CHAPTER 1: OVERVIEW OF THE CCC COHO SALMON ESU

"Pacific salmon matter not only as a delicacy and an economic resource but also as an indicator of the state's environmental health. Wild salmon are to the rivers and the watershed and the ocean what the canary is to the miners in the coal mine."

Congressman Mike Thompson 2008

A SPECIES AT THE BRINK OF EXTINCTION

Central California Coast coho salmon are gravely close to extinction. Despite being listed under both the Federal and California Endangered Species Acts, the populations of the CCC coho salmon have continued to decline precipitously. The dire status of this salmon requires immediate and focused action to increase survival of, and provide the highest protection for, each individual and all remaining populations.

Photo Courtesy: A juvenile CCCC coho salmon from Scott Creek, Santa Cruz County, California. Morgan Bond, SWFSC.

Regrettably, many of our streams are inhospitable to our salmon. For millennia salmon have successfully persisted in abundance under catastrophic and shifting environments. The human altered landscape over the last two centuries, and human harvesting, has placed additional pressures on these populations. This altered landscape with competing demands for water, stream channel modifications (*e.g.*, bank stabilization, levee development, etc.), water pollution, land use practices, and many other unsustainable uses of our land and water are resulting in significant detrimental changes to our streams and rivers. As rivers become more inhospitable to salmon, fewer salmon survive and populations decline. As fewer and fewer individuals survive, the population as a whole becomes more vulnerable to shifting ocean environments and natural catastrophic events. This condition, when low populations cannot overcome ongoing declines, when genetic diversity is compromised, when habitats become degraded and fragmented, and when spawners are at such low numbers they cannot find one another to reproduce is often referred to as an extinction vortex (Gilpin and Soule 1986). "Extinction vortex" is the term used to describe the process that declining populations undergo when "*a mutual reinforcement occurs among biotic and abiotic processes that drives population size downward to extinction*" (Brook, Sodhi & Bradshaw 2008). Current information on adult escapement in the ESU is very limited; however, information from current monitoring on Scott, Lagunitas, Noyo, Caspar and Pudding Creeks indicate a significant CCC coho salmon decline and that coho salmon are in this vortex.

