play a role in freshwater and riparian ecosystems as well as predators and prey in food webs and they also provide nutrients to terrestrial vegetation (Gende and others 2002). Habitat that is capable of supporting healthy fish populations is an important goal of the 1997 *Habitat Conservation Plan* (HCP).

The highest diversity of freshwater fish on the Olympic Peninsula occurs within the OESF (Mongillo and Hallock 1997). Seventeen species of non-game fish, including lampreys, minnows, suckers, and sculpins share those waters with nine resident or anadromous salmonid species. While several of the anadromous salmonids play central ecological and economic roles in the western Olympic Peninsula, those other species are also important ecologically.

Current Conditions for Fish

In general, freshwater environments in the OESF have been less affected by humans than elsewhere in the Pacific Northwest. However, human populations around the OESF exist at a low density, no rivers are dammed, the headwaters of most major rivers are preserved in the Olympic National Park, and little

agricultural, commercial, or residential development has occurred in floodplains.

Most of the riparian areas in the OESF have been subject to timber harvest activities (McHenry and others 1998). Early logging techniques during the 19th and 20th century were destructive, altering stream morphology, removing large woody debris, and increasing sediment delivery (Seddell and Luchessa 1982). In the 1940s, log trucks were used, resulting in road construction throughout the basins in steep terrain. The early roads caused large landslides and debris flows (Cederholm and others 1981; Swanson and others 1997).

Harvests peaked in old-growth dominated forests between the mid-1960s and late 1980s when over one billion board feet were harvested near the Forks area on DNR-managed lands, the Olympic National Forest, and private forest lands. Many of the extensive roads needed for this level of harvest crossed steep and unstable slopes, which resulted in dramatic increases in landslides and debris flows. During this period, the State of Washington developed its first Forest Practices Rules. The Rules have continually evolved since then, with a goal of improving protection to salmonid habitat; however, the legacy of historical harvest practices continues to negatively affect fish habitat in some areas.

Text Box 3-6. Salmon Definitions

Salmonids: Fish belonging to a group that includes salmon, trout, and char. This group belongs to the family *Salmonidae*.

Anadromous salmonid: Salmon that divide their lives between freshwater and the ocean. They are born in freshwater, mature at sea, and return to their natal streams to spawn a new generation.

Resident salmonid: Salmon that spend their entire lives in freshwater.

In 1998, the Washington State Legislature commissioned a comprehensive assessment of habitat factors limiting salmon and steelhead populations statewide. Those mostly qualitative assessments were based on information from regional experts (Smith 2000; Smith and Caldwell 2001). A tabular summary of limiting factors and habitat restoration priorities recommended in those reports provides an informative overview of current conditions of key salmonid habitat components across all ownerships in the OESF (Table 3-58).

A limiting-factor analysis is focused on human-controlled modification or destruction of saltwater and near-shore habitats and the changes to ecological processes that affect those habitats. DNR has directly-measured data available to summarize two key limiting factors: mapped stream segments where high temperatures preclude healthy salmonid habitat, and mapped locations where roads impede fish passage. Large forest landowners were required to have all roads within their ownership covered under Forest Practices-approved Road Maintenance and Abandonment Plans (RMAPs) by July 1, 2006, which included identification of all road-related barriers to fish passage and a schedule describing their repair by July 1, 2016.¹ On state trust lands in the OESF, DNR land managers identified 252 barriers and reported the repairs of 158 (63 percent) by the end of the 2009 construction season.

What Is the Current Distribution of Salmonids?

In the OESF, the distribution and status of populations of salmon and steelhead stocks are, in part, a reflection of the quality of their freshwater habitat that provides for spawning and egg incubation, juvenile rearing, migration of juveniles to saltwater, and adult migration to their spawning grounds. While habitat elements vary somewhat by species or stock², all of these fish need clean, cool water at a level capable of sustaining all their freshwater life stages, spawning riffles and pools, and functional riparian zones (refer to the *Riparian* section).

