4.5.1 Aquatics

4.5.1.1 Introduction

While the conservation of all aquatic habitat remains a priority in the management of vegetation treatment projects, management practices for the conservation of threatened and endangered salmonids is of primary concern. The freshwater habitat for salmonids and other aquatic species has been heavily impacted by land management and development practices. Timber management, commercial fishing, rural development, and limited agriculture have been on-going since the mid-1800s. In many respects, the condition of stream systems within California contributes to the pattern and distribution of salmonid and other species listings. The California Advisory Committee on Salmon and Steelhead Trout (CACSST, 1988) reported habitat blockages and fragmentation, logging and agricultural activities, urbanization, and water withdrawals as the most predominant problems for anadromous salmonids in California's coastal basins. Most major rivers draining the Sierra Nevada Mountains are dammed at foothill elevations. Introduction of non-native fish species is also considered one of the three main reasons (habitat change and over-fishing being the other two) for the endangerment or extinction of what once were some of the most abundant native fish species in aboriginal California (Moyle, 1976). Introduced fish species make up 53 of the 120 freshwater species found in California (Moyle and Davis, 2000). These species, now the most abundant fish in many of California's waterways, were introduced primarily to improve sport and commercial fishing, as an agent of pest control, for agriculture, or by accident. The introductions have generally worked in concert with habitat degradation to force the extirpation or extinction of native species through introduction of disease, competition for food or space, predation, habitat change brought about by the introduced species, or genetic swamping through hybridization (Moyle, 1976). A total of 34 species and subspecies of fishes are listed as either threatened or endangered by the State of California or the federal government (http://www.dfg.ca.gov/hcpb/species/t_e_spp/tefish/tefisha.shtml).

Board of Forestry Anadromous Salmonid Protection Rules

In 2009 the California Board of Forestry adopted new rules to enhance the protection of anadromous salmonids and anadromous salmonid habitat. These rules, known as the Anadromous Salmonid Protection (ASP) rules replace the Threatened or Impaired Watershed Rules (T/I Rules) that had been in place since 2000. The new rules are based on current science and are consistent with partner agency mandates.

The primary objective of the ASP rules is to implement practices to maintain, protect and contribute to restoration of properly functioning salmonid habitat and repair conditions detrimental to the species or species habitat. Practices to meet the new ASP objectives include thinning for increased conifer growth; felling or yarding trees for wood placement in the channel; restoration of conifer deficient areas; management to promote a mix of conifers and hardwoods; abandonment and upgrading of non- functioning or high risk roads, watercourse crossings, tractor roads, and landings; and fuel hazard reduction activities that will reduce fire hazards and stand replacing wildfires which would result in significant adverse effects to salmonid species or riparian habitat.

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The ASP rules apply in planning watersheds with state or federally listed anadromous salmonids, and those planning watersheds that may not currently have anadromous salmonids but are restorable. The ASP rules do not apply where there is an approved Habitat Conservation Plan (HCP) that addresses anadromous salmonid protection; a valid Incidental Take Permit (ITP) issued by California Department of Fish and Game (DFG); a valid Natural Community Conservation Planning (NCCP) permit approved by DFG; or project revisions, guidelines, or take avoidance measures pursuant to a Memorandum of Understanding (MOU) or a planning agreement between the plan submitter and DFG in preparation of obtaining a NCCP that addresses anadromous salmonid protection.

To reduce adverse impacts from transported fine sediment, the new rules also apply to planning watersheds immediately upstream of and contiguous to any watershed with listed anadromous salmonids. Projects in other watersheds further upstream that flow into watersheds with listed anadromous salmonids may be subject to these provisions based on a cumulative impacts assessment. These requirements do not apply to upstream watersheds where permanent dams trap and prevent downstream transport of fine sediments.

The new ASP rules also contain a geographic element with the establishment of the Coastal Anadromy Zone (see Figure 4.5.1). More conservative prescriptions apply to Class I and II watercourses within the Coastal Anadromy Zone (CAZ). Protection measures also vary by forest district within the CAZ.

