II. Background: Setting the Context

A. Introduction to Basic Needs of Salmon

To achieve salmon recovery, we must understand their life history, biological and physiological needs, and reasons for their decline. The life history of salmon is complex and varies by species. If any or all of the environments which support salmon are not maintained in a healthy state, populations will decline over time and eventually either become extinct or drastically change in character. The salmon life cycle can be described as a series of biological functions - spawning, feeding, rearing and migration - that are carried out in a series of connected environments.

1. Salmon Species in Washington

The life cycles of salmon, steelhead, and trout vary widely. (See Figure 1. Salmon Life Cycle.) Some species are anadromous; born in freshwater, they migrate to the ocean before returning home. Others reside in freshwater their entire lives. Anadromous salmon spend part of their lives in freshwater (streams, rivers, lakes, ponds, etc.) where they spawn, their eggs incubate and hatch, and juveniles develop and grow. After varying periods of freshwater residence, again, depending on the species, the juveniles go to marine environments as "smolts" to feed and grow to adulthood. Salmon acquire most of their adult size during their ocean residence. Except for steelhead and resident trout and char, all Pacific salmon die after returning to spawn. Upon death, anadromous salmon return critically important marine-derived nutrients to watersheds, nutrients that the productive potential of salmon stocks may depend on. Trout have the potential to survive to spawn more than once. Non-anadromous salmonids stay in freshwater their entire lives, but seldom achieve as large a size as the ocean-going species.

There are several species of native salmonids in Washington. Each species is comprised of many stocks and populations which vary from one another in their genetic makeup, life history and other characteristics. The National Marine Fisheries Service (NMFS) uses the concept of "evolutionarily significant units" or "ESUs" to refer to any distinct group of salmon populations and to further clarify the meaning of subspecies under the Endangered Species Act (ESA). Similarly, the U.S. Fish and Wildlife Service (USFWS) refers to "distinct population segments" for species under their jurisdiction. Native salmonids in Washington that have been listed, or are proposed for listing, include:

Chinook Salmon

Currently, NMFS has identified 15 distinct groups of Chinook salmon from southern California to the Canadian border and east to the Rocky Mountains. Chinook typically reach maturity in three to five years, and are by far the biggest of any salmon. They are commonly referred to as king salmon. They have several distinct spawning runs: fall, winter, spring, and spring/summer. Chinook use a variety of freshwater habitats, but it is more common for them to spawn in larger mainstream rivers, compared to other salmon species.

Coho Salmon

Coho, or silver salmon, were once widespread throughout Washington and remain an important salmon species. They spend about the first half of their life cycle rearing in small streams and freshwater tributaries before migrating to the ocean as smolts. Most adults return as three-year-old fish to spawn in fall and winter months.

Chum Salmon

Chum salmon spawn in the lowermost reaches of rivers and streams. After hatching, they migrate almost immediately to estuarine and ocean waters, in contrast to most other salmonids which migrate to sea after months or even years in freshwater.

Sockeye Salmon

These salmon are one of the most complex of any Pacific salmon species because of their variable freshwater residency (one to three years) and different forms. Sockeye are the only Pacific salmon that depend on lakes as spawning and nursery areas. Sockeye salmon have greatly declined over the last 70 years and in some areas are now extinct.

Steelhead

Steelhead are the anadromous form of rainbow trout. They belong to the same scientific genus as other Pacific salmon and coastal cutthroat trout. They are highly prized by anglers. Steelhead spawn in mainstem and upriver tributaries, and juveniles typically rear in freshwater from one to three years before migrating to the ocean where they grow for another one to three years. After their ocean stage is complete, they return to the streams of their birth to spawn. Steelhead have the capacity to survive after spawning and may spawn more than once.

Coastal Cutthroat Trout

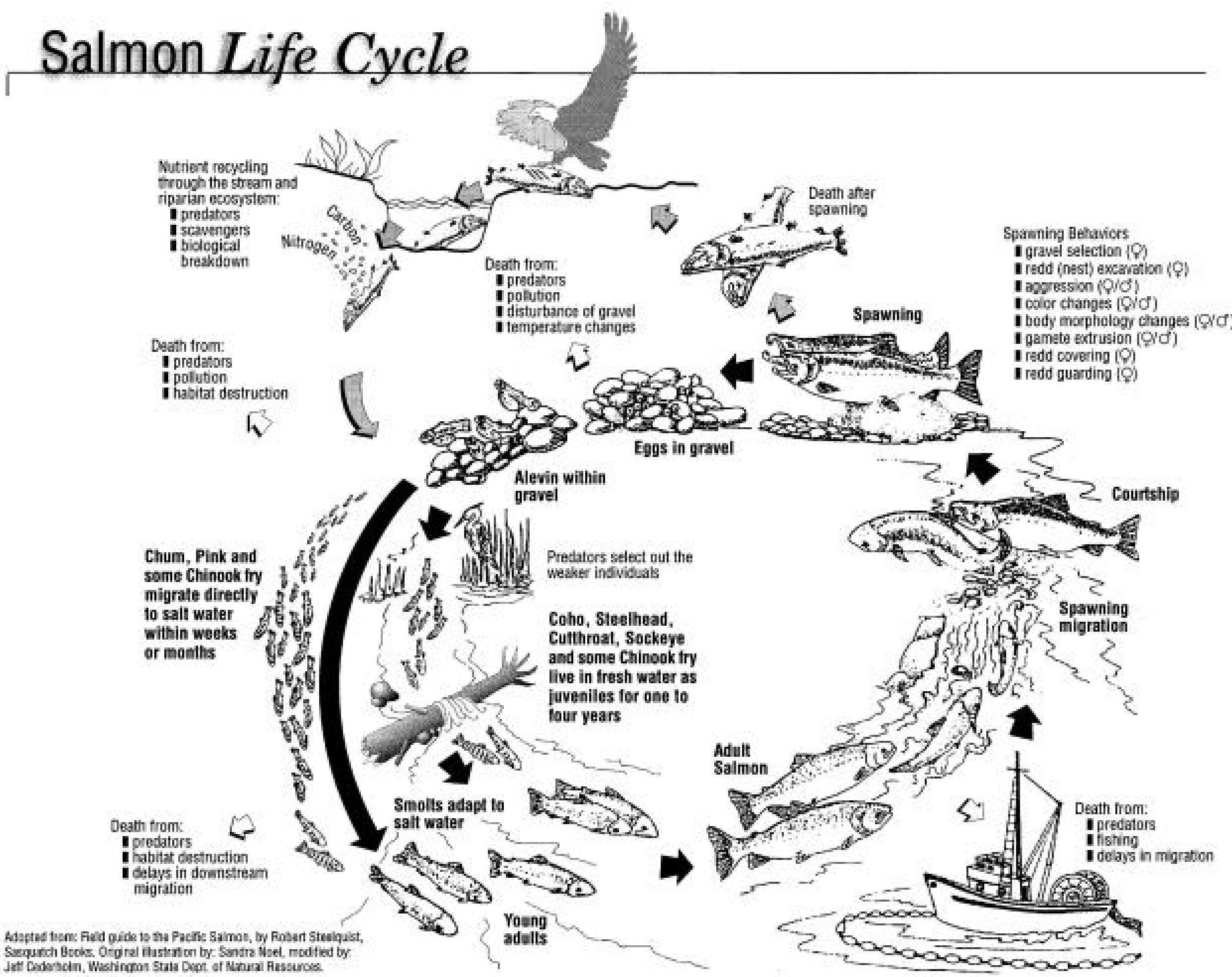
The coastal cutthroat trout, which occur only in western Washington, belong to the same scientific genus as Pacific salmon and steelhead. They have diverse life histories (e.g., resident and anadromous forms), are smaller than other salmon, rarely remain at sea over the winter, and usually don't make extensive ocean migrations. Unlike Pacific salmon, which die after they spawn, coastal cutthroat trout have been known to spawn each year for more than six years. They utilize smaller streams as well as large rivers, and spawn and rear higher up in watersheds than do salmon and steelhead.

Bull Trout

Bull trout are members of the char genus of the salmonid family. They have resident and anadromous forms and can grow to more than 20 pounds in a lake environment, but rarely exceed four pounds in streams. Some trout migrate up to 155 miles to spawn while others stay close to the hatching site their entire lives.