DNR manages forested state trust land in 28 watershed administrative units within the OESF, where the distribution and habitat use by eleven run-types³ of seven native salmonid species are mapped by Washington State Department of Fish and Wildlife (WDFW). The four salmon, and three trout include: coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*) sockeye (*O. nerka*), and chum salmon (*O. keta*); steelhead (*O. mykiss*) and cutthroat trout (*O. clarkii*); and bull trout (*Salvelinus confluentus*) (Table 3-59). Stream miles were based on Washington Department of Fish and Wildlife data (WDFW 2010).

¹ Chapter 222-24-051 Washington Administrative Code [WAC]

² **Fish stock** means a population of fish, including migratory species, which constitutes a coherent reproductive unit.

³ **Run-type** refers to the period in which spawning occurs: winter, spring, summer, or fall.

Table 3-58. Summary of Limiting Factors and Habitat Restoration Priorities

Watersheds draining to the Strait of Juan de Fuca	Floodplains	<ul style="list-style-type: none"> • Reduce riparian road impacts either by road abandonment or through better road surfacing. • Increase off-channel habitat, particularly in areas vulnerable to scour. • Increase large woody debris in areas of channel incision to allow sediments to accumulate for reconnection of the river to its floodplain. This is needed in the lower reaches of Lyre River, Deep Creek, Hoko River, and Sekiu River.
	Streambed Sediment	<ul style="list-style-type: none"> • Reduce sediment inputs, particularly from roads, railroad grades, and mass wasting sites. • Properly abandon roads that had used side-cast technology. • Cease deposition of spoils near streams (for example Murdock and Jim Creeks). • Increase large woody debris to aid in channel stability and gravel storage. • Stop the removal of in-stream large woody debris.
	Riparian Conditions	<ul style="list-style-type: none"> • Plant conifers in open riparian areas. • Thin hardwood riparian areas to allow conifer introduction. • Conserve areas of mid- to late-seral stage riparian forest. • Increase large woody debris to allow for pool habitat development.
	Water Quality	<ul style="list-style-type: none"> • Reduce sediment inputs into Deep Creek, Pysht River, Clallam River, Hoko River, Little Hoko River, and Sekiu River to lessen channel widening and pool filling. • Plant conifers in open riparian areas of all streams, and manage stand health to contribute to both shade and large woody debris needs in the long-term. • Reduce sources of turbidity, such as poorly surfaced roads. • Increase large woody debris where needed (refer to <i>Riparian</i> and <i>Stream Channel Conditions</i> sections). Large woody debris will help form pools that provide important thermal refuge for salmon. • Maintain the important thermal refuge function of Sonnybrook Creek in the Sekiu Basin.
	Water Quantity	<ul style="list-style-type: none"> • Increase large woody debris where needed to slow water velocity and create pools for thermal refuges important in low flow reaches. • Reduce summer water withdrawals from the Hoko River, especially in years of anticipated low flows, and maintain current summer flows in other streams.
Watersheds in the Quillayute and Hoh Basins, including Goodman and Mosquito Creeks	Floodplains	<ul style="list-style-type: none"> • Size new structures to reflect expected peak flows (100-year flows plus debris). • Address road-related blockages to salmon and steelhead habitat. • Clean streams affected by cedar spalts, which not only prevent salmon from accessing habitat, but also degrade water quality and biological productivity. Streams impacted by spalts include Winfield Creek, Braden Creek, Clear Creek, Nolan Creek, and Red Creek in the Hoh basin. Other basins needing cleaning are Sand Creek, Steamboat Creek, and Cedar Creek.
	Streambed Sediment	<ul style="list-style-type: none"> • Increase large woody debris in “poor” rated areas, and in the Hoh and Bogachiel off-channel habitat where clay seams have been accessed by channel incision. • Increase road drainage and re-route road sediments to the forest floor rather than to stream channels. • Decommission side-cast roads. • Improve road surfacing to reduce sediment inputs into streams.
	Riparian Conditions	<ul style="list-style-type: none"> • Plant conifers and native vegetation in open riparian areas. • Disturb streambanks as little as possible to avoid disruption of macro-invertebrate populations.