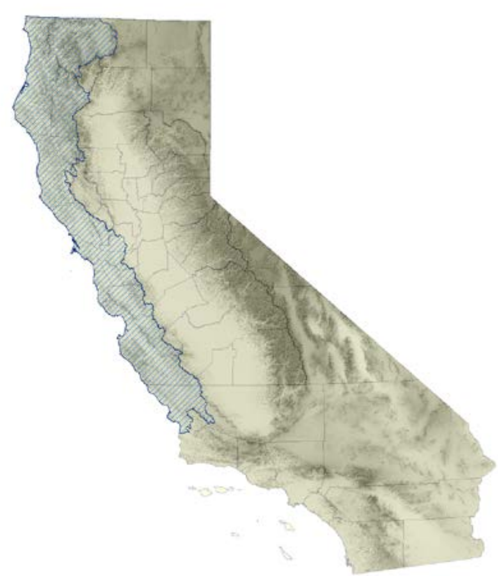

Figure 4.5.1 Coastal Anadromy Zone 1

Flood prone areas and channel migration zones also receive additional protection as these are important spawning and rearing habitat for listed species. Large Class II watercourses located near Class I confluences are considered “biological hotspots” and additional protection measures are also now required for these areas. For the smallest headwater streams (standard Class II watercourses and Class III watercourses), additional protection is required to ensure adequate bank stability and sources of wood to slow sediment transport down into fish bearing watercourses.

To address site and regional variability, the new ASP rules incorporate a site-specific plan section that both recognizes the high degree of biological and physical variability throughout the state and provides flexibility for landowners, while meeting or exceeding the results of the prescriptive standards. The California Board of Forestry has assembled a technical advisory committee to assist in the implementation of the new planning section of the ASP rules. For more information see http://www.bof.fire.ca.gov/board_committees/vtac.

4.5.1.2 Overview of Aquatic Habitat Conditions

Riparian Function

Riparian lands include instream habitat and stream channels, adjacent floodplains, and wetlands. These lands form a critical link between stream channels and the hillslope processes that deliver material to the channels (Murphy and Meehan, 1991). Water is present at or near the soil surface during all or part of the year, resulting in variable soil moisture conditions and distinct plant communities. Periodic flooding causes habitat disturbances that produce greater natural plant diversity than is present in the surrounding upland areas. The area adjacent to streams also contributes substantially to the quality of aquatic habitat.

Riparian vegetation provides shade, contributes organic matter and nutrients to streams, helps stabilize stream banks, and provides habitat for a variety of plants and animals (Gregory et al., 1991). Riparian floodplain vegetation buffers the effects of flooding on downstream areas by decreasing stream velocity over floodplain areas and increasing storage time for flood waters, which may also result in sediment deposition on the floodplain (Bisson et al., 1987; Spence et al., 1996). Subsequent growth of riparian vegetation can help stabilize these floodplain deposits, while the deposited sediments can provide valuable nutrients for the vegetation. Lateral channel migration frequently undermines riparian vegetation, resulting in the introduction (recruitment) of large wood (and sediment) to the stream channel. Large wood may also be recruited into the channel directly by treefall from adjacent riparian zones or from hillslopes by means of episodic mass soil movement or windthrow (Bisson et al., 1987; Spence et al., 1996).

Riparian vegetation can also be important in regulating stream water temperature. The temperature of water entering headwater streams in forested ecosystems is typically close to that of the subsoil environment. As this water flows through the stream system, water temperature becomes increasingly influenced by solar radiation and ambient air temperature (Burns, 1972; Beschta et al., 1987). Warm water temperatures that occur during the summer low-flow period because of increased solar radiation are of particular concern. Above specific thresholds, higher stream temperatures may limit the survival and growth of salmonids (Bjornn and Reiser, 1991), some amphibians (Claussen, 1973; Nussbaum et al., 1983; Leonard et al., 1993; Hayes, 1996), and other aquatic species. The amount of streamside canopy provided by riparian vegetation is a major factor affecting the amount of solar radiation reaching the stream surface. The degree of stream shading provided by riparian vegetation affects daily water temperature, as well as the magnitude of daily or seasonal fluctuation in water temperature. Vegetation management activities in the riparian zone have the potential to reduce stream shading, which may result in increased water temperature and pose a significant threat to the survival of juvenile salmonids. The potential for increases in water temperature are generally greatest during summer low flow periods because of increased solar radiation, reduced inflow from cold groundwater sources, and the more limited availability of thermal refugia (e.g., reduced pool depth) compared with periods of higher stream flow (Beschta et al., 1995; Spence et al., 1996).