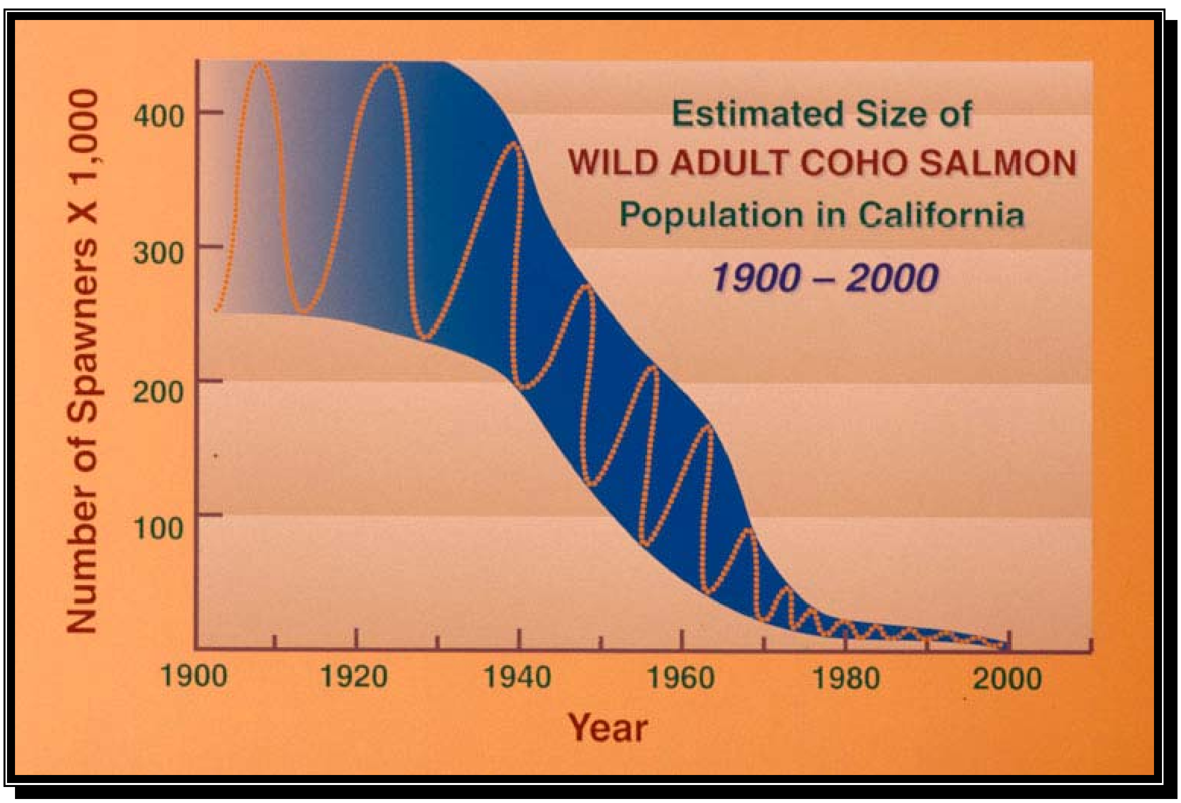


Figure 2: Visual Representation of Extinction Vortex of Coho Salmon (Peter Moyle, pers. comm.)

The dire status of CCC coho salmon is a call for immediate action to prevent their extinction by:

1. Implementing actions that increase survival of all current individuals and populations;
2. Expanding their distribution through focused restoration actions in critical areas;
3. Preventing degradation of existing high quality habitats across the historical range (especially areas that have supported populations within the last four generations);
4. Restoring habitat conditions and watershed processes across their historical range; and
5. Controlling and abating threats and providing for their long-term survival and recovery.

The situation is daunting, but it is not hopeless. Coho salmon persist in many watersheds, particularly in Mendocino County, and, in some years, these areas witness good numbers of adults returning from the ocean to their natal streams. Lagunitas Creek, in Marin County, also maintains a consistent run of coho salmon. It is imperative to protect and maintain the remaining populations to ensure survival of the species across the ESU.

Photo Courtesy: A very rare sighting; three wild juvenile coho salmon (and one juvenile steelhead – bottom left) in the Russian River in 2008. Joe Pecharich, Russian River coho monitoring project, UC Cooperative Extension – Sonoma County.

Innovative approaches and partnerships will be necessary to save our salmon. The persistence and recovery of salmon will require re-thinking our land and water resource conservation values to work towards mutually beneficial solutions to both mankind and our environment. Any one effort will not act alone, but will work in synchrony with the many others who are working to save this species. Since the Federal listing in 1996 much has been done. The Monterey Bay Salmon and Trout Project (MBSTP) and Corps of Engineers (USACE) are working with NMFS' Science Center and the California Department of Fish and Game (DFG) to ensure the King Fisher Flat facility on Scott Creek are managed appropriately. The Sonoma County Water Agency, USACE, NMFS, CDFG and others are collaborating on operations for the Congressman Don Clausen facility (Warm Springs) in the Russian River to maximize genetic diversity and improve distribution and abundance of coho salmon. DFG, NOAA Restoration Center, Trout Unlimited, The Nature Conservancy, Resource Conservation Districts and many others have dedicated substantial sums of money to restore passage, install woody debris, and reduce sediment inputs from problem roads in many watersheds. The Marin Municipal Water District operates their reservoirs and the non-profit group, SPAWN, work in such a way to ensure Lagunitas Creek maintains a strong population. The National Park Service is conducting extensive monitoring for Lagunitas and Olema Creeks and water agencies have provided funding to the recovery efforts. The Counties have joined together under the FishNet 4C and meet regularly to pool resources in an effort to streamline permitting, train their staffs, and obtain addition grant monies for the benefit of coho salmon. Timber companies and conservation organizations have dedicated numerous resources, including staff and equipment, to monitor coho populations and their habitat, fix problem roads and stream crossings, and restore instream habitat.