		<ul style="list-style-type: none"> • Increased protection is greatly needed for riparian areas prone to windthrow. Current windthrow data specific to the north coastal streams should be used to guide harvest in these areas. • Restore degraded riparian areas, recognizing that both <i>Habitat Conservation Plan</i> and new forest and fish regulations will provide guidance to create much better conditions. • Protect riparian areas surrounding wetlands to ensure groundwater recharge.
	Water Quality	<ul style="list-style-type: none"> • Increase instream large woody debris to aid in nutrient cycling (by retaining salmon carcasses) and pool development. • Improve riparian conditions to increase shade and decrease current high summer water temperatures. Restore and protect riparian conditions around wetlands. This will help maintain lower temperatures in waters that will recharge streams. • Address water quality problems in Lake Creek. This stream is important for salmon habitat, but is negatively affected by residential development, failing septic systems, water withdrawals, and other human impacts. • Address sediment sources to reduce channel widening and higher water temperatures.
	Water Quantity	<ul style="list-style-type: none"> • The water velocity in the Quillayute River needs to be reduced in peak flow events, and the Technical Advisory Group recommends using an engineered natural model to reduce water velocity. • Examine ways to reduce water rights within the Sol Duc basin.
Watersheds in the Queets basin, including Kalaloch Creek	Floodplains	<ul style="list-style-type: none"> • Maintain natural conditions in the delineated geologic floodplain in the Salmon and Queets Rivers. Protect floodplain habitat in other streams. • Maintain existing functional off-channel habitat, particularly in the Clearwater River, Lower Queets River, Sam's River, Lower Salmon, and Matheny Creek. • Restore lost or degraded off-channel habitat in the above areas.
	Streambed Sediment	<ul style="list-style-type: none"> • Address potential sediment sources from roads, especially roads with large fills or undersized culverts (those that do not meet 100-year flows plus debris). • Address other road sediment problems, including specific road decommissioning, stabilization, and improvements. This also includes removal of side-cast material. • Limit inappropriate removal of instream large woody debris. • Increase channel complexity. Utilize instream structures as an interim part of a broader restoration plan in appropriate areas.
	Riparian Conditions	<ul style="list-style-type: none"> • Plant conifers into hardwood riparian areas that were historically conifer and take out shade-tolerant trees to increase the size, abundance, and distribution of large conifers. • Identify funding, lands, and easement opportunities to purchase areas of mid- to late-seral stage (and older) riparian forests for conservation and protection, with higher priority given to older stands. • Protect riparian areas surrounding wetlands to ensure groundwater recharge. • Decrease and prevent the introduction of non-native plant species
	Water Quality	<ul style="list-style-type: none"> • Prioritize riparian restoration in open riparian areas of temperature-impaired streams.
	Water Quantity	<ul style="list-style-type: none"> • Maintain sufficient hydrologic maturity to limit the contribution of land management practices to increased peak flows and decreased hydrologic lag times. • Decrease artificial drainage (roads) to streams in the Queets Basin.

Table 3-59. Estimated Stream Miles Used by Native Salmonids, by Watershed Administrative Units