Headwater Stream Ecosystems

Headwater streams and drainages (Forest Practice Rule Class II and III) are areas that contribute to stream ecosystem function. These areas can represent 60-80% of total channel length in mountainous terrain (May and Gresswell, 2003). These small streams contribute structural components such as large woody debris, spawning gravels and stream substrate, and invertebrate and detritus inputs. These sites also contribute to water quality and provide for storage of potentially deleterious fine sediment. Similarly, they can have a strong influence on the rates of sediment and wood delivery to larger watercourses, and consequently, habitat value for a variety of aquatic and semi-aquatic vertebrates and other biota (Welsh et al., 1998).

Disturbance as an influence on the structure and function of stream ecosystems has been extensively studied and reinforces the concept of the “river continuum” (Vannote et al., 1980). That being that energy and organic material inputs to stream processes change in a predictable way along the stream course from headwaters to downstream reaches. A variety of land uses, including timber harvest and forest management, can influence background erosion and sedimentation regimes, recruitment of large woody debris and other ecological processes. The delivery, time in residence, and transport of these additional sediments and woody debris influence stream channel conditions and associated biota. Change in vegetation in the vicinity of headwater streams can markedly alter the function of these stream types and those larger stream systems supported. Change in the efficiency of the channel to recharge groundwater, meter trapped sediments and water flow, and process organic material and other nutrients for use by aquatic biota downstream can be expected. Past management practices that reduce local sources of wood and rate of wood recruitment increase the relative importance of wood contributed by debris flows in colluvial tributaries where this means of recruitment occurs.

The type of disturbance also can have markedly different results on the structure and function of stream and associated riparian ecosystem processes. Floods, fire, and mass wasting events are generally less frequent and result in large localized changes to stream system, whereas, timber harvest, land conversion, agricultural and urban development are more frequent and regional in effects. For example, regionally, the “natural” (fire, flood) and man induced (timber harvest, land conversion) disturbance regime within the redwood zone likely exceeds that under which the plant community and associated biota evolved (Reeves et al., 1995; Sawyer et al., 2000). Stream communities, as shaped by past and present disturbance events have led to widespread and long-lasting alteration of stream conditions. Principle among these is alteration of the amount, size, and recruitment of large woody debris and coincident metering of sediments through the stream system. Large woody debris increases the sediment storage capacity of headwater streams. With sufficient wood inputs, low-order channels have the potential of storing large volumes of sediment and are one of the dominant sediment storage reservoirs.

Headwater Habitat Relationships

Because of the small size of headwaters and close connection with uplands, these areas are readily influenced by adjacent land uses. Species that inhabit headwater environments can be especially vulnerable to habitat alteration. These species, amphibians and other taxa, generally achieve higher population densities in headwater habitats. In addition, individual species inhabiting headwater habitats generally exhibit low levels of vagility (mobility) sometimes spending their entire life cycle in a few square meters of habitat. Recolonization of suitable vacant habitat may require extensive periods of time or, lacking movement into vacant habitat, result in local population extirpation.