Evolution of different runs and life histories has occurred in response to differences in the streams, rivers and watersheds in which salmon spawn and rear. Salmon have an inherent resiliency and have the capacity to colonize or re-colonize new areas after disturbances. This complex set of behaviors helps salmon populations compensate for environmental fluctuations in ocean and freshwater habitat, adapt to changes in watershed conditions and buffer their populations against catastrophes. A good example of resiliency and adaptation of the salmon can be seen in the recovery of salmon in the Cowlitz and Lewis rivers after the eruption of Mount St. Helens.

Figure 1.



2. Critical Salmon Habitat

Wild salmon have evolved a wide range of behavioral and physical characteristics that allow them to survive through time and disturbances. But this flexibility can't always help salmon in the face of challenges presented by human population growth and development.

The National Marine Fisheries Service (NMFS) is developing recovery goals and analytical tools for determining which actions are likely to be most effective for recovery and long term survival. The recovery goals are based on the concept of "viable salmonid populations" (formerly "properly functioning populations"). This concept takes into consideration the range of wild salmon behavioral and physical characteristics, and is intended to establish biological goals for ESUs and guidance on how to achieve those goals. The parameters and thresholds for viable salmonid populations being considered by NMFS address, in general:

- Population size
- Population productivity (e.g., potential for populations to increase and maintain population size in the future)
- Genetic diversity (e.g., the range of variability in genetic, life history, and other characteristics to ensure the viability of the species by conserving its evolutionary potential)
- Population substructure (e.g., sufficient and suitable habitat patches and migration corridors and how they are connected)

For wild salmon to continue to exist and evolve, specific habitat conditions must be maintained, protected or restored. Specific habitat elements include water quality, base and peak water flows, riparian vegetation, habitat access and passage, channel and watershed conditions, floodplain connectivity, and estuarine and nearshore water quality and physical conditions. These habitat elements, or indicators, have been defined by NMFS for properly functioning habitat conditions. They will be used as guidance to assess the effects of proposed human activities on freshwater and estuarine salmon habitat. (See References - NMFS Coastal Salmon Conservation, 1996)

Freshwater Habitat

Freshwater habitat consists of four major components: 1) habitat for spawning and incubation; 2) juvenile rearing habitat; 3) juvenile and adult migration corridors; and 4) adult holding habitat. The important features of freshwater habitat for spawning, rearing and migration include:

- Water quality - Temperature is a very critical factor affecting growth rates and timing of life history events including migration, food requirements, and other important physiological and ecological processes. Turbidity and sediments can affect abundance of food and impact spawning and incubation habitats. Salmon also require a high level of dissolved oxygen. Other chemical criteria (e.g., nutrients) influence the condition and function of habitat.
- Water quantity - Appropriate quantities of cool, clean water in streams are a key habitat requirement for sustainable fish production. Minimum streamflow must be of sufficient depth and velocity to allow passage, migration and spawning; floods must not scour channels. Salmon seek out slow velocity areas adjacent to faster water for feeding, resting and growing. Salmon life cycles are very sensitive to changes in stream flow and, to some extent, salmon time their movements according to flow regimes. Natural base and peak stream flows vary greatly from year to year, seasonally and even on a daily basis. Fish have adapted over thousands of years to the natural flow regime in their individual watersheds. Natural low flows are important for establishment of vegetation along stream banks. High flows add gravel, flush sediments from gravel, create new rearing channels, and perform other important functions. Protection of salmon requires

streamflows to fluctuate within the natural flow regime for a given location and season.

- Channel stability - All salmon require sufficient, clean and appropriately-sized cobbles and gravel for spawning and incubation.
- Riffles, rapids, pools and floodplain connectivity are important for production, rearing, cover, and aeration.
- Riparian vegetation performs a number of functions such as providing shade, moderating stream temperature, stabilizing banks, controlling sediment input, providing nutrients, and contributing large woody debris which increases channel complexity, creates backwater and increases depth in pools.
- Access and passage - All species require unobstructed access downstream and upstream for migration or feeding. Access can be affected by physical structures or by lack of adequate streamflow or high temperature.
- Food - Aquatic plants, organic litter, and insects are the main sources of food for salmon. Riparian vegetation, temperature, stream flow and substrate affect the composition and abundance of food.

Estuarine and Marine Nearshore Habitats

Estuarine and marine nearshore habitats support estuarine and ocean rearing, and juvenile and adult migration.

Nearshore habitats are critical to the health of marine life in Puget Sound and other coastal areas. A wide variety of habitats occurs in the nearshore, such as marine tidal marshes, tidal channels, eelgrass beds and kelp beds. In addition to providing shelter, spawning, rearing and feeding grounds, they protect the shoreline from erosion, filter pollutants, reduce flooding by retaining stormwater during high-flow periods, and maintain a natural flow discharge into marine waters because of their capacity to store flood waters and release them slowly over time.

Estuaries are also very important to anadromous salmonids as they transition from juvenile to adult, and transition from fresh to salt water and back again. Salmon pass through estuaries as juveniles on their downstream migration to the ocean and as adults on their upstream migration to spawn. Some species, such as chinook, are dependent on estuaries as rearing areas. Research has shown that depriving juveniles of access to estuaries appears to decrease their survival in the marine environment. Estuaries also provide juveniles refuge from floods and predators. In addition, coastal marshes are important for the absorption of toxic compounds, nutrients, and bacteria.

Human activities induced major changes to estuarine and nearshore habitats from shoreline armoring, port development (deepening), over-water structures, passage barriers like docks and dams, and degradation of water quality from adjacent upland uses.

3. Salmon: A Resource in Decline

Many wild salmon, steelhead and bull trout stocks have been listed under the Endangered Species Act (ESA) by the National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service (USFWS). More than 75% of the state will likely be affected by ESA listings of salmon. (See Table 1. Chapter I. A Sense of Urgency.)

In 1992, the Washington Department of Fish and Wildlife (WDFW) and Western Washington Treaty Indian Tribes, concerned over the continual decline of wild salmonid populations, began a comprehensive inventory defining existing Washington salmonid stocks and their status. The first inventory report, the Salmon and Steelhead Stock Inventory (SASSI) was published in 1993 by WDFW and the Tribes. It showed that less than 50% of Washington's salmon stocks were in a healthy state. Generally, species in the inland areas of the Columbia River system have been extirpated over a greater percentage of their range than species primarily limited to coastal rivers. Coastal populations currently tend to be better off than populations inhabiting interior drainages. Puget Sound stocks are intermediate between coastal and Columbia River stocks.

In 1998, WDFW extended the stock inventory effort to bull trout and Dolly Varden char. The name of the original inventory (SASSI) was changed to "Salmonid Stock Inventory" (SaSI) to reflect the broadened inventory scope encompassing all wild salmonids. This name will be used in future stock inventory efforts.

The 1998 bull trout and Dolly Varden inventory found that, of those stocks for which sufficient information was available, 63% were rated as healthy. It is important to note, however, that only about 20 of the 80 stocks in the state had enough information for scientists to be able to determine their status. This lack of information is a key concern for some species.

Anadromous species that rear in freshwater for extended periods (up to a year), include spring/summer chinook, coho, sockeye, sea-run cutthroat and steelhead, and non-anadromous species. They are generally extinct, endangered, or threatened over a greater percentage of their historical ranges than species with abbreviated freshwater residence (less than a year), such as fall chinook, chum and pink salmon.

Table 2. is a summary of salmonid stock status. [1]

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[1] **Healthy**- A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Depressed – A stock of fish whose productions is below expected levels based on available habitat and natural variations in survival rates but above the level where permanent damage to the stock is likely.

Critical – A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Unknown – There is insufficient information to rate stock status.

Extinct – A stock of fish that is no longer present in the original range, or as a distinct stock elsewhere. Individuals of the same species may be observed in very low numbers consistent with straying from other stocks.