Recovery actions have been developed for each watershed, and across the ESU, with the intent of preventing extinction and reversing the coho salmon trajectory back towards persistence and recovery. These recovery actions are in draft and NMFS is requesting the public, stakeholders and agencies work with us to find mutually beneficial solutions to salmon recovery. Working together, we believe it is possible to restore coho salmon populations to the large numbers witnessed by our parents and grandparents, just fifty years ago.

THE TAXONOMY, RANGE AND ESA LISTING OF COHO SALMON

Taxonomy

There are six species of Pacific salmon within the *Oncorhynchus* genus: *O. kitsutch, keta, gorbuscha, tshawytscha, nerka,* and *masou*. Within this group, coho and Chinook salmon are the most closely related. The English translation of the genus name, *Oncorhynchus*, is hooked snout. Coho salmon, the common name accepted by the American Fisheries Society for *O. kisutch*, comes from a Native American name for the species. Silver salmon is another commonly used name. Other common names include sea trout, blueback, jack salmon, hooknose, and silversides (Hassler 1987).

Range

The current North American range of *O. kitsutch* extends from Point Hope, Alaska, south to the East Branch Soquel Creek in Santa Cruz County, California. NMFS has designated seven evolutionarily significant populations of coho salmon in Washington, Oregon, and California. The CCC coho salmon ESU is the southern-most extant population. CCC coho salmon occupy an area from Punta Gorda in northern California south to Soquel Creek in Santa Cruz County, California; their historical range includes the San Francisco Bay and many of its tributaries). Two artificial propagation programs are considered part of this ESU: the Don Clausen Fish Hatchery Captive Broodstock Program and the Scott Creek/King Fisher Flats Conservation Program (MBSTP). Both of these coho salmon programs are managed as conservation facilities and not for fishing supplementation.

Coho salmon may have persisted as far south as the Big Sur River in Monterey County and east into streams of the Sierras in the Central Valley (Gustafson *et al*., 2007). According to recently discovered archeological data from Elkhorn Slough, this species once ranged as far south as the Pajaro River in Santa Cruz and Santa Clara counties and/or possibly the Salinas River in Monterey and San Luis Obispo counties (Gobalet, in press). The first known collection of CCC coho salmon for scientific purposes occurred in 1860 when Alexander Agassiz collected the species in San Mateo Creek in San Mateo County. Today, not only are coho extirpated from San Mateo Creek, they have been extirpated from every tributary stream and river flowing into San Francisco Bay.

On November 12, 2003, NMFS received a petition to redefine the southern extent of the CCC coho salmon ESU by excluding coho salmon populations occupying watersheds in Santa Cruz and coastal San Mateo counties, California, from the CCC ESU designation. NMFS rejected the petition. The petitioner's assertions were based on the following: (1) early scientific species range descriptions and newspaper accounts failing to document coho south of San Francisco prior to artificial introductions in 1906; (2) absence of coho salmon remains in the refuse sites (middens) of the native people; (3) various physical characteristics (climate, geology, and hydrology) render the streams of the Santa Cruz mountains inhospitable to coho salmon; and 4) incorrect application of the ESU/DPS policies.

NMFS rejected the petition on all points (71 FR 14683). NMFS found that, not only did the best available evidence contradict the thesis of Plaintiff's petition, but the purported evidence submitted by Plaintiff in support of his petition was flawed to the point of not being reliable. The evidence was refuted based on the following:

1) Juvenile coho salmon were collected from four streams in San Mateo and Santa Cruz county streams in 1895, eleven years before a hatchery program was initiated in Santa Cruz County. These specimens are housed at the California Academy of Sciences in San Francisco;
2) The midden sampling effort was too small to determine absence, a point made by the investigator who conducted the sampling (Gobalet *et al*., 2004)[2];
3) Information suggesting physical conditions are too extreme for coho salmon in Santa Cruz and San Mateo (in comparison to areas north of San Francisco Bay) was not compelling to suggest these conditions were significant enough to preclude species presence – particularly since these same conditions are present throughout other watersheds in the CCC ESU that remain occupied by coho salmon; and
4) NMFS' ESU policy was properly applied to these populations.

Additional information regarding coho salmon south of San Francisco Bay was summarized in Fisheries (Adams *et al.*, 2007).