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Headwater stream reaches, lacking fish populations, provide areas with little or no fish predation pressure to the benefit of several aquatic and semi-aquatic amphibians. For example, amphibians that breed primarily in stream habitats represent a large component of stream biomass and in the Pacific Northwest may exceed fish in both numbers and biomass (Hawkins et al., 1983). Welsh and Ollivier (1998) examined the impact of sediments on aquatic amphibian densities in coast redwood. Three species were sampled in numbers sufficient to be informative: tailed frog (*Ascaphus truei,* larvae), Pacific giant salamander (*Dicamptodon tenebrosus,* paedomorphs and larvae), and southern torrent salamander (*Rhyacotriton variegatus,* adults and larvae). Densities of amphibians were significantly lower in the streams impacted by sediment. While sediment effects were species-specific, reflecting differential use of stream microhabitats, the shared vulnerability of these species to infusions of fine sediments was probably the result of their common reliance on interstitial spaces in the streambed matrix for critical life requisites, such as cover and foraging.

Sources of Large Wood Recruitment and Delivery Mechanisms

Numerous studies have shown that large wood is an important component of fish habitat (Swanson et al., 1976; Bisson et al., 1987). Trees entering stream channels are critical for sediment retention (Keller and Swanson, 1979; Sedell et al., 1988), gradient modification (Bilby, 1979), structural diversity (Ralph et al., 1994), nutrient production (Cummins, 1974), and protective cover from predators.

The potential for trees to enter a stream channel from tree mortality, windthrow, and bank undercutting in the riparian zone is mainly a function of slope distance from the stream channel in relationship to tree height. As a result, the zone of influence for large wood recruitment is determined by specific stand characteristics rather than an absolute distance from the stream channel or floodplain. Slope and prevailing wind direction are other factors that can affect the amount of large wood recruited to a stream (Spence et al., 1996).

The Forest Ecosystem Management Assessment Team (FEMAT) concluded that the probability of wood entering the active stream channel from greater than one tree height is generally low (Thomas, et al., 1993). Two widely used models of large wood recruitment also assume that large wood from areas outside one tree height seldom reaches the stream channel (Van Sickle and Gregory, 1990; Robison and Beschta, 1990). Cederholm (1994) reviewed the literature regarding recommendations of buffer widths for maintaining recruitment of large wood to streams and found that most authors recommended buffers of 100 to 200 feet to maintain this function. A number of studies suggest buffers approaching one site-potential tree height are sufficient to maintain 100 percent natural levels of recruitment of instream large wood (Spence et al., 1996).

The potential size distribution of large wood is also an important factor when considering the appropriate activities in buffer strips relative to large wood potential recruitment. Larger pieces of wood form key structural elements in streams, which serve to retain smaller debris that would otherwise be transported downstream during high flows (Murphy, 1995). In addition to the amount and size of large wood input, the species of large wood contributed is also important. Coniferous large wood significantly outlasts deciduous large wood in the stream system (Harmon et al., 1986; Grette, 1985). As a result, riparian management zones must ensure not only an appropriate species amount or volume of wood, but wood of sufficient size to serve as “key pieces” (Spence et al., 1996).

Aquatics

Detritus Production (Leaf and Litterfall)

Vegetation management practices can lead to changes in leaf litter distribution and dynamics in upland and riparian areas, which in turn affect availability in streams. Harvest intensity (i.e., the proportion of forest canopy removed) and cutting frequency affect the rate of nutrient removal from the system (Beschta et al., 1995).

Detritus enters a stream primarily by direct leaf or debris fall, although organic material may also enter the stream channel by overland flow of water, mass soil movements, or shifting of stream channels. Few studies have been done relating litter contributions to streams as a function of distance from the stream channel; however, it is assumed that most fine organic litter originates within 98.4 feet or approximately 0.5 tree height from the channel (Thomas, et al., 1993). In most cases, however, buffers designed to protect most large wood recruitment would likely ensure nearly 100 percent of detrital input (Spence et al., 1996). Spence et al. (1996) concluded that a buffer width of 0.75 of a site-potential tree height is needed to provide full protection for litter inputs.