Table 2. Regional and statewide summary of salmon and steelhead[2] and Bull trout and Dolly Varden[3] stock status

	HEALTHY		DEPRESSED		CRITICAL		UNKNOWN		EXTINCT[4]	
PUGET SOUND	**Salmon/ Steelhead**	**Bull Trout Dolly Varden**	**Salmon/ Steelhead**	**Bull Trout Dolly Varden**	**Salmon/ Steelhead**	**Bull Trout Dolly Varden**	**Salmon/ Steelhead**	**Bull Trout Dolly Varden**	**Salmon/ Steelhead**	**Bull Trout Dolly Varden**
North Puget Sound	27	2	12	0	4	0	28	7	0	0
South Puget Sound	40	0	7	0	1	0	13	6	1	0
Hood Canal	17	1	11	0	1	0	7	2	0	0
Strait of Juan de Fuca	9	1	14	0	5	0	12	3	0	0
TOTALS	**93**	**4**	**44**	**0**	**11**	**0**	**60**	**18**	**1**	**0**
COASTAL										
North Coast	35	1	4	0	0	0	33	5	0	0
Grays Harbor	21	0	3	0	0	0	4	1	0	0
Willapa Bay	9		1		0		5		0	
TOTALS	**65**	**1**	**8**	**0**	**0**	**0**	**42**	**6**	**0**	**0**
COLUMBIA										
Lower Columbia	18	0	35	1	0	0	7	0	0	0
Upper Columbia	11	9	35	1	1	6	4	34	0	0
TOTALS	**29**	**9**	**70**	**2**	**1**	**6**	**11**	**34**	**0**	**0**
515 TOTAL STOCKS	**187**	**14**	**122**	**2**	**12**	**6**	**113**	**58**	**1**	**0**
% OF TOTALS FOR SALMON AND STEELHEAD	**43%**		**28%**		**3%**		**26%**		**0%**	
% OF TOTALS FOR BULL TROUT AND DOLLY VARDEN	**18%**		**3%**		**8%**		**72%**		**0%**	

2 Source from 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI)
3 Source from 1998 Salmonid Stock Inventory (SaSI)-Bull Trout/Dolly Vardon Appendix
4 The Extinct rating is included here to identify any current and future losses of stocks identified during the annual review and inventory of Washington's wild salomonid stocks.

B. Factors Contributing to Salmon Declines

This section briefly describes the natural and human factors contributing to salmon decline and highlights currently recognized threats from invasive exotic species.

1. Natural Phenomena Affecting Salmon

Natural disturbances, which include seasonal high flows and floods, droughts, wildfires, volcanic eruptions, seasonally extreme temperatures, landslides and debris flows provide a context for human activities that affect salmon, grouped as harvest, hatcheries, habitat, or hydropower. With some exceptions, however, natural phenomena are out of peoples' direct control. Nevertheless, they can be significant factors that influence survival rates of wild salmonids and can be exacerbated by human influences. While some natural disturbances can result in diminished salmon populations in the short term, they may lead to increased productivity and habitat in the long term. Extreme floods, fires, mass wasting and erosion events, for example, are part of the dynamic environment that shapes stream, estuarine, and shoreline ecosystems. Salmon recovery planning should be based on an understanding of these natural phenomena, the likelihood and frequency of their occurrence, and their implications for salmon production.

Wild salmon have evolved in conjunction with their natural predators, including marine mammals, birds and fishes. Human alterations can affect the frequency and magnitude of natural disturbances and increase the vulnerability of salmon to capture by predators through loss of cover, obstruction of passage or delay of migration. Human actions can also directly affect predation abundance and predation rate on salmon.

Ocean Conditions

The condition of marine environments has a key influence on salmon and steelhead survival over time. Wild salmonids may spend up to several years growing in the estuarine and/or marine environment before returning to freshwater to spawn. Some species spend extended periods in estuaries, whereas others spend more time in the ocean. The migratory patterns of salmon may extend well into the North Pacific Ocean; some species follow clear paths, others move in a more dispersed fashion.

Climatic changes can affect numerous physical, biological and chemical processes in the ocean that directly or indirectly influence fish population dynamics and survival. Variations in sea surface temperatures, air temperatures, strength of upwelling, salinity, ocean currents, wind speed and ocean productivity have all been shown to directly or indirectly cause or reflect fluctuations in abundance and survival of salmonid populations. Oceanic conditions can vary on seasonal, annual, decadal, and longer time scales. Our ability to predict climate impacts on salmon and steelhead stocks is very limited.

Although ocean conditions have an important influence on salmon and steelhead abundance they are not thought to be the primary factors limiting recovery of Washington's salmonids. It is important to note that salmon, steelhead and other salmonids have evolved in a context of wide-ranging oceanic environmental variability. The long-term survival of wild stocks has depended on their development of compensating mechanisms (e.g., diversity of life histories and run timing, repeat spawning by steelhead) that allow them to remain viable under such conditions. Marine conditions can affect survival of wild salmon but are probably not solely responsible for declines spanning the last three decades. Dr. Robert Francis of the University of Washington puts it this way:

> "I know some people will look at the data (declining salmon runs) and say it's the ocean' fault. I would say that it's clearly not the ocean's fault. Salmon have survived changing ocean conditions for thousands of years, but the big decline in the runs occurred in recent decades. So you have to ask yourself, what's occurred during that time - what's different? And the clear answer is man's impact - dams, habitat destruction, over fishing, hatcheries. We can't use the ocean as an excuse to stop our efforts to improve passage, spawning, and rearing conditions."

There is little that the Statewide Strategy to Recover Salmon can offer to directly influence ocean conditions. However, ocean conditions and variability must be kept in the proper context. Wide annual and longer term cyclic fluctuations in adult returns are common for salmon and steelhead. Given that variability, the best conditions (and lowest risks) for salmon occur when cycles in ocean productivity are high and freshwater conditions are good. In contrast, risks to these fish are greatly increased when cycles in ocean productivity are low and freshwater conditions are poor or decreasing.

Predation

Marine mammals, birds and fishes have evolved to coexist in fully-functioning ecosystems and to utilize wild salmonids as food sources. In fact, many wildlife species depend on salmonids, either directly or indirectly, for their well-being. For example, salmon carcasses have been shown to play an important role for some wildlife, such as turkey vultures and mink. Larger runs of salmon returning to watersheds and the carcasses left behind contribute levels of predominantly ocean-derived nutrients. More nutrient-rich stream systems support a broader array of invertebrate life, and support more diverse aquatic systems and associated wildlife populations. As the health of salmonid populations improves, it’s likely the health of various other wildlife species will improve as well.

The occurrence and magnitude of predation by marine mammals, birds and fishes on individual salmonid species is difficult to assess and has generally not been quantified. However, human-caused alterations to the environment have increased the occurrence and magnitude of predatory impacts to wild salmonids. We’ve introduced non-indigenous fish species, constructed hydroelectric dams, removed riparian vegetation along streams and nearshore habitat, and made other broad scale alterations to salmonid habitat. All of these can cause problems in the ecosystem, throwing predator-prey relationships off-balance. The following summarizes risks posed by predation.

Marine Mammals

The Marine Mammal Protection Act of 1972 and related conservation measures have been successful in helping to rebuild depleted populations of marine mammals. Some of these mammals, such as harbor seals and California sea lions, have close associations with salmon, including feeding on salmon. Where increasing marine mammal and at-risk salmon populations co-occur, concerns exist about the potential for marine mammal predation to play a role in limiting the recovery of wild salmonid stocks.

Scientific information indicates that populations of seals and sea lions in the Pacific Northwest have increased at a rate of six to eight percent per year since the mid-1970s. Available studies have shown that while salmonids do not form the majority of the seals' and sea lions' diets, they can create a localized problem. They prey on salmon near man-made structures such as dams or fish passage facilities where salmon congregate. The presence of large numbers of seals and sea lions in estuaries during migration raises concerns for predation on already depressed salmon populations. In most other areas, seals and sea lions feed on non-salmonid fishes.

Various efforts have explored seal and sea lion predation on salmonids but quantifiable data on consumption rates are scarce, as noted in a National Marine Fisheries Service (NMFS) report published in 1997. This report summarized the findings of an interagency group working on the issue ("Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California"). The report suggested that although predation by the seals and sea lions is not the principal factor causing the decline of salmon population, it is a factor that may effect salmon recovery. The NMFS report indicated that concern was warranted where known or potential predation impacts are known to occur, and in areas with depressed or significantly declining salmonid stocks exist.

The National Marine Fisheries Service (NMFS) submitted, as a follow-up to its 1997 report, a report to Congress in early 1999 on "Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems." The report addresses the conflict between the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA) regarding appropriate steps to protect listed species of salmon from predation by expanding California sea lion and Pacific harbor seal populations. The report recommends that Congress: 1) consider a new framework that allows state and federal resource management agencies to immediately address site-specific conflicts involving seal lions and seals; 2) safe and effective non-lethal deterrence methods should be developed; 3) Congress should selectively reinstate authority for the intentional lethal taking of sea lions and seals by commercial fishers to protect gear and catch; and 4) additional information and research is needed to evaluate and monitor the impacts of sea lions and seals on salmon and the west coast ecosystems. The state of Washington supports these recommendations.

Populations of orca whales which also rely on salmon in their diets inhabit Puget Sound. However, orca whale populations are not known to be critical factors for the decline of salmon and steelhead stocks in general.