---

[2] Soon after NMFS issued its finding, Dr. Gobalet examined fish remains of two salmonids recovered during excavations from archaeological site CA-SMA-18 in Año Nuevo State Park, Santa Cruz County. Those remains, which predate European arrival in North America, also were independently evaluated by two other fish osteological (bone) identification experts, with the following result: "[o]ne vertebra was determined to be from a coho salmon by all three experts and the second was identified as coho salmon by two of the three" (Adams *et al.*, 2007).

State and Federal Listings of CCC Coho Salmon

NMFS listed the CCC coho salmon ESU on October 31, 1996, as Federally threatened (61 FR 56138) under the Federal Endangered Species Act (ESA) of 1973, as amended. The State of California listed coho salmon south of San Francisco Bay as a state endangered species in 1995. In 2002, the State listed the CCC coho salmon ESU as State endangered and the California portion of the Southern Oregon Northern California coho salmon ESU as threatened. A recovery strategy for the California ESUs was developed by the State and finalized in 2004 (DFG 2004). Due to severe population declines between 1996 and 2004, NMFS relisted CCC coho salmon and changed its status from threatened to endangered (*i.e.*, in danger of extinction throughout all or a significant portion of its range) on June 28, 2005 (70 FR 37160). In spite of the protections afforded by these listings, the development of a State Recovery Plan and ongoing implementation of many recovery actions recommended in the plan, the population has not stabilized and continues to decline.

THE IMPERILED CCC COHO SALMON

Only rough estimates exist of the historical CCC coho salmon adult abundance. There are still no long term data sets for wild coho salmon abundances across individual river systems in the ESU. Despite these limitations, the pronounced decline of CCC coho has been documented over the course of 70 years by various researchers and agencies with estimates of (Figure 3): 200,000 to 500,000 coho salmon statewide in the 1940's (Brown, 1994); 99,000 statewide with approximately 56,100 (56%) in CCC coho salmon ESU streams in the 1963 (DFG 1965); 18,000 wild CCC coho salmon adults in the 1984/1985 spawning season (Wahle and Pearson 1987); 6,000 wild CCC coho salmon adults in the 1990's (61 FR 56138) and the most recent estimate of less than 500 wild adults in 2009 (Spence pers. comm. 2009). In fact, more recent studies are indicating a probable population collapse (MacFarlane *et al.* 2009, in draft) and impending extinction. Coho salmon, as of this writing in 2009, are extirpated or severely reduced in most of the watersheds they historically occupied. All early estimates (including both wild and hatchery fish) from within the CCC ESU (Table 1) are considered "best professional guesses" based on a limited catch statistics, hatchery records, and personal observations of local biologists (Brown *et al*., 1994).

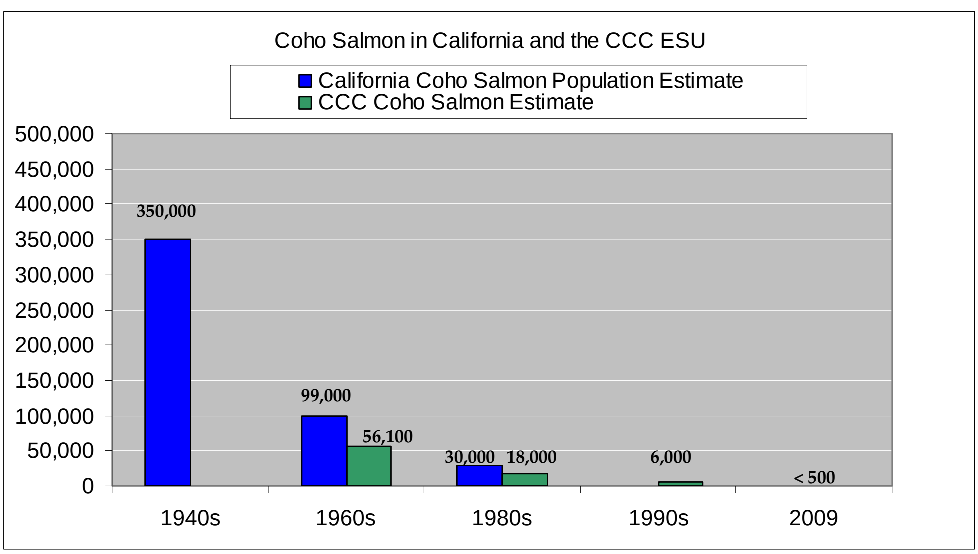


Figure 3: Historical and Current Estimate of Coho Salmon Abundance

Table 5: Historical Estimates of coho salmon spawner abundance across the CCC coho salmon ESU