Watershed Administrative Units (stream miles)	Coho	Bull Trout	Fall Chinook	Fall Chum	Kokanee	Resident Cutthroat	Sockeye	Spring Chinook	Summer Chinook	Summer Steelhead	Winter Steelhead	Total	Total on DNR-managed Lands (percent of WAU Total)
Bogachiel	38	0	22	18	0	52	0	17	17	26	40	230	45 (20%)
Cedar	16	3	0	0	0	16	0	0	0	0	16	51	14 (27%)
Clallam River	19	0	0	12	0	17	0	0	0	0	19	67	31 (46%)
East Fork Dickey	69	0	18	16	0	42	0	0	0	0	30	174	60 (34%)
Goodman-Mosquito	35	11	2	0	0	56	0	0	0	0	35	139	51 (37%)
Hoko	52	0	33	35	4	37	0	0	0	0	52	213	24 (11%)
Kalaloch Ridge	7	2	0	2	0	--	0	0	0	0	7	18	2 (10%)
Lower Calawah	16	0	12	11	0	16	11	11	11	16	16	118	4 (4%)
Lower Clearwater	57	20	35	3	0	--	20	20	0	20	46	221	51 (23%)
Lower Dickey	23	0	16	11	0	33	0	0	0	0	21	103	24 (24%)
Lower Hoh River	56	24	27	25	0	46	18	18	19	19	40	291	34 (12%)
Lower Queets River	49	29	32	26	3	33	28	26	0	28	32	285	9 (3%)
Matheny Creek	18	9	8	1	0	37	0	0	0	0	20	94	26 (28%)
Middle Hoh	72	51	42	37	0	96	27	25	34	27	53	463	158 (34%)
North Fork Calawah	26	0	17	11	0	49	0	4	4	30	24	164	19 (12%)
Ozette Lake	90	0	5	19	25	93	47	0	0	0	83	362	28 (8%)
Pysht River	34	0	16	22	6	22	0	0	0	0	26	126	1 (0%)
Quillayute River	25	0	17	17	0	33	14	14	14	14	23	170	15 (9%)
Salmon River	28	16	11	6	0	38	0	0	0	0	21	121	10 (8%)
Sekiu	22	0	11	12	12	19	0	0	0	0	22	97	11 (12%)
South Fork Calawah	23	0	18	5	0	67	7	15	16	23	28	203	12 (6%)
Sol Duc Lowlands	58	0	26	20	0	46	19	19	19	19	32	256	24 (10%)
Sol Duc Valley	75	0	40	20	4	76	35	33	33	37	50	403	91 (23%)
Sooes	60	0	23	20	0	76	0	0	0	0	58	237	2 (1%)
Twin Rivers-Deep Creek	13	0	1	4	0	6	0	0	0	0	8	31	4 (12%)
Upper Clearwater	42	15	12	0	6	--	6	6	0	20	38	146	144 (98%)
Upper Sol Duc	40	5	13	0	10	64	9	12	13	40	38	245	9 (4%)
West Fork Dickey	83	0	16	21	0	58	0	0	0	0	46	224	29 (13%)
Total	1,274	287	524	398	75	1,330	287	257	227	431	1,057	6,147	933 (15%)
Total on DNR-managed Lands (percent of Species Total)	255 (20%)	50 (17%)	68 (13%)	34 (9%)	18 (24%)	208 (16%)	24 (8%)	26 (10%)	20 (9%)	48 (11%)	182 (17%)		

Source: ROPA.WDFW_FISHDIST_SV, 3/8/2010

What is the Current Status of Salmonids?

Salmon populations have diminished worldwide (Lackey 2008) and the history of their status, trends, and the variety of human impacts to them has been well-reviewed in both academic and popular literature (Lichatowich 1999; Montgomery and others 2003). Several classifications have been developed to examine the status of a given fish stock with listing under the federal *Endangered Species Act* considered the over-riding regulatory priority. The *Endangered Species Act* applies listing decisions to “distinct population segments,” called “evolutionarily significant units,” of salmonid stocks. In 2005, the U.S. National Marine Fisheries Service reviewed the status of “evolutionarily significant units” of selected species in the OESF and found that, except for the threatened Lake Ozette sockeye, an *Endangered Species Act* listing was “not warranted” (Good and others 2005).

The status of five sea-run and/or resident coastal cutthroat stocks (western Strait of Juan de Fuca, Ozette, Quillayute, Hoh, and Queets Coastal Cutthroat) remains unclassified due to insufficient data (Blakley and others 2000). None of the fish stocks assigned to the Olympic Peninsula evolutionarily significant units was

judged to be in current danger of extinction, nor likely to become so in the foreseeable future (Johnson and others 1999). Bull trout are listed as “threatened” under the U.S. Endangered Species Act. A 2005 U.S. Fish and Wildlife Service review described the status of bull trout stocks in 121 “core areas,” two of which are in the Hoh and Queets Rivers within the OESF. Populations in those areas were ranked “at risk” and “potential risk”, respectively, which indicate a medium-high and medium-low level of risk to their recovery (USFWS 2005).

Broadly speaking, the western Olympic Peninsula, including the OESF, hosts many of the healthiest salmon and steelhead stocks in the lower 48 states. The fish in these streams support thriving tribal and sport freshwater fisheries, managed jointly by Washington State Department of Fish and Wildlife and western Washington Tribes. The 2002 Salmon and Steelhead Inventory (SaSI), a detailed assessment of stock status and trends compiled by the Washington State Department of Fish and Wildlife, identified 65 salmonid stocks in the OESF and the majority were ranked “healthy”. Most of the remainder were ranked “unknown” due to lack of data (Table 3-60). Most stocks with sufficient data showed “stable” trends in abundance, when comparing 1992 with 2002 assessments (SaSI 2002, Table 3-60).