Marine mammal populations are relatively high in recent years and they are natural predators on salmon. It is difficult, if not impossible, to accurately determine how much marine mammal predation is contributing to the problem of salmon recovery. The state continues to be involved, in collaboration with neighboring states, federal agencies and other interests, in field investigations and review of data to determine the extent of marine mammal predation on threatened and endangered salmonids in Washington.

Birds

In healthy ecosystems, various bird species may include salmonids as basic food sources. Bald eagles, ospreys, gulls, common mergansers, belted kingfishers, great blue herons, Caspian terns, murres, puffins, and double-crested cormorants include salmonids in their diets. As with marine mammals, there is little quantitative information available documenting the extent of bird predation on salmonids, but increasing evidence suggests problems can occur. What is known about population sizes, geographic location and feeding habits suggests Caspian terns, double-crested cormorants, and perhaps common mergansers are the bird species most likely to impact juvenile salmon and steelhead.

Recent evidence suggests that under certain conditions, predation by birds can cause significant mortality of juvenile salmonids. There is a significant Caspian tern population breeding on Rice Island, an artificial island in the lower Columbia area formed by accumulation of dredge spoils. Preliminary study results in the area suggest that this tern population has increased from 1,300 breeding pairs in 1987 to more than 10,000 pairs in 1998. This is the largest Caspian tern colony in North America, and perhaps the world. Preliminary estimates suggest that these terns consumed between six and 25 million smolts, or three to 12 percent of the combined hatchery plus wild smolts in the basin. For reasons that are yet unclear, hatchery fish appear to be more vulnerable to these predators.

An interagency Caspian Tern Working Group comprised of federal, state, and tribal entities is actively involved in developing a strategy to address predation risks posed by the terns and a relocation program is being prepared for implementation. In the spring of 1999 Department of Fish and Wildlife (WDFW) and local volunteers helped National Marine Fisheries Service and U.S. Army Corps of Engineers erect hundreds of rows of plastic mesh fences across seven acres of Rice Island to discourage terns from nesting. The idea is to move the birds 17 miles downstream to East Sand Island, a natural island in the Columbia River. This will allow the birds to feed off other species such as sculpins and shiner perch because of the closer proximity to the ocean.

The abundance of other predatory birds (e.g., double-crested cormorants) also appears to be increasing in recent years and may lead to increased risks for wild salmonid stocks. For example, certain double-crested cormorant populations appear to have increased up to 15-fold in some areas along the West Coast. Double-crested cormorant predation has been identified as a significant concern in some areas for salmonids rearing in lakes. In addition, common mergansers may consume substantial numbers of salmon.

It's important to note that many bird species are under the federal protection of the Migratory Bird Protection Act and other laws. In some cases, large-scale efforts have been taken to address risks to them and to develop conservation responses (e.g., bald eagles, great blue herons, marbled murrelets, etc.). It will be important to carefully consider predation by birds as a factor for the decline of salmon in an ecosystem context, one that recognizes the contributions and significance of all species.

Fishes

Predatory fishes may consume wild salmonids in both marine and freshwater environments. In some years, predators such as Pacific mackerel may deplete juvenile salmon in nearshore areas. Impacts increase when concentrations of ocean predators move north during ocean warming cycles. Some salmon species may be less vulnerable than others due to the manner in which they migrate from estuaries to offshore areas.

Non-indigenous predatory fishes such as walleye, smallmouth bass and channel catfish, and native species such as northern pikeminnow (squawfish), have been found to consume significant numbers of juvenile salmonids.

With the exception of areas of the Columbia River mainstem, information is generally limited on the extent and quantitative impacts of fish predation on wild salmonids. Identification and consideration of predation by fishes in the estuarine, ocean and freshwater environments will occur under the Statewide Salmon Recovery Strategy, generally through joint efforts with federal agencies and in the development of associated regional conservation initiatives.

2. Human Factors Affecting Salmon

Many factors have reduced salmon populations over the years, including natural phenomena such as ocean conditions, floods, drought and predators, as well as human-caused factors. Most notable of all factors are past and continuing intensive use and development of land and water resources, such as timber harvest and agricultural practices; urbanization; water diversions; hydropower; over-fishing and hatcheries. Continual urbanization and land disturbances associated with the projected 36% increase in population by the year 2020 will expand the geographical extent and intensity of habitat loss.

If improperly managed, the most serious human threats to salmon populations and habitat include:

- Land use practices, including conversion of forests, coastal tidelands, and floodplains; agricultural practices; grazing in riparian zones; forest practices; road construction; and urban and rural development;

- Impoundments and diversions of water, which result in water quality or quantity problems;
- Dams and hydropower operation;
- Fish harvest;
- Hatcheries; and
- Introduction of non-native species.

Agricultural Practices
Agriculture in Washington is a diverse industry and a significant contributor to the state's economy. Agricultural lands, especially in western Washington, generally are in lowland valleys that historically contained the majority of floodplains and wetlands. Agricultural practices that may adversely affect salmon include diking, draining, filling, stream channelization, removal of large woody debris, installation of riprap along stream banks, removal of riparian vegetation, road building, diversion of surface and ground water for irrigation and agricultural processing, and pesticides and fertilizer applications.

There are more than 1.8 million acres of irrigated land in Washington, 90% of which are located in eastern Washington. Irrigated agriculture requires diversion of water, which reduces streamflows. In some years this leaves little or no water for salmon and other aquatic species. Return flows, while perhaps increasing the amount of water in streams, degrade the water quality by raising its temperature and adding dissolved chemicals. Unscreened or improperly screened diversions can have devastating effects on juvenile fish.

Dryland farming, particularly in areas where soils are highly erodible, such as in the Palouse region, can alter natural erosion rates. Erosion caused by rain and snowmelt affects 4.3 million acres (69%) of non-irrigated cropland statewide. Loss of soil results in discharge of substantial quantities of fine sediments to streams and rivers.

Livestock grazing and rangeland management have damaged upland and riparian natural vegetation in many areas of the state. Rangeland covers 7 million acres, with an additional 5.5 million acres in grazable woodlands. Heavy and continual grazing practices compact the soil and modify soil characteristics (e.g., reduce the rate of infiltration of surface water). Grazing affects salmon largely through degradation of stream riparian areas, where the intensity of use by livestock leads to erosion and sedimentation, water quality degradation, loss of riparian vegetation, and modification of the stream channel.

The dairy industry in Washington consists of 758 commercial dairies and 298,000 cows, with 145,000 concentrated in the counties around Puget Sound. Effects on surface and ground water quality from improperly managed dairy farms have been well-documented. Increased nutrient loads, sedimentation, excess surface water from overgrazed pastures, trampling of streamside vegetation, and animals with direct access to streams result in loss and degradation of aquatic and riparian salmon habitat.

While the magnitude of the effects of agricultural practices vary by watershed and stream, overall, associated habitat alterations have reduced or eliminated spawning and rearing habitat, interfered with adult and juvenile migration, altered stream habitat, and increased predation.

Forest Practices

The timber industry is important to the state's economy. About half of the land area in Washington is covered by forests, which supports many functions benefiting fish. Most salmon-bearing streams in Washington have their headwaters, and in many cases the majority of their watersheds, in forested areas.

Salmonid species in forested ecosystems have evolved in streams in which large woody debris (LWD) plays a major role in forming in-channel and off-channel habitats, providing cover, influencing the sediment process and trapping nutrients. Forest riparian corridors provide critical functions, including shade, supply of logs or large woody debris, sediment filtering and bank stability. Other riparian features (e.g., reduction of floodwaters and off-channel habitat) are also important to both forest and aquatic systems.

Historical forest practices left a legacy of degraded habitats. Stream surveys conducted by federal agencies show that habitat in forested areas is fair to poor. In addition, the intense harvesting in the past 30 years resulted in 67% of forest lands being occupied by young trees, which provide lower quality habitat than the original forests.