Streambank Stability

Streambank erosion is a natural process that occurs sporadically in forested and nonforested watersheds (Richards, 1982). Under natural conditions, this process is part of the normal equilibrium of streams. The forces of erosion (water), resistance (root strength and bank material), and sediment transport maintain an important balance. Human activity can accelerate streambank erosion. Important alterations of the system components that may result from timber harvesting activities include: (1) removing trees from or near the streambank; (2) changing the hydrology of the watershed; and (3) increasing the sediment load, which fills pools and contributes to lateral scour by forcing erosive stream flow against the streambank (Pfankuch, 1975; Cederholm et al., 1978; Chamberlin et al., 1991).

Sediment Control and Transport

Activities that cause land disturbance (including burning) can alter watershed conditions by changing the quantity, timing and size distribution of sediment. These alterations can lead to stream channel instability, pool filling by coarse or fine sediment, or introduction of fine sediment to spawning gravels. Stream sedimentation can cause significant impacts on aquatic habitat and in turn on fish populations.

Sediment delivery to streams can be reduced significantly by streamside buffer strips. The ability of riparian buffer strips to control sediment inputs from surface erosion depends on several site characteristics, including the presence of vegetation or organic litter, slope, soil type, and drainage characteristics. These factors influence the ability of buffer strips to trap sediments by determining the infiltration rate of water and the velocity of overland flow. In addition, activities within the riparian zone that disturb or compact soils, destroy organic litter, or remove large down wood can reduce the effectiveness of riparian buffers as sediment filters (Spence et al., 1996). Burning within the riparian zone is one such action that can reduce or diminish buffer effectiveness in the short term until a new duff and vegetation layer redevelops. Although fires are not currently prescribed in riparian buffers, incidental burning could occur within them when adjacent prescribed burns escape into the riparian zone or are allowed to naturally extinguish due to moisture-laden conditions.

Stream Shading

Water temperature is an important habitat parameter potentially influencing reproductive success and survival during all freshwater life stages for fish and many amphibians, aquatic macro-invertebrates, and other organisms (Bjornn and Reiser, 1991). Water temperature influences metabolism, behavior, and mortality of fish and other organisms in their environment. Although fish may survive at temperatures near the extremes of the suitable range, growth is reduced at low temperatures because all metabolic processes are slowed and at high temperatures because most or all food energy must be used for maintenance (Bjornn and Reiser, 1991). In areas where partial or complete exposure of the stream causes increased stream temperature, the rate of shade recovery depends on streamside conditions, vegetation, and stream size (Beschta et al., 1987). Small streams may be quickly overtopped by brush and effectively shaded from solar radiation. As streams become progressively larger and wider, riparian vegetation shades a progressively smaller proportion of the water surface (Beschta et al., 1987; Spence et al., 1996; Murphy and Meehan, 1991).

Microclimate

Important components of the microclimate in a forested area include solar radiation, soil temperature, soil moisture, air temperature, wind velocity, and air moisture or humidity (Chen, 1991; Chen et al., 1992). Changes in microclimatic conditions within the riparian zone resulting from removal of adjacent vegetation can influence a variety of ecological processes that may affect the long-term integrity of riparian ecosystems (Spence et al., 1996). Vegetation removal may interrupt natural microclimatic gradients.

Of all the components that make up the microclimate, humidity has the greatest influence. Studies by Chen (1991) and Chen et al. (1993) suggested that humidity achieved conditions found in interior old-growth at a distance of 575 feet from the edge of a clearcut. FEMAT (1993), based on studies from Chen (1991), suggests that as many as three site-potential trees are needed to provide complete protection of riparian microclimate. However, riparian buffer effects for soil moisture, radiation, and soil temperature reach maximum effectiveness near one site-potential tree height. To avoid significantly altering the microclimate of a riparian zone, Ledwith (1996) recommends leaving buffer strips over 100 feet wide. Buffers wider than 100 feet would still affect the microclimate, but at a lower rate of change (Ledwith, 1996).

