PART I: INTRODUCTION

2. Salmon Habitat Needs

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Since the recession of the last ice age 10,000 years ago, Washington State anadromous salmonid populations have evolved in their specific habitats (Miller, 1965). Water chemistry, flow, and the physical and biological components unique to their natal streams, estuaries and ocean environment have helped shape the genotypic and phenotypic characteristics of each salmon population. These unique attributes have resulted in a wide variety of distinct salmon stocks for each salmon species throughout the state. Within a given species, stocks are relatively distinct population units that do not extensively interbreed with each other. Stocks do not extensively interbreed with each other because returning adults rely on a stream's unique chemical and physical characteristics to guide them to their natal spawning grounds. This maintains the separation of stocks during reproduction, thus preserving the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the environment and a stock continues. For example, adults spawn in areas near their origin because reproductive survival favors natural selection for those that exhibit this behavior. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It has been theorized that rapid out-migration reduces predation on the young salmon and perhaps coincides with favorable feeding conditions in the estuary (Wetherall, 1971). These are a few examples that illustrate how a salmon stock and its environment are intertwined throughout the entire life cycle.

Salmon habitat includes the physical, chemical and biological components of the environment that support salmon. Within freshwater and estuarine environments, these components include:

- Water quality;
- Water quantity or flows;
- Stream and river physical features (e.g., sediment, substrate, and woody debris);
- Riparian zones;
- Upland terrestrial conditions; and
- Ecosystem interactions as they pertain to habitat.

These components are closely intertwined. Low stream flows can alter water quality by increasing temperatures and decreasing the amount of available dissolved oxygen, while concentrating toxic materials. Heavy sediment loads can also impact water quality by increasing in channel instability and decreasing spawning success. The riparian zone interacts with the stream environment, providing nutrients and a food web base, woody debris for habitat and flow control (stream features), filtering runoff prior to surface water entry (water quality), and providing shade to aid in water temperature control. Riparian zones serve similar functions in the estuarine and nearshore environment.

Optimal freshwater habitat for salmonids includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for each stage of freshwater life. Salmonid survival depends upon specific habitat requirements for egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These requirements can vary by species and even by individual stock.

When adults return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools with vegetative cover and instream structures such as root wads for resting and shelter from predators. Successful spawning and incubation requires sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location.

After spawning, the eggs need stable gravel that is not choked with fine-grained sediment. River channel stability is vital at this life history stage. Floods have their greatest impact to salmon populations during incubation where they can scour redds. Flood impacts may be exacerbated by human activities that lead to increased sediment loads, point and non-point source pollutants, and the removal of instream LWD. Floods also produce and maintain habitats. They provide the necessary energy to scour deep pools and create side channels. In a natural river system, the upland areas are forested. Trees and their roots store precipitation, which slows the rate of storm water into the stream. A natural, healthy river is sinuous and contains large pieces of downed wood contributed by an intact, mature riparian zone. Both slow the speed of water downstream. Natural river systems have floodplains that are connected directly to the river at many points, allowing the floodplains to store flood water and later discharge this storage back to the river during lower flows. In a healthy river, erosion or sediment input is great enough to provide new sediments (i.e.: gravel) for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. A stable incubation environment is essential for salmon, requiring a complex interaction of nearly all the habitat components contained within a natural river ecosystem.

After the young salmonid fry emerge from the gravel nests (redds), certain species (such as chum, pink, and some chinook salmon) quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bull trout, cutthroat, sockeye and chinook, will search for suitable rearing habitat within the side sloughs and channels, tributaries, and spring-fed “seep” areas, as well as the outer edges of the stream. These quiet-water side margins and off channel slough areas are vital for early juvenile rearing habitats. The presence of woody debris and overhead cover aid in food and nutrient inputs, provide localized areas of reduced water velocities for energy conservation as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye populations migrate from their gravel nests quickly to larger lake environments where they have unique habitat requirements. The adult sockeye observed spawning in the Green River may be strays from other systems or represent a riverine life history stock.