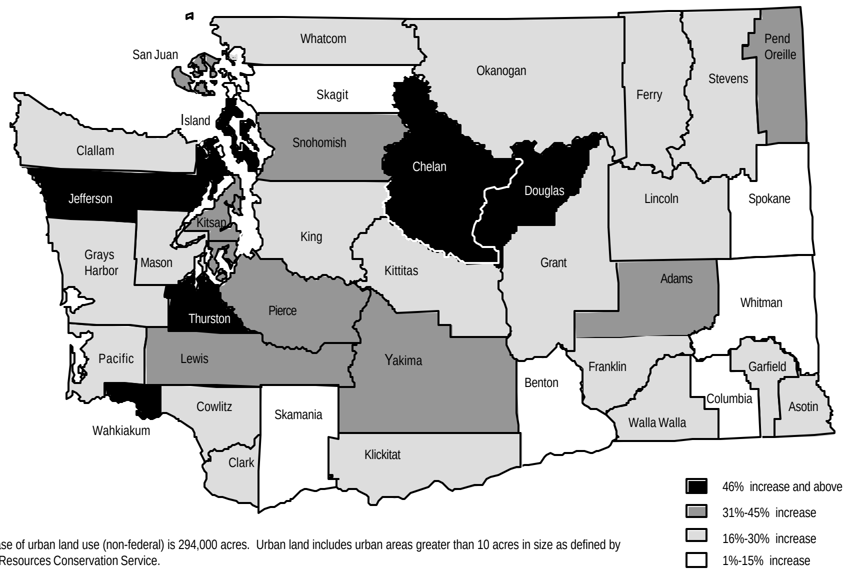
Forest management activities such as road building, timber harvest near streams or on steep or unstable areas, and the application of chemicals have damaged fish habitat and water quality. The most profound impacts include: increased stream temperature, diminished opportunities for large woody debris recruitment, alteration of groundwater and surface water flows (increased runoff and reduced percolation of rain and snowmelt into the ground), and degradation or loss of riparian habitats. These forest practices also resulted in loss or degradation of spawning and rearing habitats, contributing to the listing of some salmon runs.

In addition to the threat to salmon from poor forest practices over the last 30 years, more than 2.3 million acres (or nearly ten percent of the state's forest lands) have been converted to other uses, such as roads, cities, farms and rural development. The loss of forests contributes to elimination and degradation of habitat for fish, and diminished water quality and quantity in streams and groundwater aquifers.

Urbanization

The tremendous population growth experienced by the state in the past 30 years has taken a toll on the state's natural resources. The State Office of Financial Management's Forecasting Division estimates show the state's population has grown by 20% every 10 years since the 1960s. It stands now at 5.6 million, and is forecasted to reach 5.9 million in the year 2000 and 7.7 million by 2020. While growth was experienced in many counties in the state, urban counties along Interstate-Five have grown the most, with some counties experiencing up to 33% increase in population between 1990 and 1997. The population increase and associated development have drastically altered many natural habitats critical for salmon survival. Managing growth will continue to be a major challenge facing the state for many years to come. Map 1 shows the increase in urban land over a ten year period due mostly to the population growth experienced during that period.

Map 1 – Increase in Urban Land*
Percentage Change (1982 – 1992)



*Total increase of urban land use (non-federal) is 294,000 acres. Urban land includes urban areas greater than 10 acres in size as defined by the Natural Resources Conservation Service.

SOURCE: National Resources Inventory, Natural Resources Conservation Service, 1992.

Urbanization, which occurs when land is developed in both urban and rural areas, starts with forest and farm lands conversion and/or low-density development, and continues with increasing intensities of land use. Many cities and towns were built along rivers and often within floodplains. Urban areas are frequently located in important salmon migration corridors and rearing areas. The areas most significantly affected by urbanization are small streams, riparian corridors and associated wetlands, and shorelines and estuaries.

The impacts occurred mostly in increments, with no single action significant enough to cause any noticeable harm. However, this incremental damage has resulted in a wide-scale disturbance of the natural landscape and degradation of the environment, and insufficient or diminished habitat quality for salmon. Early attempts to address public safety and property losses due to flooding - by building dikes, stormwater retention ponds and other structural solutions - were inadequate, costly and caused widespread environmental problems. For example, levees along rivers have all but eliminated connectivity between rivers and remaining off-channel waters, and increased the speed and volume of run-off.

It's a well-known and documented fact that streams, wetlands and estuaries are being degraded by urbanization. Streams in urbanized areas continue to be highly altered and degraded. Scientific information demonstrates that the proportion of streams within urban areas that are degraded is greater than the proportion of altered streams and rivers on agricultural and forest lands.

Between 45% to 62% of Washington's estuarine habitats have been lost to diking, channelization, dredging and filling. We've also lost more than 30% of the original 1.35 million acres of wetlands. More than 90% of the wetlands in urban areas have been lost to development. It's estimated that one-third of Puget Sound's shoreline has been modified by human development, with 25% occurring in the intertidal zone. Conversion of forest and agricultural lands, filling, diking, dredging, creation of impervious surfaces (parking lots, roofs, etc.), construction of bulkheads and docks, and introduction of contaminants and exotic species are some of the primary causes of loss of wetlands and estuarine/nearshore habitats in urbanizing areas.

Sand and gravel mining for road construction, industrial and urban development occurs either in streams or adjacent floodplains. Sand and gravel operations - dewatering, extraction of the sand and gravel, washing and processing - degrade channel conditions (wider and more shallow channels), reduce streamflow and lower ground water levels, eliminate gravel needed for spawning, and add sediment and minerals to streams.

Water quality in urbanized streams is highly degraded. Nearly 700 water bodies in Washington state are on a list of those failing to meet water quality or sediment standards. While the list represents only about 2% of the state's waters, most estuaries and river systems in the state are on the list, including those important for salmon. Bacteria, temperature, toxics, dissolved oxygen and acidity are the most common water quality criteria exceeding standards - all except for bacteria are critical for the survival of salmon and other aquatic life.

Residential, commercial and/or industrial development changes the natural hydrologic cycle by stripping vegetative cover, removing and destroying native soil structure, modifying surface drainage patterns, and adding impervious and nearly impervious surfaces, such as roads and other compacted soils. Loss of water in stream channels and riparian areas due to water withdrawal and consumptive use of water from streams, rivers and aquifers further reduces groundwater recharge.

Research conducted by the University of Washington, and experiences recorded by King County on small Puget Sound lowland watersheds and larger watersheds (e.g., Cedar River) have demonstrated that the biological and physical health of stream and wetland systems are degraded by urbanization. The geographic extent and degree of degradation is roughly equivalent to the geographic extent and degree of urbanization that has occurred upstream. The incremental degradation is most rapid in the first stages (up to 10% of total impervious area created) of development within a watershed. The rate of degradation becomes more constant as urbanization progresses. Alteration of the watershed hydrologic regime is the leading cause for the degradation, with increases in the frequency and duration of high and low streamflows the most obvious problems. The loss of adequate riparian zones, chemical and physical water quality degradation, and construction of fish passage barriers are also products of urbanization that contribute to habitat degradation and loss. (*Salmon in The City, May 20 – 21, 1998, Mount Vernon, WA, Abstracts*)

Streamflow Modification

Fish need cool, clean water in adequate amounts and at the right time. Stream flows which are either too high or too low to sustain healthy production levels are among the many factors contributing to the poor status of many naturally reproducing fish stocks. Natural flow conditions have been affected by several human activities in the past 100 years, chiefly through the diversion of water from streams for irrigation, municipal and industrial uses, water storage operations, and land use changes. Changes in the frequency and duration of both floods and low flows due to land use and water development activities are having considerable detrimental effects on salmon.

Human activities have resulted in some streams being so over-appropriated that they are nothing but dry streambeds during the low flow period in the summer. In many other streams, flows are reduced well below natural flow levels. Over-appropriation conditions occurring in many streams and rivers used by salmon can be found in at least 16 watersheds throughout the state, representing about a quarter of the state's basins. These basins also contain 65% of the state's population. (See map included in Chapter IV. A. 5. Ensuring Adequate Water in Streams for Fish.) Over-appropriation means more water is being withdrawn from rivers and streams in those watersheds, especially in late summer and early fall, when flows are naturally low and when fish need water for migration, spawning or rearing. In some cases, flows that are too low can not provide sufficient spawning areas to accommodate all returning adult fish. Flows that are depressed below natural low flows generally cause fish production to decline by reducing the total amount of habitat and food sources available in the stream. Low summer flows are also associated with higher water temperature (due to loss of riparian canopy or water withdrawal) and higher concentrations of pollutants (due to land use impacts), which can be debilitating or even lethal to fish.

Fish Barriers

Salmonids need access to spawning and rearing habitat, and unimpeded migration to and from the ocean in the case of anadromous fish. Unnatural physical barriers interrupt adult and juvenile salmonid passage in many streams, reducing productivity and eliminating some populations. Barriers may also cause poor water quality (such as elevated temperature or low dissolved oxygen levels) and unnatural sediment deposition. Impaired fish access is one of the more significant factors limiting salmonid production in many watersheds.