	Estimated Escapement			
River/Region	DFG (1965)[3] 1963		Wahle & Pearson (1987)[4] 1984-1985	Brown et al. (1994)[5] 1987-1991
Ten Mile River		6,000	2,000	160[6]
Noyo River		6,000	2,000	3,740
Big River		6,000	2,000	280
Navarro River		7,000	2,000	300
Garcia River		2,000	500	
Other Mendocino County		10,000	7,000[7]	470[8]
Gualala River		4,000	1,000	200
Russian River		5,000	1,000	255
Other Sonoma County		1,000		180
Marin County		5,000		435
San Mateo and Santa Cruz Counties		4,100	550	140
San Mateo County	1,000			
Santa Cruz Co (excl. SLRiver)	1,500		50	
San Lorenzo River	1,600		500	
ESU Total	**56,100**		**18,050**	**6,160**

---

[3] Values excludes ocean catch

[4] Estimates are for wild or naturalized fish; hatchery returns excluded.

[5] Estimates are for wild or naturalized fish; hatchery returns excluded. For streams without recent spawner estimates (or estimates lower than 20 fish), assumes 20 spawners.

[6] Indicates high probability that natural production is by wild fish rather than naturalized hatchery stocks.

[7] Value may include Marin and Sonoma County fish.

[8] Appears to include Garcia River fish.

No time series of adult abundance free of hatchery influence and spanning eight or more years are available for the CCC ESU. Adult counts from the Noyo egg collecting station (ECS) represent a mixture of naturally produced and hatchery fish, and counts are incomplete for most years because trap operation was sporadic during the winter season and typically ceased after quotas were met (Figure 4). These data, at best, represent an index of abundance. Assuming these counts reflect general population trends, there appears to have been a significant decline in abundance of coho salmon in the South Fork Noyo beginning in 1977. That year was one of the driest rainfall years on record for California and also marked a dramatic shift in the prevailing polarity in the oscillation ocean-atmosphere climatic variability centered over the mid-latitude of the North Pacific basin. This shift corresponded with dramatic shifts in salmon production regimes in the North Pacific Ocean (Mantua *et al*., 1997). Since 2000 the ECS has stopped collecting fish and recent estimates (see Noyo River strategies for graph of recent adult escapement in the South Fork Noyo River) reflect the actual run size at the ECS. Despite the caveats described above, the trend for coho salmon in the South Fork Noyo is clear, they have declined and continue to decline in abundance.

