THE RELATIVE ROLE OF HABITAT IN HEALTHY POPULATIONS OF NATURAL SPAWNING SALMON

During the last 10,000 years, Washington State salmon populations have evolved in their specific habitats (Miller, 1965). Water chemistry, flow, and the physical stream components unique to each stream have helped shape the characteristics of each salmon population, which has resulted in a wide variety of distinct salmon stocks for each salmon species throughout the State. Within a given species, stocks are units that do not extensively interbreed because returning adults rely on a stream's unique chemical characteristics to guide them to their natal grounds to spawn. This maintains the separation of stocks during reproduction, thus maintaining the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the stream and a stock continues. Adults spawn in areas near their own origin because survival favors those that do. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It is thought that the faster speed during out-migration reduces predation on the young salmon and perhaps is coincident to favorable feeding conditions in the estuary (Wetherall, 1972). 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 supports salmon. Within freshwater and estuarine environments, these components include water quality, water quantity or flows, channel physical features, riparian zones, sediment regime, upland conditions, and ecosystem interactions as they pertain to habitat. However, these components closely intertwine. Low stream flows can alter water quality by increasing temperatures and decreasing oxygen levels. The riparian zone interacts with the stream environment, providing nutrients and a food web base, large woody debris for habitat and flow control (stream features), filtering water prior to stream entry (water quality), sediment control and bank stability, and shade to aid in temperature control.

Salmon habitat includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for all stages of freshwater life. In addition, salmon survival depends upon specific habitat needs for the different life history stages, which include egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These specific needs can vary by species and even by stock.

When adult salmon return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools for resting with vegetative cover and instream structures such as rootwads for shelter from predators. Successful spawning depends on 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. Delayed upstream migration can be critical. After entering freshwater, most salmon have a limited time to migrate and spawn, in some cases, as little as two to three weeks. Delays can result in pre-spawning mortality or spawning in a sub-optimum location.

After spawning, the eggs need stable gravel that is not choked with sediment. River channel stability is vital at this life history stage for all species of salmonids. Floods have their greatest impact to salmon populations during incubation, and flood impacts are worsened by human activities that alter stream hydrology. In a natural river system, the upland areas are forested, and the trees and their roots store precipitation, which slows the rate of storm water into the stream, lessening the impact of a potential flood. The natural, healthy river is sinuous and contains numerous large pieces of wood contributed by an intact, mature riparian zone. Both reduce the energy of water moving downstream. Natural systems have floodplains that are connected directly to the river at many points, allowing wetlands to store flood water and later discharge this storage back to the river during lower flows. This not only decreases flood impacts, but also recharges fish habitat later when flows are low. In a healthy river, erosion or sediment input is great enough to provide new gravel for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. Lastly, a natural river system allows floodwaters to freely flow over unaltered banks rather than constraining the energy within the channel, scouring out salmon eggs. A stable egg incubation environment is essential for all salmon, and is a complex function of nearly all habitat components.

Once the young fry leave their gravel nests, certain species such as chum, pink and some chinook salmon quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bulltrout, and chinook, will search for suitable rearing habitat within the side sloughs, side-channels, spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off-channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye salmon populations quickly migrate from their gravel nests to larger lake environments where they have unique habitat requirements. These include water quality sufficient to produce the necessary complex food web to support one to three years of salmon growth in that lake habitat prior to outmigration to the estuary.

As growth continues, the juveniles (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. These include coho, steelhead, bull trout/Dolly Varden, and certain chinook. For some of these species, this movement is coincident with the summer low flows. Low flows constrain salmon production for stocks that rear within the stream. In non-glacial streams, summer flows are maintained by precipitation, connectivity to wetland discharges, and groundwater inputs. Reductions in these inputs will reduce the amount and quality of habitat; hence the number of salmon from these species.

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/Dolly Varden, and remaining chinook need habitat to sustain their growth and protect them from predators and winter flows. Wetlands, off-channel habitat, undercut banks, rootwads, and pools with overhead cover are important habitat components during this time.

Except for bull trout/Dolly Varden and resident steelhead, juvenile parr 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 population'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 on natural flow patterns, particularly during migration times.

The estuary provides an ideal area for rapid growth, and some salmon species are 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, so adequate natural habitat must exist to support the detritus-based food web, such as eelgrass beds, mudflats, and salt marshes. Also, the processes that contribute nutrients and woody debris to these environments must be maintained to provide cover from predators and to sustain the food web. Common disruptions to these habitats include dikes, bulkheads, dredging and filling activities, pollution, and alteration of downstream components such as lack of woody debris and sediment transport.

All salmonid species need adequate flow, similar water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability, but some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon 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. Washington State adult pink salmon typically begin to enter the rivers in August and spawn in September and October, although Dungeness summer pinks enter and spawn a month earlier (WDFW and WWTIT, 1994). During these times, low flows and associated high temperatures and low dissolved oxygen can be problems. Other disrupted habitat components, such as a shallow and less frequent pools due to elevated sediment inputs and lack of canopy from an altered riparian zone or widened river channel, can worsen these flow and water quality problems because there are fewer refuges for the adults to hold prior to spawning.

The pink salmon fry emerge from their gravel nests in February to April, and migrate downstream to the estuary within a month. 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 are only in the rivers in odd years. The exception is the Snohomish Basin, which supports two pink salmon stocks. One stock spawns in odd years, and the other stock spawns in even years.

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in February and March migrate rapidly offshore. This migration rate decreases in May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo, 1982). Both chum and pink salmon 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 because they rely heavily on the estuary for growth, good estuary habitat is essential.