James (2003) has collected detailed information on microclimate and water temperature changes associated with different levels of harvest in buffer strips and differing buffer strip widths at the Southern Exposure research site in the northern Sierra Nevada. Microclimate results revealed that edge effects from adjacent upslope clearcut harvest units had no discernible impact within 40 ft. (12.2 m) of the stream bank. Timber operations conducted in the summers of 2000 and 2001 resulted in $\pm$ 1.5^{o}C changes in daily maximum water temperature pattern along the experimental reach. The average and maximum daily air temperature patterns within the riparian zone harvest units (stream bank out to 40 ft.) were increased at most up to 0.5°C due to the adjacent upland experimental harvest treatments. Average and maximum daily air temperatures were increased up to 5°C beyond 40 ft. from the stream bank within the harvested blocks. When the buffer was reduced from 150 ft. to 100 ft., the average daily soil temperature increased up to 2°C for the microclimate station located between 80 ft. to 175 ft. from the stream bank. No change in the average daily soil temperature pattern was found in the riparian zone adjacent to the harvest units (stream bank out to 40 ft.) after the two experimental harvest treatments during the three-year study.

Coho and Chinook salmon and steelhead (anadromous salmonids) are of particular ecological and economic importance in California, and each have undergone well-documented declines in overall abundance. For example, the coho salmon population within the Central California Coast coho salmon Evolutionarily Significant Unit (ESU) was listed as a federal endangered species in 2005. Similarly, 4 steelhead ESUs were listed as threatened in 2006 and one was listed as endangered. The Sacramento River Winter run of Chinook salmon is also a federal endangered species.

4.5.1.3 Overview of Distribution and Population Status

Coho Salmon

A comprehensive review of estimates of historic abundance, decline and present status of coho salmon in California is provided by Brown et al. (1994). They estimated that the coho salmon annual spawning population in California ranged between 200,000 and 500,000 fish in the 1940s, which declined to about 100,000 fish by the 1960s, followed by a further decline to about 31,000 fish by 1991, of which 57 percent were artificially propagated. The other 43 percent (13,240) were natural spawners, which included naturally-produced, wild fish and naturalized (hatchery-influenced) fish. Brown et al. (1994) cautioned that this estimate could be overstated by 50 percent or more. Of the 13,240, only about 5,000 were naturally-produced, wild coho salmon without hatchery influence, and many of these were in individual stream populations of less than 100 fish each. In summary, Brown et al. (1994) concluded that the California coho salmon population had declined more than 94 percent since the 1940s, with the greatest decline occurring since the 1960s.

Steelhead

West Coast steelhead are presently distributed across 15 degrees of latitude, from approximately 49°N at the U.S.-Canada border, south to 34°N at the mouth of Malibu Creek, California. In some years steelhead may be found as far south as the Santa Margarita River in San Diego County (Busby et al., 1996). Historically, steelhead likely inhabited most coastal and many inland streams along the west coast of the United States. During this century, however, over 23 indigenous, naturally reproducing stocks have been extirpated, and many more are at risk for extinction. In California, known spawning populations of steelhead (*Oncorhynchus mykiss*) are found in coastal rivers and streams from Topanga Creek in Los Angeles County to the Smith River near the Oregon border, and in the Sacramento River system.

Chinook Salmon

The following pose significant risks to Chinook salmon: degradation of freshwater habitats due to a variety of agricultural and forestry practices, water diversions, urbanization, mining and severe recent flood events (exacerbated by land use practices). Depending on the population of Chinook salmon, the effects of hatcheries and transplants on genetic integrity varies.

Chinook salmon in the Coastal California ESU continue to exhibit depressed population sizes relative to historical abundances; this is particularly true for spring-run Chinook, which may no longer be extant anywhere within the range of the ESU. Recent favorable ocean conditions have contributed to apparent increases in abundance and distribution for a number of anadromous salmonids, but the expected persistence of this trend is unclear. Agriculture, logging, and mining activities, in combination with periodic flood events (e.g. 1955, 1964), have affected all of the coastal river systems to some degree. The construction of dams in the Rogue, Klamath, and Eel River Basins has restricted the distribution and potentially altered the life history of Chinook salmon, especially spring-run fish that historically utilized upstream habitat. Similarly, dam construction on the Klamath River Basin has eliminated much of the spawning habitat for spring-run fish and increased the potential for interbreeding between spring and fall runs.