Fish blockages or barriers are caused by dams, culverts, tide gates, dikes and other instream structures. The Departments of Transportation and Fish and Wildlife have estimated that at least 80,000 miles of public roads were constructed in Washington, not including roads under private ownership (railroads, forest industry, agriculture, etc.). These roads have resulted in a minimum of 2,400 human-made barriers at road crossings. These structures block fish access to an estimated 3,000 miles of freshwater spawning and rearing habitat.

Unscreened or inadequately screened surface water diversions, whether associated with a physical barrier or not, are a serious source of salmonid mortality or injury as a result of:

- diversions that are unscreened or the screen mesh openings are too large to exclude small fish, or
- inadequately screened diversions have small enough mesh but the approach velocity at the screen exceeds the swimming capability of the fish.

If the fish are unable to locate a bypass to the waterbody, they become exhausted and are swept against the screen, resulting in injury or death. Recent inventories of unscreened or inadequately screened diversions in the Snake, Yakima and mainstem Columbia Rivers show that only 25-40% of diversions are adequately screened to protect salmonid fry.

There are about 1,000 dams in the state blocking or impeding movement of adult and juvenile fish, obstructing the flow of water in many streams, modifying the streamflow regime, destroying riparian habitat, and modifying the water quality temperature and the level of dissolved oxygen.

Hydropower

Years ago, hydropower dams were built with little or no consideration for protecting river ecosystems and fish and wildlife resources. The example of the Columbia-Snake River system (including the dams and hydropower facilities above Bonneville dam) best illustrates the impact of hydropower on salmon and the difficulty of addressing these impacts. The river system was once host to salmon and steelhead populations numbering 10 -16 million fish. As many as eleven major hydropower dams on the Columbia River within Washington State now block or impede the progress of fish on their way to and from the Pacific Ocean. Furthermore, thousands of square miles of salmon habitat are inundated or inaccessible due to the reservoirs behind the dams.

Construction and management of hydropower dams have dramatically altered flows and riparian habitat by diverting and impounding rivers and streams throughout Washington State. Dams and hydropower operations modify the level, timing, frequency and duration of stream flows; block fish movement both upstream and downstream; dewater stream segments below dams; cause loss of upstream habitat; and increase predation in reservoirs. Smolts and juvenile fish migrating downstream through the reservoirs encounter slower moving water, which increases the time it takes for them to reach the ocean. These altered migration patterns increase their chances of dying from predation and diseases. In addition, the absence or inadequacy of fish ladders or other by-pass systems block or limit adult migration upstream, closing off many miles of potential spawning and rearing habitat. Dams and hydropower operations impact downstream habitat. Channel structure and erosion sedimentation patterns are drastically altered.

Dams reduce water quality by altering water temperature and decreasing oxygen levels. Gas supersaturation from water passing over the spillways also impacts salmon. Too much nitrogen can be trapped in the water as it plunges over the spillway into the river below. Fish exposed to this can develop "gas bubble" disease, a condition similar to what divers call the "bends."

Harvest

Fishing has been considered by many to be a major cause of the declines in salmon abundance since the late nineteenth century. Over-fishing in the Columbia River resulted in closure of fishing seasons as early as 1915. Ocean fishing expanded after World War II with the advent of refrigeration and improvement in fishing equipment. Harvest rates of adults in many fisheries can reach 50% to 80% of the salmon populations, and though many salmon stocks can sustain this level of harvest, stock that are challenged by poor productivity or poor ocean conditions can not. In addition, size-selective gear, coupled with high rates of harvest of larger adults, can result in shifts toward younger, smaller adults with less ability to negotiate the challenges salmon face during their journey (i.e., large barriers) and lower reproductive potential.

The desire to increase harvest, as well as increases in hatchery fish mitigating for lost natural habitat, led to a rapid increase in overall hatchery salmon production and resulted in expansion of commercial and sport fishing. Some species, such as spring and summer chinook, were targeted more than others by fishermen because of their high desirability and prices. A number of wild stocks were intentionally harvested at higher than optimum rates in order to catch co-mingled surplus hatchery salmon. This was happening at a time when extensive logging, and agricultural, hydropower and rapid urban developments were altering the landscape salmon needed to sustain natural production.

Salmon management in the Pacific Northwest involves several states, tribes, regional and international institutions, agreements, treaties, and other legal mechanisms. For example, international fisheries are addressed under the Pacific Salmon Treaty, and fisheries off the coasts of Washington, Oregon, and California are managed by the Pacific Fishery Management Council. Puget Sound and coastal salmon management operate under cooperative agreements between the state and the treaty Indian tribes under the U.S. v. Washington and Hoh v. Baldrige court rulings. Columbia River fishing is managed under the U.S. v. Oregon court ruling. Because of the adaptive management mechanisms integral to each of these mechanisms, substantial changes in fishing regulations in rivers and estuaries have been implemented throughout the state, resulting in dramatic reductions in fishing over the past three decades.

It is clear, however, that harvest restrictions alone cannot ensure rebuilding of challenged salmon populations to healthy, harvestable levels. The effects of harvest reductions, natural environmental fluctuations and improvements in human-caused habitat disturbance must occur together in order to improve salmon productivity.

Hatcheries

Artificial production in hatcheries has been used for many purposes during the past 100 years. Hatcheries initially were used to augment the fishery, later to mitigate for habitat destruction by development activities, and more recently to supplement natural production and conserve salmon.

The early hatchery programs simplified and controlled salmon production systems. To offset declining wild fish runs, large quantities of eggs were collected, hatched, and the fry then transplanted into areas where fish were declining, or into bodies of water to increase catch. The program worked simply and efficiently and brought substantial results by protecting salmon eggs from predators, disease and scouring floods, and maximizing the number of fry released as well as the harvest of fish returning from the ocean.

Early salmon managers viewed rivers as agrarian-ecosystems; agricultural objectives and approaches were adapted to salmon management. The main objective of most fish management programs was to maximize consumptive utilization of the resource - similar to an agricultural model of crops. Fish not harvested were considered a wasted resource.

Hatchery production was assumed to be additive to natural production with no impact on natural populations. Freshwater production was limited by spawning habitats and hatcheries were conceived as a means to augment the natural production. Substantial hatchery efforts were developed to mitigate impacts from construction of hydropower projects and water diversions. The hatcheries were meant to replace harvest potentially lost as a result of habitat alteration and degradation. Some of the hatchery programs were associated with the Mitchell Act, the federal legislation enabling federal cost sharing of state hatcheries.

Several scientific reviews recently conducted on the use of hatcheries in Pacific salmon management have concluded that historic hatchery practices have had adverse effects on natural salmon populations. Although hatcheries have been identified as one of the causes of the current salmon decline, changes in hatchery use to favor conservation of biological diversity and marking of hatchery fish to distinguish them from wild fish. Plus new management regimes which employ adaptive management in the context of entire watersheds, will ensure hatcheries become part of the solution to salmon recovery.

Aquatic Nuisance Species

Aquatic nuisance species are plants and animals that threaten native marine life and habitat. Several aquatic nuisance species currently pose a threat, such as Spartina (a cordgrass), zebra mussel, Chinese mitten crab, European green crab, and Eurasian watermilfoil. These plants and animals are not native to Washington's waterways and therefore have few or no predators. In a new environment, without checks and balances, their populations proliferate. As a result, these unwanted residents severely alter the ecological relationships in streams, lakes, estuaries and marine environments.

For example, the noxious weed Spartina now occupies more than 6,000 acres in Washington and is successfully displacing native eelgrass in many areas along the coast. Eelgrass provides important habitat for the rearing of juvenile salmon. In the Chehalis River, parrotfeather, another invasive weed, is colonizing the sloughs and backwaters of this system. These areas are known to be vitally important for salmon habitat. Because parrotfeather alters water chemistry, these sloughs are becoming lost as rearing areas for juvenile salmon.

Aquatic nuisance species may out-compete native vegetation, resulting in a loss of biodiversity. In addition, these species severely alter or eliminate native habitat by elevating water temperatures, removing phytoplankton and zooplankton from fresh waters, reducing dissolved oxygen levels, changing pH, providing hiding places for prey species, and impacting spawning beds by colonizing areas where no native vegetation existed. The relationship between the introduction of aquatic nuisance species and the protection of salmon habitat must be fully understood and acted upon before vital habitat can be adequately preserved or restored.