As growth continues, the juvenile salmon (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. The species that exhibit this behavior include coho, steelhead, bulltrout, and certain chinook. For some of these species, this movement is coincident with the summer low flows. Low flows typically constrain salmon production for stocks that rear during summer within the stream. In non-glacial streams, precipitation, melting snow packs, connectivity to wetland discharges, and groundwater maintain summer flows inputs. Reductions in these inputs will reduce that amount of habitat; hence the number of salmon which are dependent on adequate summer flows are reduced.

In the fall, juvenile salmon that remain in freshwater begin to move out of the mainstems, and again, off-channel habitat becomes important. During the winter, coho, steelhead, bull trout, cutthroat and any remaining chinook parr require off-channel habitats to sustain their growth and protect them from predators and high winter flows. Wetlands, off-channel/side channel stream habitat protected from the effects of high flows, and pools with overhead cover are important habitat components during this time.

Except for resident bull trout, cutthroat and steelhead (rainbow), juvenile parrs convert to smolts as they migrate downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the stock's characteristics through adaptation over the last 10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends heavily on natural flow patterns.

Estuaries and nearshore areas support a critical life stage that can be a determinant to successful juvenile survival and the subsequent adult returns. The estuary provides essential habitat for physiological transition, refuge, foraging and rapid growth. Some salmon species are more heavily dependent on estuaries, particularly chinook, chum, and to a lesser extent pink salmon. Estuaries contain new food sources to support the rapid growth of salmonid smolts and an area in which to undergo physiological adaptation from freshwater to saltwater. The complexity of the healthy nearshore environment provides juvenile salmonids with necessary prey items, including insects falling from marine riparian vegetation, bottom-dwelling crustaceans, and crustaceans that live on marine plants such as eelgrass and kelp. Smolts prefer shallow-water habitats. In particular, habitats that support the detritus-based food web, such as tidal marshes and channels, eelgrass beds, and sand and mud flats, provide a complex system of protection from and opportunities for predators and while allowing juvenile salmonids opportunities for places to rest and forage. As smolts grow larger and begin to move into deeper waters, they rely more heavily on planktonic prey, but some, especially chinook, continue to eat insects that drift out from shore.. Returning adult salmonids use the nearshore as staging areas and safe places to make the physiological transition from saltwater to freshwater.

The physical, chemical, and biological processes that create nearshore and estuarine habitats must be maintained for salmonids. For example, sediment transport provides appropriate substrates for eelgrass and other organisms that contribute essential nutrients to the nearshore environment. Marine riparian vegetation must be sufficient to provide woody debris, nutrients, and insects to these environments .

Common disruptions to these habitats include dikes, shoreline armoring, dredging and filling activities, pollution, and shoreline development. Some of the most pressing problems along urban shorelines are interrupted sediment transport processes, filling of intertidal habitat to support development, removal of LWD, and the loss of marine riparian vegetation.

All salmonid species need adequate flow and water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability. However, some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon species and/or stocks of the same species within a river are often staggered in their use of a particular type of habitat. Some are staggered in time, and others are separated by distance.

Chum and pink salmon use the streams the least amount of time. While Green River-origin pink salmon were thought to have been extirpated during the 1930s, recent observations of adult (Kerwin, 1999) and juvenile (Seiler, 2000) pink salmon indicate either a remnant population or an attempt by straying adult pink salmon from out of the basin to recolonize this basin. Green-River-basin-origin adult pink salmon return at two years of age and typically begin to enter the mainstem river in August and spawn in September and October of odd numbered years. During these times, low flows and associated high temperatures and low dissolved oxygen can be problems. Other disrupted habitat components such as less frequent and shallower pools caused by sediment inputs as well as a lack of canopy from an altered riparian zone or widened river channel can worsen these flows and water quality problems because there are fewer refuges for the adults to hold prior to spawning.