Historically, the largest spring-run population in the Klamath River Basin was in the Shasta River; however, this population was extirpated in the early 1930s as a result of land use practices and water diversion dams. Since 1962, the upper limit to anadromous migration has been the Iron Gate Dam. Additionally, the Lewiston water diversion dam on the Trinity River has prevented access of spring-run Chinook salmon to their historical spawning grounds on the East Fork, Stuart Fork, Upper Trinity River, and Coffee Creek (Campbell and Moyle, 1991).

4.5.1.4 Overview of Habitat Requirements in the Stream Environment

Spawning of adult salmonids and freshwater rearing of juvenile salmonids are important stages in the freshwater life history of anadromous salmonids; and specific physical habitat conditions are required for each stage.

Spawning

Anadromous salmonids return to spawn in their natal streams in response to seasonal changes in stream flows or temperatures. Spawning sites (redds) are usually located near the heads of riffles (pool tailouts) where the water changes from smooth to turbulent flow, and where there are well oxygenated and relatively silt-free coarse gravels, and nearby cover for adults (Smith, 1941; Briggs, 1953; Stuart, 1953; Platts et al., 1979; Moyle et al., 1995).

The quantity, quality, and spatial distribution of spawning gravels, as well as water depth and velocity in spawning areas, can suffer substantial negative impacts from improperly-conducted or unmitigated land use activities, resulting in decreased survival. Sedimentation resulting from either natural or anthropogenic disturbances is typically considered to be the principal cause of salmonid egg and alevin mortality (Shapovalov and Taft, 1954; Chapman, 1988). Removal of large wood from stream channels also reduces pool quantity and quality (Bryant, 1980; Everest and Meehan, 1981; Bisson and Sedell, 1984; Bisson et al., 1987) and affects the storage and distribution of spawning gravel (Everest and Meehan, 1981).

Rearing

After emerging from the gravel, juvenile anadromous salmonids spend at least one summer rearing in fresh water before migrating to the ocean. Food and cover are two of the most important factors influencing juvenile rearing success (Chapman and Bjornn, 1969). Production of aquatic macroinvertebrates used as the primary food resource of salmonids during their freshwater residence depends on the availability of relatively silt-free, heterogeneous substrate; cold, well-oxygenated water; and a supply of organic matter and nutrients to the stream (Minshall, 1984; Bjornn and Reiser, 1991).

Relatively cold water temperatures are also required for growth and survival. For example, juvenile coho appear to prefer temperatures of 10° to 15°C (50° to 59°F) (Hassler, 1987), and Brett (1952) found that exposure to temperatures in excess of 25°C (77°F) resulted in high mortality rates. Preferred rearing temperatures reported for steelhead range from 7° to 15°C (44.5° to 59°F), with optimum water temperatures for juveniles occurring around 10°C (50°F), and lethal temperatures occurring at approximately 23.6°C (75°F) (Barnhart 1991).

During winter high flow events, floodplains, alcoves, side channels, large wood accumulations, deep pools (>3.3 ft or 1 m), and substrate interstices are important in providing velocity refugia for rearing salmonids (Chapman and Bjornn, 1969; Bjornn and Reiser, 1991). Coho salmon in particular have been observed to seek areas with low velocity and cover during the winter, including deep pools, side channels, debris jams, undercuts, and side-channel pools (Peterson, 1982; Tschaplinski and Hartman, 1983).

Lack of suitable winter habitat may result in poor survival, and several studies indicate that availability of winter habitat may be the major factor limiting coho salmon production in many areas (Chapman, 1966; Mason, 1976; Chapman and Knudsen, 1980; McMahon, 1983; Nickelson et al., 1992). Tschaplinski and Hartman (1983) documented substantial decreases in juvenile coho salmon numbers in fall and winter, particularly in response to seasonal freshets. They found that habitats such as deep pools, logjams, and undercut banks with woody debris lost fewer fish during high flow events and maintained higher juvenile populations over the winter.