The Washington Aquatic Nuisance Species Planning Committee published the1998 Washington State Aquatic Nuisance Species Management Plan, approved by the Governor. The strategies outlined in the plan together with those of the Puget Sound Water Quality Exotic Species Work Group identified ways to reduce the impact of aquatic nuisance species while protecting salmon habitat in the process. The state strategies for prevention and control of invasive species include:

- *Prevention and control action* - Identify aquatic invasive species that may be making their way to Washington's waters by monitoring aquatic invasive species occurrences along the West Coast and communicating with other states. Develop an action plan to deal with potential aquatic invasive species before they enter state waters. Work with specific industries and user groups to modify existing practices or to implement new protocols. Evaluate current eradication and control programs (state, federal, local programs) and either maintain or elevate funding when necessary. Control the spread of Spartina and working toward eradicating known infestations. Place potential invasive plants and animals on a quarantine list that prohibits their sale or transport within Washington. Contain large populations of established aquatic nuisance species to reduce their size and expansion. Enforce current laws governing aquatic nuisance species.

- *Monitoring and data collection* – Assemble a task for to design and develop a monitoring and response plan to prevent further aquatic nuisance species invasions. Design and conduct a risk assessment for each invasive species to identify waters that are at risk of infestation by the species. Monitor freshwater non-indigenous plants and animals in lakes and rivers. Develop and maintain lists of non-native species known to occur in Washington. Make baseline survey and distribution data for aquatic nuisance species available to local, state and federal governments and other interested parties.

- *Education* - Develop and provide information on aquatic nuisance species to appropriate resource managers and key decision-makers. Develop and distribute educational information targeted at specific pathways of introductions that involve the public. Develop and provide information on aquatic nuisance species identification and biology to appropriate resource managers. Compile, develop, and coordinate the dissemination of educational materials on aquatic nuisance species to increase public awareness of the aquatic nuisance species problem.

- *Coordination* – Review and enforce current laws governing aquatic nuisance species and salmon in Washington State and identify gaps, overlaps, and contradictions that may exist. Make recommendations to improve the ability to protect Washington waters from the introduction and spread of aquatic nuisance species. Identify all local, state, and federal agencies responsible for the management of aquatic nuisance species in Washington waters and created a forum for these agencies to work together and coordinate resources and efforts.

In addition to the above state actions on February 3, 1999, the President of the United States issued Executive Order 13112 on Invasive Species. The Order supplements federal activities authorized under the 1990 Non-indigenous Aquatic Nuisance Prevention and Control Act and the 1996 National Invasive Species Act. The Order establishes an Invasive Species Council (with members representing Departments of Commerce, Interior, Agriculture, Defense, State, Treasury, and Transportation) to oversee the implementation of the Order and to ensure that activities of federal agencies concerning invasive species are coordinated effective and cost-efficient. The Council has 18 months to issue the National Invasive Species Management Plan to advance methods to prevent the introduction and spread of exotics in order to minimize the impacts of invasive species.

Table 3. summarizes how fresh water habitat alterations discussed above affect salmon. The table is reprinted with the permission of the author, Bisson. It is taken from the article "Degradation and loss of Anadromous Salmonid Habitat in the Pacific Northwest", by Stanley Gregory and Peter Bisson (1997). The last column illustrates activities that are likely to cause alteration and degradation of habitat conditions.

Table 3. Types of habitat alteration and effects on salmonid fishes in the Pacific Northwest. Reproduced with permission of the author, Bisson[5]

Ecosystem feature	Altered component	Effects on salmonid fishes and their ecosystems	Activities Likely to affect salmon and their ecosystems
Channel Structure	Floodplains	Loss of overwintering habitat, loss of refuge from high flows, loss of inputs of organic matter and large wood	Activities that remove and alter riparian vegetation, remove or alter rates of large woody debris, increase sediments, alter shorelines and streambanks, alter the channel and stream beds, divert water, alter or contribute to loss of wetlands and floodplains -Forest practices, agricultural practices, urbanization, road construction, sand and gravel removal, water diversions and flood control are likely to cause the impacts listed in column 3.
	Pools and riffles	Shift in the balance of species, loss of deep water cover and adult holding areas, reduced rearing sites for yearling and older juveniles	
	Large wood	Loss of cover from predators and high flows, reduced sediment and organic matter storage, reduced pool-forming structures, reduced organic substrate for macroinvertebrates, formation of new migration barriers, reduced capacity to trap salmon carcasses	
	Substrate	Reduced survival of eggs and alevins, loss of interstitial spaces used for refuge by fry, reduced macroinvertebrates production, reduced biodiversity	
	Hyporheic zone	Reduced exchange of nutrients between surface and subsurface waters and between aquatic and terrestrial ecosystems, reduced potential for recolonizing disturbed substrates	
Hydrology	Discharge	Altered timing of discharge-related life cycle cues (e.g., migrations) changes in availability of food organisms related to timing of emergence and recovery after disturbance, altered transport of sediment and fine particulate organic matter, reduced biodiversity	Diversion of water for irrigation, municipal and industrial uses, flood control structures, compaction of soils, creation of impervious surfaces, discharge of stormwater, sewer, and runoff, dams and hydropower operation, removal of vegetation, and fish passage barriers- Agricultural irrigation, forest practices, urbanization, dams and hydropower operation, and sand and gravel removal are examples of activities affecting the hydrologic needs of salmon.
	Peak flows	Scour-related mortality of eggs and alevins, reduced primary and secondary productivity, long-term depletion of large wood and organic matter, involuntary downstream movement of juveniles during freshets, accelerated erosion of streambanks	
	Low flows	Crowding and increased competition for foraging sites, reduced primary and secondary productivity, increased vulnerability to predation, increased fine sediment deposition	
	Rapid fluctuations	Altered timing of discharge-related life cycles cues(e.g., migrations), standing, intermittent connections between mainstream and floodplain rearing habitats, reduced primary and secondary productivity	
Sediment	Surface erosion	Reduced survival of eggs and alevins, reduced primary and secondary productivity, interference	Vegetation removal, stormwater discharge, return flows and runoff, streambank and

[5] The first three columns of the table are excerpted from Gregory and Bisson (1997) table1. Contained in the article on "Degradation and Loss of Anadromous Salmonid Habitat In the Pacific Northwest".

	Mass failures and landslides	with feeding, behavioral avoidance and breakdown of social organization, pool filling Reduced survival of eggs and alevins, reduced primary and secondary productivity, behavioral avoidance, formation of upstream migration barriers, pool filling addition of new large structures to channels	shoreline alteration,- forest practices, agricultural practices, shoreline development, urban Stormwater, residential, industrial and commercial development are among the activities causing sedimentation.
Water quality	Temperature Dissolved Oxygen Nutrients	Altered adult migration patterns, accelerated development of eggs and alevins, earlier fry emergence, increased metabolism, behavioral avoidance at high temperatures, increased primary and secondary production, increased susceptibility of both juveniles and adults to certain parasites and diseases, altered competitive interactions between species, mortality at sustained temperatures >23-29ºC, reduced biodiversity Reduced survival of eggs and alevins, smaller size at emergence, increased physiological stress, reduced growth Increased primary and secondary production, possible anoxia during extreme algal blooms, increased eutrophication rate of standing waters, certain nutrients(e.g. non-ionized ammonia some metals) possibly toxic to eggs and juveniles at high concentrations	Removal of riparian vegetation, removal of large woody debris, alteration of streambank and channel, water diversions, hydropower operation, alteration of wetlands, estuaries, and floodplain- Forest practices, agricultural practices, urban stormwater, water diversion, dams, and hydropower are among the activities resulting in increased water temperature, decreased level of oxygen in the water and excess nutrients.
Riparian forest	Production of large wood Production of food organisms and organic matter Shading Vegetative rooting systems and streambank integrity Nutrient modification	Loss of cover from predators and high flows, reduced sediment and organic matter storage, reduced pool-forming structures, reduced organic substrate for macroinvertebrates Reduced heterotrophic production and abundance of certain macroinvertebrates, reduced surface-drifting food items, reduced growth in some seasons Increased water temperature, increased primary and secondary production, reduced overhead cover, altered foraging efficiency Loss of cover along channel margins, decreased channel stability, increased streambank erosion, increased landslides Altered nutrient inputs from terrestrial ecosystems, altered primary and secondary production	Removal of vegetation, mass wasting, sedimentation, removal of large woody debris, and conversion of forest land are key contributors to this effect on salmon.
Exogenous materials	Chemicals Exotic organisms	Reduced survival of eggs and alevins, toxicity to juveniles and adults, increased physiological stress, altered primary and secondary production, reduced biodiversity Increased mortality through predation, increased interspecific competition, introduction of disease, and increased habitat degradation	Increased sediment discharge, use of pesticides and herbicides, urban and industrial stormwater, waste water discharge, mining dredging, road maintenance- Forest and agricultural practices, residential, commercial and industrial developments and human introduction of exotic species are causes of this effect.

