> Aquatic habitats critical to salmonids are the product of processes acting throughout watersheds and particularly within riparian areas along streams and rivers. This document depends on the premise that salmonid conservation can be achieved only by maintaining and restoring these processes and their natural rates.

McCullough (1999) also describes the importance of understanding the requirements of salmonids on a watershed level:[8]

> In the management of coldwater fish species, the greatest degree of expression of life history variation by species is achieved by restoration of the thermal regime on a stream system-wide basis, along with other pre-management conditions of channel morphology and the watershed. Moving the summer maximum temperature threshold upstream constricts the available spawning or rearing area of all coldwater fish species. Fish zonation from headwaters to downstream reaches in the Pacific Northwest can be characterized roughly as proceeding from bull trout/cutthroat trout to steelhead, to spring chinook/coho, to summer chinook, to fall chinook, to chum (Li et al. 1987). With the exception of bull trout, the other species do not vary substantially in their response to summer maximum temperature. However, they do vary in their preference for size of spawning and rearing stream, size of spawning gravel, and stream gradient tolerated. Increase in summer maximum temperature in headwater stream zones cannot occur without causing increase to downstream reaches. Constraining species more and more to compete in high gradient streams that may provide suitable water temperatures would severely limit production and impair survival in the majority of the historic habitat of each species, but further, it is not feasible energetically for large-stream species to occupy smaller, high gradient streams."

The habitat features that determine the suitability of a stream for salmonids include (Spence et al. 1996):

1. Flow regime – depth and velocity of water, total available habitat, sediment distribution, gravel flushing and movement, vegetation dispersal
2. Water quality – cool temperatures, high dissolved oxygen, natural nutrient concentrations, low levels of pollutants
3. Habitat structure – pools, riffles, substrate cover, depth, channel complexity
4. Food sources – maintain natural inputs of food and the habitat structures needed to retain food
5. Biotic interactions – competition, predator-prey, and disease-parasite interactions

In general, salmonids require cold water with low turbidity. Since salmonids are poikilothermic, water temperature has a fundamental effect on all of their life processes. Water temperature is a trigger for some changes in salmonid life stages. "Variation in temperature is required to trigger spawning, support growth, initiate smoltification, and enable other parts of the salmonid life cycle."[9] Water temperatures outside of the preferred ranges can cause lethal and sublethal effects. "Two important elements of temperature affect the growth and survival of fish: 1) the relationship between temperature, metabolism, and food conversion efficiency over long periods, and 2) the

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[8] McCullough 1999, Page 193.

[9] Spence et al. 1996, page 4.

thermal tolerance of fish to lethal temperatures over relatively short periods."[10] Some of the salmonid life cycle processes affected by temperature include: metabolism; food requirements (appetite and digestion); growth rates; development of embryos and alevin; timing of life history events (such as adult migration, fry emergence, smoltification); competitor and predator-prey interactions; disease-host and parasite-host interactions; and, the development of aquatic invertebrate food sources (Spence et al. 1996, McCullough 1999, Sullivan et al. 2000). McCullough (1999) explains that even within the range of tolerance, water temperatures may affect salmonid behavior and survival.

> Within temperature boundaries defined by the tolerance zone, swimming, metabolism, growth, food conversion efficiency, reproductive capacity, embryonic development, and aggregation of fishes (Brett 1970, Alderdice 1972; both as cited by Griffiths and Alderdice 1972) may all have different response fields and may each have an influence on survival and fitness.[11]

For cold water fish, such as salmonids, on the North Coast the critical temperature regime is associated with summer rearing because water temperatures during summer have been recorded routinely above the preferred range. The range of temperature requirements for coho salmon are shown in Table 2.2 and are discussed as they relate to individual life stages further in this chapter.

[10] Sullivan et al. 2000, page 2-2.
[11] McCullough 1999, page 168.

TABLE 2.2
TEMPERATURE REQUIREMENTS FOR COHO (Bjornn and Reiser 1991, Spence et al. 1996, McCullough 1999, Sullivan 2000)

Temperature (°C)	Adult Migration	Spawning	Egg & Alevin Incubation	Preferred Juvenile Rearing	Smoltification & Outmigration	Lethal Limits
25						**Upper Lethal**
24						
23						**Cease Growth**
22						
21						
20						
19						
18						
17						
16						
15	**15.6**					
14				**14.6**		
13			**13.3**			
12					**12**	
11				**11.8**		
10						
9		**9.4**				
8						
7	**7.2**					
6						
5						
4		**4.4**	**4.4**		**4.5**	
3						
2						
1						**Lower Lethal**
0						

The shaded areas refer to the upper and lower temperature range limits.

Stream temperature also determines the amount of dissolved oxygen ("D.O.") that can be carried by a stream, with higher temperatures resulting in lower dissolved oxygen concentrations. Salmonids require well-oxygenated water. Spence et al. (1996) report that greater than 6 mg/l D.O. is a general requirement and that levels below saturation can be harmful.

Excess sediment in streams can affect salmonids at every life stage. Spawning and incubation are most directly affected by deposited sediments -- decreasing flow of water through the gravel interstices, thereby reducing the dissolved oxygen, raising the temperature, and physically blocking emergence of fry from the redd (Spence et al. 1996). Rhodes (1994) states, "The negative correlation of salmonid survival and production to fine sediment has been mainly attributed to reduced survival-to-emergence