Table 3-60. Summary of the Status and Trends of Selected Stocks of Native Salmonids in the OESF

Species	Stock Status (number of stocks)				Stock Trend (number of stocks)			
	Critical	Depressed	Healthy	Unknown	Declining	Stable	Increasing	Unknown
Chinook	1	2	9	3	1	9		5
Chum		1	1	6	1	1		6
Coho			13	4		10	2	5
Sockeye			1	1				2
Steelhead			10	13		9		14
Total	1	3	34	27	2	29	2	32

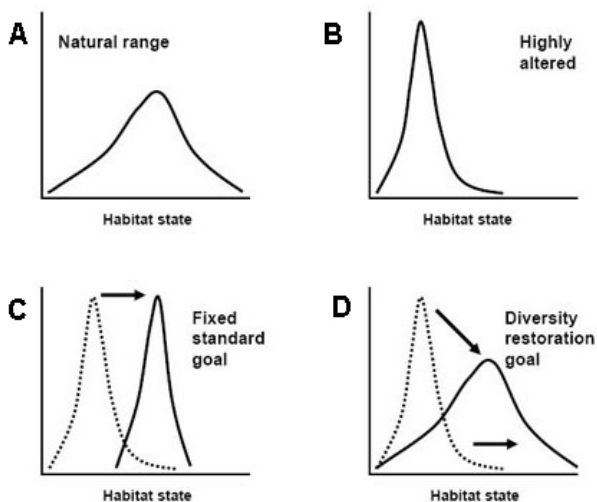
Source: SaSI (2002)

What Are the Criteria for Fish?

The 1997 *Habitat Conservation Plan* (HCP) identified the need for riparian habitat capable of supporting viable fish and salmonid populations (DNR 1997a; Naiman and others 1992). Also identified was need for the conservation of habitat complexity afforded by natural disturbance regimes on the western Olympic Peninsula, which provides a means to track the improvement or loss of fish habitat by assessing riparian functions (refer to *Riparian*).

Habitat complexity is important to fish because it provides opportunities for multiple salmonid species to meet their diverse life-history needs within and/or across watersheds (Naiman and others 1992; Quinn 2005). Habitat complexity is maintained by natural events including landslides, debris flows, floods, fires, windstorms, and other gradual or sudden changes in forest vegetation. These natural events may periodically deliver sediment, wood, nutrients, and water to riparian areas from upslope and floodplain sources (Reeves and others 1995; Montgomery and others 1999, 2003). These disturbances occur at a variety of spatial and temporal scales, from a single tree falling into a stream to a multiple-basin catastrophic windthrow event.

Figure 3-7. Hypothetical Frequency Distribution of a Given Habitat Element



At the OESF HCP planning unit scale, habitat complexity can be represented using a hypothetical frequency distribution for a given habitat element, such as large woody debris. Bisson and others (2009) propose that a broad range of habitat conditions exist under a “pristine” state, subject only to natural disturbances and variability, shown in Figure 3-7(A); while a narrow range of diminished conditions likely occur in a highly altered state as might result from severe, extensive environmental disturbance, shown in Figure 3-7 (B).

The standards by which potential adverse environmental impacts are estimated in the analyses can be compared Figure 3-7(C). It is helpful to consider the difference between panels C and D (Figure 3-7) when examining individual Type 3 watersheds that fail to meet a standard during one or more decades of the 100-year model simulation. While a fixed standard (Figure 3-7(C)) is a necessary tool for this evaluation, a more diverse set of outcomes (Figure 3-7 (D)) is more reflective of a desirable environmental state across the collection of Type 3 watersheds that constitute the OESF. Thus, ephemeral “failures” in a small proportion of watersheds may actually be more consistent with the contemporary model of healthy salmonid habitat (Bisson and others 2009).