Chinook salmon have three major run types in Washington State. Spring chinook are in their natal rivers throughout the calendar year. Adults begin river entry as early as February in the Chehalis Basin, but in Puget Sound, entry doesn't begin until April or May. Spring chinook spawn from July through September and typically spawn in the headwater areas where higher gradient habitat exists. Incubation continues throughout the autumn and winter and generally requires more time for the eggs to develop into fry because of the colder water temperatures in the headwater areas. Fry begin to leave the gravel nests in February through early March. After a short rearing period in the shallow side margins and sloughs, all Puget Sound and coastal spring chinook stocks have a component of the juvenile population that begin to leave the rivers to the estuary over the next several months, lasting until August. Within the Puget Sound stocks, it is not uncommon for other juveniles to remain in the river for another year before leaving as yearlings, so that a wide variety of outmigration strategies are used by these stocks. The juveniles of spring chinook stocks in the Columbia Basin exhibit more distinct juvenile life history characteristics. Generally, these stocks remain in the river for a full year. However, some stocks migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the mainstem Columbia River, where they are believed to over-winter prior to outmigration the next spring as yearling smolts.

Summer chinook begin river entry as early as June in the Columbia, but not until August in Puget Sound. They generally spawn in September or October. Fall chinook stocks range in spawn timing from late September through December. All Washington State summer and fall chinook stocks have juveniles that incubate in the gravel until January through early March, and downstream migration to the estuaries occurs over a broad time period (January through August). A few of these stocks have a component of juveniles that remains in freshwater for a full year after emerging from the gravel nests.

While some emerging chinook salmon fry outmigrate quickly, most inhabit the shallow side margins and side channels for up to two months. Then, some gradually move into the faster areas to rear, and others outmigrate to the estuary. Most summer and fall chinook outmigrate 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, similar to many spring chinook (Marshall et al, 1995). However, those in the upper Columbia, have scale patterns that suggest that they rear in a reservoir-like environment (mainstem Columbia River upstream from a dam) rather than in their natal streams and it is unknown whether this is a result of dam influence or whether it is a natural pattern.

The onset of coho salmon spawning is tied to the first significant fall freshet (Chuck Baranski, WDFW, personal communication). Adults typically enter freshwater from September to early December, but have been observed as early as late July and as late as mid-January (WDF et al, 1993). They often mill near the river mouths or in lower river pools until freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October and can extend into March. Spawning often occurs in tributaries and sedimentation in these tributaries can be a problem, with fine sediments suffocating eggs and excess coarse sediment decreasing channel stability. As chinook salmon fry exit the shallow low-velocity rearing areas, coho fry enter the same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas that 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 coho juveniles remain in the river for a full year after leaving the gravel nests, but during their first summer after hatching, low flows can lead to problems such as physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased water temperature, and increased predation. Juvenile coho are highly territorial and can occupy the same area for a long period of time (Hoar, 1958). Coho abundance can be limited by the number of available suitable territories (Larkin, 1977). Streams with more structure (logs, bushes, etc.) support more coho (Scrivener and Andersen, 1982), not only because they provide more territories, but they also provide more food and cover. There is a positive correlation between their primary diet of insect material in their stomachs and the extent to which 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, juvenile coho move into deeper pools, and hide under logs, 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 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. Coho begin to leave the river a full year after emerging from their gravel nests with the peak outmigration occurring in early May. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including landlocked populations of kokanee that never enter saltwater. Of the populations that migrate to sea, adult freshwater entry varies from spring for the Quinault stock, summer for Ozette and Columbia River stocks, and summer and fall for Puget Sound stocks. Spawning ranges from September through February, depending on the stock.

After fry emerge from the gravel, most migrate to a lake for rearing, although a few types of fry migrate to the sea. Lake rearing ranges from one to three years with most juveniles rearing two years. In the spring after lake rearing is completed, juveniles enter the ocean where more growth occurs prior to adult return for spawning.

Sockeye spawning habitat varies widely. Some populations spawn in rivers (Cedar River) while other populations spawn along the beaches of their natal lake (Ozette), typically in areas of upwelling groundwater. Sockeye also spawn in side channels and spring-fed ponds. The spawning beaches along lakes provide a unique habitat that is often altered by human activities, such as pier and dock construction, dredging, sedimentation, and weed control.

Steelhead have one of the most complex life history patterns of any Pacific salmonid species (Shapovalov and Taft, 1954). In Washington, there are two major run types, winter and summer steelhead. Winter steelhead begin river entry in a mature reproductive state in December and generally spawn from February through May. Summer steelhead enter the river from about May through October with spawning from about February through April. They enter the river in an immature state and require several months to mature (Burgner et al, 1992). Summer steelhead usually spawn farther upstream than winter stocks (Withler, 1966) and dominate inland areas such as the Columbia Basin. Coastal streams support more winter steelhead populations.

Juvenile steelhead can either migrate to sea (anadromy) or remain in freshwater as rainbow trout. In Washington, those that are anadromous usually spend one to three years in freshwater, with the greatest proportion spending two years (Busby et al, 1996). Because of this and their year-round presence in steelhead-bearing streams, steelhead greatly depend on the quality and quantity of freshwater habitat.

Bull trout/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 rear 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, bull trout/Dolly Varden are generally recognized as a sensitive species by natural resource agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of habitat degradation.

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, Dolly Varden char, 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 and competing for food items. These are just a few examples.

Most streams in Washington are 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. For just as habitat dictates salmon types and production, salmon production contributes to habitat and to other species.