Pink salmon fry in the Green River basin are believed to emerge from their redds around March and migrate downstream to the estuary within a month. The downstream migrant trap located at approximately RM 34.0 has reported pink salmon fry captured as early in the year as March 2000. After a limited rearing time in the estuary, pink salmon migrate to the ocean for a little over a year, until the next spawning cycle. Most pink salmon stocks in Washington State return to the rivers only in odd years. The exception is the Snohomish Basin, which supports both even- and odd-year pink salmon stocks.

In the Green River basin, chum salmon (adults are three to five years in age) are from one run type (fall) but have two stocks. These fall chum adults enter from late October through early December and spawn from mid November through late December. Chum salmon fry emerge from the redds in February and March, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum salmon follow prey availability. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo, 1982).

Chinook salmon have three major run types in Washington State. Spring chinook are typically in their natal rivers throughout the calendar year as juveniles, adults or both. Spring chinook were historically present in the Duwamish/Green River basin and would have entered into freshwater during April or May. However, this run either returns in such low numbers as to be difficult to detect, became extirpated after the initial construction efforts of the Tacoma Headworks Dam in 1911, or were isolated from the basin with the diversion of the White River in 1906. Historically, they would have spawned from July through September and typically in the headwater areas where the higher gradient habitats they prefer exist. There does exist some evidence of early September spawning of chinook salmon but it is unclear if these fish are truly spring chinook or early spawning fall chinook. Incubation would have continued throughout the autumn and winter and generally required more time for the eggs to develop into fry because of the colder temperatures in the headwater areas. Fry would have begun to leave the redds in February through early March. After a short rearing period in the shallow side margins and sloughs, Puget

Sound and coastal spring chinook juveniles begin to leave the rivers to the estuary throughout spring and into summer (August). Juveniles have been found in the Lower Duwamish through September, and may remain in the estuary even longer. Exact outmigration and residence time in any part of the system is variable, controlled by environmental cues, and requires additional investigation for a better understanding of timing and habitat requirements. In the White River spring chinook stock, historically associated with the Green/Duwamish river basin, juveniles exhibit similar rearing characteristics to summer/fall chinook stocks and leave as sub-yearlings. This is indicative of one variety of outmigration strategies commonly used by spring chinook stocks.

Duwamish/Green river basin summer/fall chinook stocks range in spawn timing from late September through December. Juveniles are believed to incubate in the gravel until late January or early February through early March, and outmigration to the estuaries occurs over a broad time period. Typical fall chinook stocks outmigrate from January through August but the complete migratory time period for juvenile Duwamish/Green River fall chinook is not currently known. While some emerging chinook salmon fry outmigrate quickly, most inhabit the shallow side margins, side channels and side sloughs for up to two months. Then, some gradually move into the faster water areas of the stream to rear, while others outmigrate to the estuary. Typically, the Green/Duwamish river basin summer/fall chinook migrate within their first year of life, but a few stocks (Snohomish summer chinook, Snohomish fall chinook, upper Columbia summer chinook) have juveniles that remain in the river for an additional year. There are no data to indicate that there is a large component of Duwamish/Green River basin stock summer/fall chinook juveniles that remain in freshwater for a full year after emerging from the redds, but a few juvenile chinook with this life history characteristic have been captured in the Mill Creek/Mullen Slough subbasin.