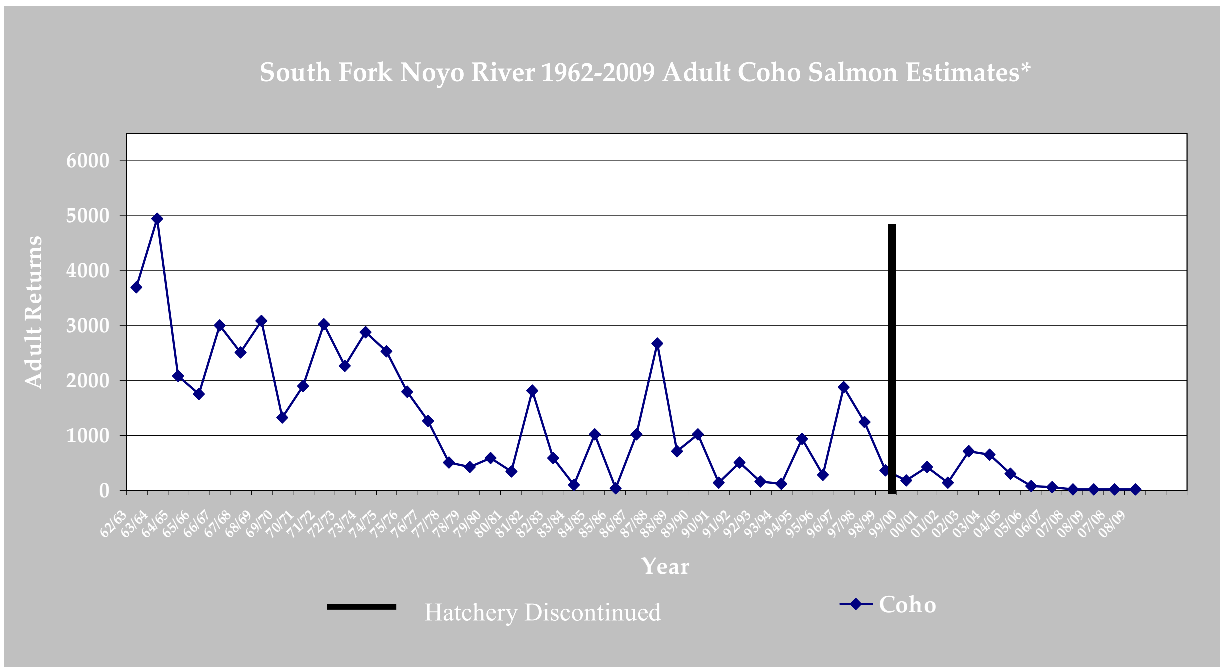


Figure 4: Adult coho salmon returns to Noyo Egg Collecting Station (1965 – 2009)