The complex pattern and distribution of habitat elements provide opportunities for multiple salmonid species to meet their diverse life-history needs within and/or across watersheds (Naiman and others 1992; Quinn 2005). Upstream adult migrants need access, free of artificial blockages, sufficient flow and water volume, well-distributed holding and hiding cover, and good water quality including thermal refuge in summer. Successful spawning and incubation requires sufficient gravel of appropriate quality and stability, well-distributed within and across watersheds. Juvenile rearing

habitat includes sufficient flow and water volume, a diversity of flow regimes that include refuge from winter high flows and deep pools during summer low flows, hiding cover, cool summertime water temperatures, sufficient space to accommodate density-limited populations, and well-distributed abundant aquatic and terrestrial prey. The spatial and temporal scales at which salmonids fulfill the freshwater portion of their life histories varies by species, run (spring, summer, fall, winter), and watershed (Quinn 2005).

Robust, quantitative descriptions of optimal salmonid freshwater habitat are lacking and the notion of a static optimal state is contrary to current understanding (Bisson and others 2009). The concept of “habitat complexity” is therefore used to represent the multi-dimensional nature of habitat, the spatial and temporal patterns of its distribution and use by multiple species with varying life histories (Bisson and others 1992, 2009).

What Are the Indicators for Fish?

A variety of instream and riparian characteristics can be used to define and measure progress towards habitat complexity (Bisson and others 1992, 2009; DNR 1997a). Table 3-61 lists the indirect and direct measures of the elements of fish habitat proposed as indicators in this analysis. These proposed indicators are used as

surrogate measures and provide mostly indirect, qualitative assessments of habitat quantity, quality, and trends.

Changes in these indicators are coupled with available estimates of channel sensitivities (refer to *Channel Conditions*) to these inputs in order to measure potential effects to fish. As a surrogate measure of water quality, the predicted changes in riparian shade are compared to the locations of temperature-impaired stream segments. Predicted changes to each indicator are then compared to the mapped distribution of salmonids, as summarized in Table 3-59.

The analysis described in this section is restricted to Type 3 watersheds with greater than 20 percent DNR-managed lands (426 of 594 Type 3 watersheds, encompassing 91 percent of DNR-managed acres within the planning unit by area). This threshold was selected as the minimum level of management within a given watershed necessary for DNR land management practices to have an effect on watershed processes.

LARGE WOODY DEBRIS

Large woody debris in streams provides food, cover, and building material for many aquatic life forms, is important for stream nutrient cycling, and provides cover for juvenile and adult fish (Marcus and others 1990). Pools formed by large woody debris accumulations are

Table 3-61. Indicators for Fish Habitat

Indicator	Indirect Measure (Surrogate)	Combined with
Instream Large Woody Debris	Large woody debris recruitment potential	Channel sensitivity to large woody debris input
Water Quantity (Peak Flow)	Percent change in peak flow resulting from extent of hydrologically immature stands within Type 3 watershed	Channel sensitivity to peak flow
Fine Sediment	Sediment delivery potential	Channel sensitivity to fine sediment input
Coarse Sediment	Sediment delivery potential from mass-wasting due to road construction and maintenance	Channel sensitivity to coarse sediment input
Water Quality (Temperature)	Percent of riparian area with adequate shade	Temperature impaired stream segments (303d)

important habitat for rearing salmon and trout (Heifetz and others 1986; Murphy and Koski 1989). Debris also slows water velocity in flood events, lessening the likelihood that fish spawning habitat would be scoured, which could have a detrimental effect to eggs and fish that may be incubating in the stream gravel (DNR 2004). Refer to the *Riparian* section for an additional discussion on large woody debris.

While the actual recruitment of instream large woody debris from streamside forests and its functional integration into the riparian ecosystem can take many decades (Abbe and others 2003), the capability of those forests to deliver sufficient large woody debris is one meaningful indicator of fish habitat potential. The proposed analysis is a synthesis of large woody debris recruitment potential (refer to the *Riparian* section) for stream channels classified as highly sensitive to large woody debris input (refer to *Stream Channel Conditions*) at the Type 3 watershed scale.

WATER QUANTITY (PEAK FLOW)

Peak flow events (such as storms and rain-on-snow occurrences) can destabilize and transport large woody debris, fill pools with sediments, and destroy salmon spawning habitat. A peak flow event can scour complex channels into uniform channels (streams devoid of riffles, pools, and large woody debris) resulting in limited habitat value (DNR 1997a). Low water quantity can limit stream reaches used for habitat and spawning and delay salmon from moving from the marine environment into freshwater. Refer to the *Riparian* section for additional information.