Duwamish/Green River chinook use the mainstem Green River, Big Soos Creek, and Newaukum Creek (Williams et al. 1975), as well as Burns Creek (Malcom 1999), Mill Creek (Jones and Stokes 1989), and Springbrook Creek (Malcom 1999) and Crisp Creek (Malcom 1999). The extent of any natural juvenile chinook rearing in non-natal tributary streams is unknown. Fall chinook adults have been observed spawning in the mainstem Green River primarily between RM 24.0 and RM 61.0 (Williams et al. 1975, WDFW Spawning Ground Survey Database). However, recent spawning ground survey observations from 1996 through 1999 inclusive, indicate that the majority of the chinook spawning begins at RM 25.4 (Malcom 1999). The downstream extent of adult chinook spawning appears to vary from year to year. It is unclear what determines the downstream extent but it is likely influenced by environmental factors such as water flow and temperature. The two areas of preferred spawning have been reported from RM 29.6 to 47.0 and from RM 56.0 to 61.0 (Grette and Salo 1986). Because of changing environmental conditions and increased survey efforts, the analysis of the preferred spawning reaches is unclear and ongoing. In 1998, the bulk of the spawning occurred upstream of RM 33, with distinct areas of dense chinook spawning observed and other sections of the river lacking any redds (Muckleshoot Indian Tribe Fisheries Division (MITFD), unpub. data). In 1999, large numbers of redds were located near the confluences of Soos and Icy Creeks with the Green River. Recently, helicopter spawning ground surveys have indicated a large number of redds in the Green River Gorge (WDFW unpub. data; MITFD unpub. Data; Kerwin 1999). The spawn timing for Newaukum Creek summer/fall chinook peaks in October, ranging from September through November. Green-Duwamish summer/fall chinook spawn from early September into early November. Spawning in the mainstem Green River is considered to have ended by 1 November.

Historically, naturally produced adult chinook were present in the mainstem Green River and some tributaries upstream of the City of Tacoma's diversion dam located at RM 61 (Riseland 1913). Juvenile chinook produced by natural spawning have been recovered from Soos and Covington Creeks and adult chinook have been observed at the entrance to Lake Sawyer.

The onset of coho salmon spawning is tied to the first significant fall freshet. Green/Duwamish river basin coho stocks typically enter freshwater from September to early December, but have been observed as early as late-July and as late as mid-February (MIT unpublished data). They often mill near the river mouth or in lower river pools until the fall freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October. Spawning typically occurs in tributary streams. High stormwater flows and sedimentation in these tributaries can suffocate eggs. As chinook salmon fry exit the shallow low-velocity rearing areas, coho fry utilizes those same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas which adults cannot access (Neave 1949). Pool habitat is important not only for returning adults, but for all stages of juvenile development. Preferred pool habitat includes deep pools with riparian cover and woody debris.

All Green/Duwamish river basin coho juveniles remain in the river for a full year after leaving the gravel nests, but during the summer after early rearing, low flows can lead to problems such as a physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased temperature, and increased predation. Juvenile coho are highly territorial and can occupy the same area for a long period of time (Hoar, 1958). The abundance of coho can be limited by the number of suitable territories available (Larkin, 1977). Streams with more structure (logs, undercut banks, etc.) support more coho (Scrivener and Andersen, 1982), not only because they provide more territories (useable habitat), but they also provide more food and cover. Large wood also assists in the retention of salmon carcasses by adding habitat complexity in the form of pools where these carcasses may settle out and add nutrients for stream productivity. There is a positive correlation between their primary diet of insect material in stomachs and the extent the stream was overgrown with vegetation (Chapman, 1965). In addition, the leaf litter in the fall contributes to aquatic insect production (Meehan et al., 1977).

In the autumn as the temperatures decrease, the juvenile coho move into deeper pools, hide under submerged logs, overhanging and submerged tree roots, and undercut banks (Hartman, 1965). The fall freshets redistribute them (Scarlett and Cederholm, 1984), and over-wintering generally occurs in available side channels, spring-fed ponds, and other off-channel sites to avoid high stream velocities associated with winter floods (Peterson, 1980). The lack of side channels and small tributaries may limit coho survival (Cederholm and Scarlett, 1981). As coho juveniles grow into yearlings, they become more predatory on other salmonids. Green/Duwamish river basin origin coho begin to leave the river over a year after emerging from their gravel nests with the peak outmigration occurring in early May. Coho use estuaries primarily for interim feeding while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including the landlocked populations of kokanee, which never enter saltwater. The origin of adult sockeye observed spawning in the

Green/Duwamish river basin is not known. It is hypothesized that the adult sockeye spawning in the Duwamish/Green River are: (1) strays from outside the basin; (2) a riverine form of sockeye or; (3) some combination of both. The first trajectory is thought to be the most likely because of the close proximity of Lake Washington and its associated sockeye stocks. However, because sockeye adults are observed annually in rivers throughout Puget Sound, some professional fishery biologists theorize that there are small populations of riverine sockeye throughout western Washington rivers. Adult sockeye are observed annually in low numbers in the spawning in the Green/Duwamish river Basin.