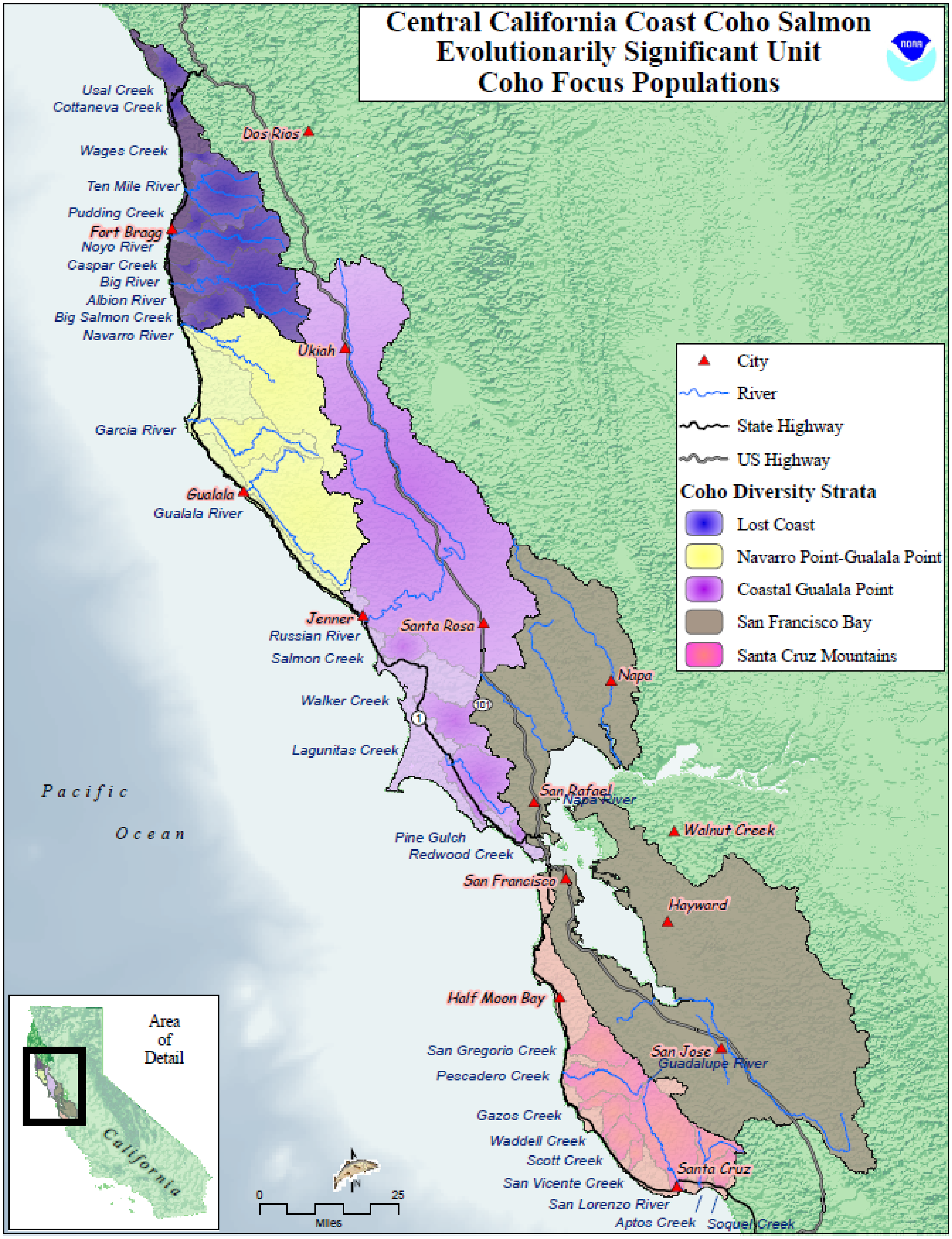


Figure 5: Historical Range of CCC coho salmon and Focus Populations for Recovery

COHO SALMON LIFE HISTORY

Juveniles: Juvenile salmon are blue-green on the back with silver sides and 8-12 parr marks (Hassler 1987). The parr marks are centered along the lateral line and are narrower than the spaces between marks. The adipose fin is finely speckled with uniform pigmentation making it appear dark grey (Moyle 2002). The anal, pectoral, and pelvic fins lack spots and are tinted orange with varying intensity. The anal fin is pigmented between the rays which can produce a black banding effect (Hassler 1987).

Characteristics commonly used to identify juvenile coho salmon from other salmonid species are their sickle shaped anal and dorsal fins and their large eyes (Pollard *et al.* 1997).

Freshwater Adult: Adult coho salmon have a fusiform body shape that is laterally compressed (Hassler 1987). Considered a medium to large salmon, coho salmon typically reach fork lengths of 4–70 cm and weights of 3–6 kg (Shapovalov & Taft 1954; Moyle 2002). Dorsal, anal, pectoral, and pelvic fins range from 9–12, 12–17, 13–16, and 9-11 rays respectively (Moyle 2002). The lateral line is straight with 121–148 single pored scales. The white gum line of coho salmon can be used to distinguish this species from Chinook salmon, which have black gums. Coho salmon can be distinguished from chum and sockeye salmon by the dark spots on the back, dorsal fin, and upper lobe of the tail (Hassler 1987).

Ocean Adult: In the ocean, the coloration of adult coho salmon is steel blue to greenish on the back, silvery on the sides, and white on the belly (Hassler 1987). The coloration of spawning males is dark green on the back, bright red on the sides, and gray to black on the belly (Scott & Crossman 1973). In addition to the red lateral line, spawning males are also characterized by a hooked jaw, enlarged and exposed teeth, and slightly humped backs. Females have duller coloration than males with a pale pink hue on the sides (Moyle 2002). Males and females both have small black spots on the back, upper sides, base of the dorsal fin, and upper lobe of the caudal fin.

Life History Strategy

Coho salmon are anadromous fish, meaning they migrate between the ocean and freshwater environments at different stages of their three-year life; many return to the stream they were born. These life stages are egg, alevin, summer rearing/winter rearing juvenile, outmigrant or smolt and ocean adult. Coho salmon are also semelparous; they die shortly after spawning.

The life history of coho salmon is similar to most Pacific salmonids in that they hatch and rear in freshwater, migrate downstream, grow to adults in the ocean, and return to natal freshwater to spawn and die (Figure 6). Within this cycle coho salmon exhibit less flexibility than other salmonid species, predominantly adhering to a three year life cycle. The exceptions to the three year life cycle are jack males which return to freshwater at two years of age and a small percentage of smolts which remain in freshwater for two years rather than one year. These exceptions prevent genetic isolation between temporal runs (Moyle 2002). The life history and habitat requirements of CCC coho salmon have been well documented by Shapovalov & Taft (1954); Hassler (1987); Emmett *et al.*, (1991); Sandercock (1991); Pearcy (1992); and Moyle (2002).