The proposed analysis examines the potential for detectable peak flows, based on hydrologic maturity (refer to *Riparian*) within channel segments classified as highly sensitive to elevated peak flows (refer to *Stream Channel Conditions*).

FINE SEDIMENT

High levels of fine sediment in streams can affect water quality and aquatic habitat. Sediments may contribute nutrients, oxygen-demanding organic materials, harmful minerals, or chemicals that can impair water quality and fish survival. Sediment can fill the spaces between the gravel, preventing the flow of oxygen-rich water to fish eggs (Bjornn and Reiser 1991), and can smother fish eggs and developing young found within the gravel (Spence and others 1996; DNR 2001). Fine sediment can interfere with feeding behavior and damage fish gills (Hicks and others 1991), decrease salmon prey, smother insects, and decrease available habitat of macroinvertebrates (Spence and others 1996). Spaces between individual pebbles and gravels in a streambed are important for the incubation and survival of eggs and embryos, overwintering of juvenile salmonids, and production of macroinvertebrates (Bjornn and Reiser 1991; Furmis and others 1991; Henjum and others 1994; Rhodes and others 1994). Refer to *Soils* for additional discussions on sediment.

The proposed analysis examines the potential for sediment delivery from roads (refer to *Soils*) within sub-watersheds (Map 3-12 in *Soils*) that contain channel segments classified as highly sensitive to inputs of fine sediments (refer to *Stream Channel Conditions*).

COARSE SEDIMENT

Particles of sand, gravel, or soil carried by the flow of a stream on or immediately above the stream bed are necessary to provide a substrate for cover and spawning habitat for fish. Increased levels of coarse sediment particles can lead to pool filling and changes in water flow within the stream channel (Spence and others 1996). Refer to *Soils* for additional discussions on sediment.

DNR developed a simple index for the potential for road related mass wasting as a function of road density, delivery potential and the abundance of potentially unstable slopes (refer to *Soils*). This index will be used to evaluate potential impacts of coarse sediment input on salmonid habitat and classify Type 3 watersheds with channel segments that are highly sensitive to inputs of coarse sediment (refer to *Stream Channel Conditions*).

WATER TEMPERATURE

Water temperature influences virtually every biotic component of stream ecosystems and cool water is particularly critical to salmon and trout. Water temperature can affect disease resistance, the rate of egg maturity, when fry emerge, when adult salmon return to their natal streams, and survival during warm summer months (Thompson 2005). Refer to the *Riparian* section for additional information on riparian microclimates and stream shading and its effect on water temperature.

The proposed analysis consists of two parts. The first examines Type 3 watersheds for their stream shade potential (refer to the *Riparian*) relative to mapped salmonid habitat. A second, more focused analysis will evaluate the potential for riparian forests to provide stream shade within those Type 3 watersheds that contain channel segments classified as impaired for high water temperatures (refer to *Water Quality*).

Comparison of Alternatives

A summary of inferences based on the work completed in the *Riparian*, *Soils*, *Channel Conditions*, and *Water Quality* is presented below. In general, those analyses suggest a widespread, gradual improvement in fish habitat conditions under either alternative. However, focused analyses of four of the five indicators noted above suggest there are slight differences between the No Action and Landscape

Alternatives that may affect their influence on fish habitat.

LARGE WOODY DEBRIS

Review of Table 3-58 suggests that deficiencies in large woody debris in key stream segments are responsible for the greatest limitations to salmonid habitat potential across the OESF. These limitations are manifest in a broad variety of habitat elements, as large woody debris influences many physical and biological functions in streams. Thus, the strongest comparison of the influence of the alternatives on fish habitat may be in the potential for streamside forests to deliver in-stream large woody debris under their different management approaches.