C. Endangered Species Act and Its Consequences: Understanding ESA

Congressional efforts to conserve endangered species began with the passage of the Endangered Species Preservation Act of 1966 and the Endangered Species Conservation Act of 1969. In 1973, Congress enacted the Endangered Species Act (ESA), which is a complete rewrite of the two acts. The Endangered Species Act has been amended several times, and although further reauthorization is pending, it remains vital to the conservation of species.

The purposes of ESA are to "provide a means whereby the ecosystems upon which endangered species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of treaties." The ultimate goal of the Act is to return endangered and threatened species to the point where they no longer need the statute's protection.

The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) are the administering agencies of the ESA and its implementing regulations. Under the ESA, both NMFS and USFWS have three basic missions:

1) Identify species needing protection and the means necessary to protect and recover those species (including development of recovery plans);
2) Prevent harm to listed species; and
3) Prevent and enforce against the taking of listed species and destruction of their habitats.

Species can be determined to be either threatened or endangered. The term endangered refers to any species which is in danger of extinction throughout all or a significant portion of its range. Threatened species are those determined likely to become endangered within the foreseeable future.

Under the ESA a species is defined to include "any subspecies of fish or wildlife or plants, or any distinct population segment of any species of vertebrate fish and wildlife which interbreeds when mature". The National Marine Fisheries Service (NMFS) has adopted a definition to further clarify the meaning of subspecies and distinct population segment. The definition of species is based on the concept of "evolutionary significant units" or "ESUs" (Waples 1991). The goal of the ESU concept is to ensure viability of the biological species by conserving the genetic diversity of species and the ecosystems that species inhabit, two of the fundamental goals of ESA (Waples 1991). The decision to list is made under section 4 of the ESA, by either the USFWS (for terrestrial species) or by NMFS (for all marine species with few exceptions).

A decision to list as endangered or threatened must be made "solely on the basis of the best scientific and commercial data available." Economic impacts cannot be considered in the listing decision. However, economic considerations may be taken into account in the exception and exemption processes and in designating critical habitat. Also, state and local programs may be considered as part of the decision on whether to list a species.

NMFS or USFWS must designate “critical habitat” to identify and protect habitat essential to the survival and recovery of the species. Designation is generally done at the time of listing. Critical habitat means the areas within the geographic region occupied by the species at the time it is listed which are judged crucial to species survival. Critical habitat contains the physical or biological features essential to the conservation of the species, or that require special management.

After the decision to list a species, NMFS or USFWS must develop and implement a recovery plan for the conservation and survival of the listed species. Listing also triggers key regulatory mechanisms of the Act, which include prohibition against take, procedures for getting exceptions from take, and enforcement of the requirements of the Act. There are three major ways in which the ESA affects state and local governments and private citizens:

- First, where a proposed federal action might impact a listed species, the federal agency is required to consult with either the National Marine Fisheries Service (for anadromous fish) or the U.S. Fish and Wildlife Service (for wildlife and non-marine fish) to determine if the action will jeopardize the species. If it does, the action is either prohibited or modified so that jeopardy does not occur. In this kind of situation, the types of actions affected range from curtailing or reducing the amount of water available to irrigators, to making major changes in the way the Columbia River power system is operated, or to restricting timber harvest on federal forest lands. Earlier this decade, timber harvests from federal forests in the Pacific Northwest were shut down for three years, pending development of a federal forest plan that met the requirements of the ESA to protect the northern spotted owl.

- Second, to provide protection from ESA sanctions, private landowners, public agencies and others have developed Habitat Conservation Plans (HCPs) which allow reduced impacts on certain listed species while ensuring their long-term protection. The Mid-Columbia Public Utility Districts, for example, have spent millions of dollars in habitat improvements and dam modifications to protect listed fish species, and the Washington State Department of Natural Resources (DNR) has adopted an HCP for 1.6 million acres of forest land to protect the spotted owl and listed fish.

- Third, where actual harm has occurred to a listed species, litigation can be initiated by the federal government or a citizen to enforce the protection requirements of the ESA. For example, an irrigation district in southwest Oregon was forced to remove an irrigation dam to protect a listed fish species.

Since 1973 private, state, local, tribal and federal actions have increasingly been impacted by the regulatory requirements of ESA and have been subject to many consequences for not complying with those requirements. The followings are pertinent examples of ESA consequences:

- Restrictions on the ability of farmers to use water: Courts have held in California that state water rights do not prevail over the requirements of the ESA when there is a conflict. For example, a court forced an irrigation district with a very senior (1883) water right to change its practices regarding use of a water diversion channel (U.S. v. Glenn Colussa, 1992). In another instance, the National Marine Fisheries Service (NMFS) required an irrigation district to install a fish screen to protect a listed species (Anderson-Cotton Irrigation District, 1991). In other California cases, irrigators lost use of significant allocations of water, despite contracts with the federal Bureau of Reclamation, because of the needs of ESA- listed species (Orange Cove, 1997; O'Neill v. U.S., 1995; Westland Water District, 1993). In an administrative action, NMFS prevented an Oregon agriculture corporation from further exercising its water right by preventing the corporation from installing a pump to withdraw water from the Columbia River.

- Restrictions on dam operations and power generation: Operations of the Snake and Columbia River dams were modified significantly because of listed fish in the Columbia River Basin. As a result, water that would be used for power generation was kept in river to speed the down river migration of listed fish species, costing annually well over a hundred million dollar in foregone revenue from power generation.

- Restrictions on commercial fisheries: In Alaska, the National Oceanic and Atmosphere Administration determined that one of the world's most lucrative fisheries was reducing the availability of food for the Stellar sea lion, a protected species under the ESA. As a result, significant restrictions were placed on the pollack fisherey, costing commercial fishermen millions of dollars in lost revenue.

- Restrictions on private citizens and state and local governments: In a series of court cases around the country, the reach of the ESA extended to the local level. In Massachusetts, state officials were found in violation of the ESA by issuing licenses and permits allowing fishing in a manner which jeopardized the northern right whale, an ESA listed species (Strahan v. Coxe, 1997). In Florida, local government was held liable for failing to regulate actions which harmed threatened sea turtles (Loggerhead Turtle v. Volusia County Counci, 1995). In another Massachusetts case, a court issued a permanent injunction to ban off-road vehicles (ORVs) from using a beach until the local government follows guidelines to protect piping plovers, a listed shorebird (U.S. v. Town of Plymouth, 1998). In a landmark case establishing the clear authority of the ESA over habitat, a court in Hawaii held that the state" practice of allowing goats and sheep in the habitat of the endangered palila bird was a violation under the ESA (Palila v. Hawaii Department of Natural Resources, 1988). In Oregon, a federal judge threw out a state conservation plan to protect coho in an effort to prevent an ESA listing; the court said that Oregon's plan was based on voluntary actions, which provide no certainty that the fish would be protected.

- Restrictions on timber harvest: In the Pacific Northwest, a federal judge issued an injunction resulting in the shutdown of timber harvest on federal forest land until the federal government drew up a timber harvest plan that protected the northern spotted owl, an ESA listed species. Such a plan was drawn up for the federal forest, resulting in significant reductions in timber harvests with corresponding economic impacts on timber companies, loggers and rural communities. The ESA requirements for the spotted owl also resulted major reductions in harvest from millions of acres of private and state forest land in the Pacific Northwest.

D. Summary

To achieve long-term protection for a diverse and abundant salmon resource in Washington, two conditions must be met.

- First, everyone must recognize and protect the genetic diversity of salmon. It is not enough to focus only on the abundance or mere numbers of salmon; their long-term survival depends on genetic diversity within and between local breeding populations. This diversity and the protection and rehabilitation of salmon habitat are the basis of sustained production of anadromous salmon and of the species' evolutionary futures. All impacting sectors - habitat, harvest, hatcheries and hydropower - must keep genetic diversity as the highest priority.
- Second, any solution to the salmon problem must take the effects of growth in human population and economic activity into account. If economic and population growth in the region continue, many of the forces that have reduced salmon runs will continue to make it harder and more expensive to rehabilitate salmon successfully. The social structures and institutions that have been operating in the state have proved incapable of ensuring a long-term future for salmon, in large part because they do not operate at the right time and spatial scales. This means that institutions must be able to operate at the scale of watersheds; in addition, a coordinating function is needed to make sure that this larger perspective as well as issues associated with accountability, enforcement and performance monitoring are also considered.