After sockeye fry emerge from the gravel, the typical life history trajectory is that most migrate to a lake for rearing, although some types of fry migrate to the sea and others rear in mainstem rivers. Lake rearing ranges from 1-3 years. Because a lake rearing environment is not present in the Green River any sockeye juvenile and resultant smolt production would have to be riverine in origin. Riverine sockeye are found in some river systems in Alaska where they rear in larger mainstem rivers.

Steelhead have one of the most complex life history patterns of any anadromous Pacific salmonid species (Shapovalov and Taft, 1954). In Washington, there are two major run types, winter and summer steelhead. Green/Duwamish river basin winter steelhead adults begin river entry in a mature reproductive state in December and generally spawn from February through May. The Green/Duwamish river basin also supports a hatchery origin summer steelhead run. Specific run and spawn timing for summer-run steelhead is unknown but generally is May through October and February through April respectively.

Naturally produced juvenile winter steelhead can either migrate to sea or remain in freshwater as a resident rainbow trout. The vast majority of juvenile steelhead smolt and migrate to saltwater. Duwamish/Green River basin origin steelhead usually spend 1-3 years in freshwater, with the greatest proportion spending two years. Because of this, steelhead rely heavily on the freshwater habitat and are present in streams all year long.

The presence or absence of self sustaining bull trout populations in the Green/Duwamish river Basin are not well documented and are discussed in detail elsewhere in this report. Bulltrout-Dolly Varden stocks are also very dependent on the freshwater environment, where they reproduce only in clean, cold, relatively pristine streams. Within a given stock, some adults remain in freshwater their entire lives, while others migrate to the estuary where they stay during the spring and summer. They then return upstream to spawn in late summer. Those that remain in freshwater either stay near their spawning areas as residents, or migrate upstream throughout the winter, spring, and early summer, residing in pools. They return to spawning areas in late summer. In some stocks juveniles migrate downstream in spring, overwinter in the lower river, then enter the estuary and Puget Sound the following late winter to early spring (WDFW, 1998). Because these life history types have different habitat characteristics and requirements, bulltrout are generally recognized as a sensitive species by natural resource management agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of habitat degradation.

All of the salmonid species have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and a healthy estuarine environment. Some species, such as chinook, pink and chum rely heavily on the estuary for foraging, growth, and physiological transition that requires good estuary habitats.

In addition to the above-described relationships between various salmon species and their habitats, there are also interactions between the species that have evolved over the last 10,000 years such that the survival of one species might be enhanced or impacted by the presence of another. Pink and chum salmon fry are frequently food items of coho smolts, cutthroat, bull trout, and steelhead (Hunter, 1959). Chum fry have decreased feeding and growth rates when pink salmon juveniles are abundant (Ivankov and Andreyev, 1971), probably the result of occupying the same habitat at the same time (competition). Salmon carcasses can provide a direct and indirect food resource for the same or other salmonid species. These are just a few examples.

The Green/Duwamish river basin is home to several salmonid species, which together, rely upon freshwater and estuary habitat the entire calendar year. As the habitat and salmon review indicated, there are complex interactions between different habitat components, between salmon and their habitat, and between different species of salmon. Just as habitat dictates salmon types and production, salmon contribute to habitat and to other species. Specific information about individual runs and stocks is contained the next chapter, “Current Salmonid Population Conditions in the Green/Duwamish River Basin.”