The *Riparian* analyses found that while the general trend under either alternative was for an increase in large woody debris recruitment potential, individual Type 3 watersheds may experience a decline at times over the 100-year modeling simulation. Those analyses found that the net potential impact was small under either alternative—0.5 and 1.8 percent of the theoretical maximum under the No Action and Landscape Alternatives, respectively. However, the numbers of Type 3 watersheds with potential adverse environmental impacts was substantially greater under the Landscape Alternative than the No Action Alternative, 692 potential impacts compared to 91 within 406 watersheds over the entire modeling horizon. The potential for recruitment of large woody debris is not a precise indicator of fish habitat conditions within individual Type 3 watersheds, because in part, 38 percent of the analysis area is along Type 4 waters, which do not support fish habitat (Table 3-29 in *Riparian*). Type 4 waters generally are not capable of transporting large, habitat-forming wood downstream to fish-bearing waters (Abbe and others 2003). These statistics suggest that the No Action Alternative is likely to have generally positive impacts on

fish habitat; however, has the potential for some local and ephemeral adverse effects. Although under the Landscape Alternative the trend is likely to be generally positive as well, a greater number of individual Type 3 watersheds may experience adverse effects. These adverse effects were also predicted to be of longer duration in some instances.

WATER QUANTITY (PEAK FLOW)

Under either alternative, the numbers of Type 3 watersheds with potentially detectable levels of increased peak flows related to timber harvest are projected to decline over time (Chart 3-55 in *Riparian*). Elevated peak flows are projected for some Type 3 watersheds during some time periods, with somewhat more watersheds affected under the Landscape Alternative. However, the average magnitude of the impacts was predicted to be greater under No Action Alternative, 4.6 percent of the theoretical maximum versus 1.3 percent under the Landscape Alternative. These potential impacts cannot be translated directly to influences on fish habitat because most Type 3 watersheds in the OESF exhibit low sensitivity to damage from peak flows (Map 3-11 in *Stream Channel Conditions*), and because site-specific influences of instream large woody debris are not incorporated in the analyses. In summary, it is difficult to predict that either alternative would pose much risk of adverse impacts to fish habitat.

FINE SEDIMENT

Under either alternative, the median values for road and traffic-related fine sediment delivery at the sub-watershed scale are predicted to double over time (Chart 3-73 in *Soils*). Sediment delivery is greater and more widespread under the Landscape Alternative because of the more extensive timber harvests. However, harvest-related traffic under the Landscape Alternative was predicted to result in the delivery of high levels of fine sediment to no more than 40 to 50

sub-watersheds in any decade, compared to 30-to-40 sub-watersheds under No Action Alternative (Chart 3-70 in *Soils*). While the predicted rates of road- and traffic-related sediments are orders of magnitude less than background sedimentation rates compiled over geologic time (Chart 3-74 in *Soils*), they are recognized as having the potential to affect fish habitat. Thus, the increased levels and spatial extent of timber harvest with consequently increased traffic levels proposed under either alternative could pose some risk of adverse impacts to fish habitat in the absence of mitigation.

WATER TEMPERATURE

Under either alternative, the potential for riparian forests to shade streams and thus provide healthy water temperatures, increases from its current high level over time (Chart 3-42 *Riparian*). It is projected that individual Type 3 watersheds will show slight decreases in shade potential during some decades. These potential impacts are predicted to be more frequent and widespread under the Landscape Alternative. Overall, the net potential impact of the Landscape Alternative was estimated at 8.2 percent of the theoretical maximum, compared to 3.4 percent under No Action Alternative (Tables 3-39 and 3-40 in *Riparian*). Given the overall increasing trend for high shade levels under both alternatives and the relatively small potential impacts predicted, neither alternative is expected to pose much risk of adverse impacts to fish habitat.

Mitigation Measures

DNR's standard procedures incorporate many mitigation measures as part of its routine land management planning and implementation, including site-specific riparian buffering, pre-harvest assessments of hydrologic maturity, road management and maintenance, and weather-related restrictions on timber harvest and road use. These and other measures will likely avoid, minimize, or mitigate many of the adverse impacts on the indicators of fish habitat summarized above.

Fish habitat is the outcome of a variety of physical and biotic processes that interact within streams and riparian areas. Parameters that indirectly index the quality of habitat components provide less biologically-meaningful estimates when considered individually. Improved estimates of fish habitat quality will come from focused investigations as outlined in *Research and Monitoring*. Some of these investigations may directly address findings of analyses reported here with the objective of understanding how to adapt forest management to better integrate conservation and commercial objectives and minimize or avoid adverse environmental impacts.