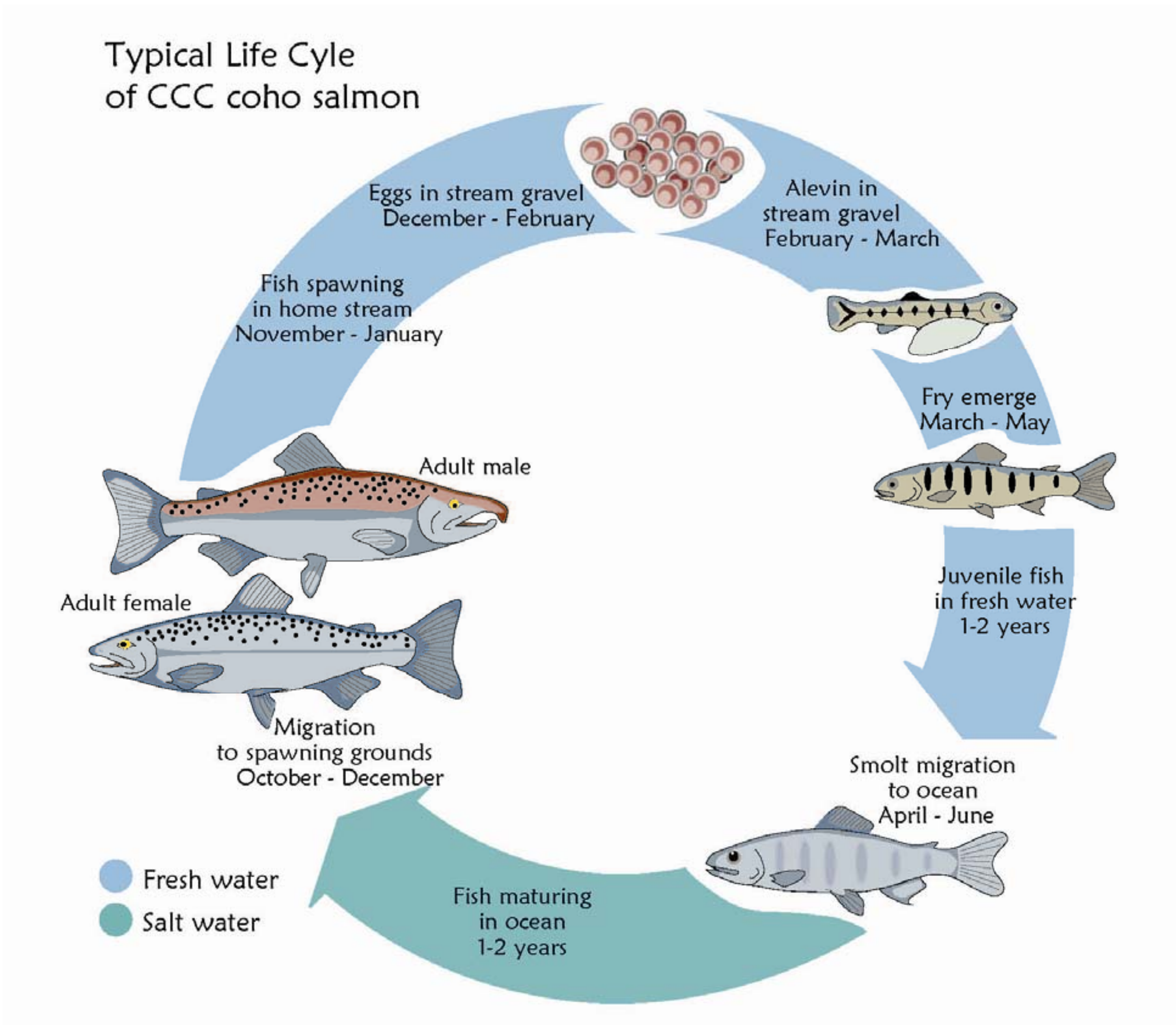
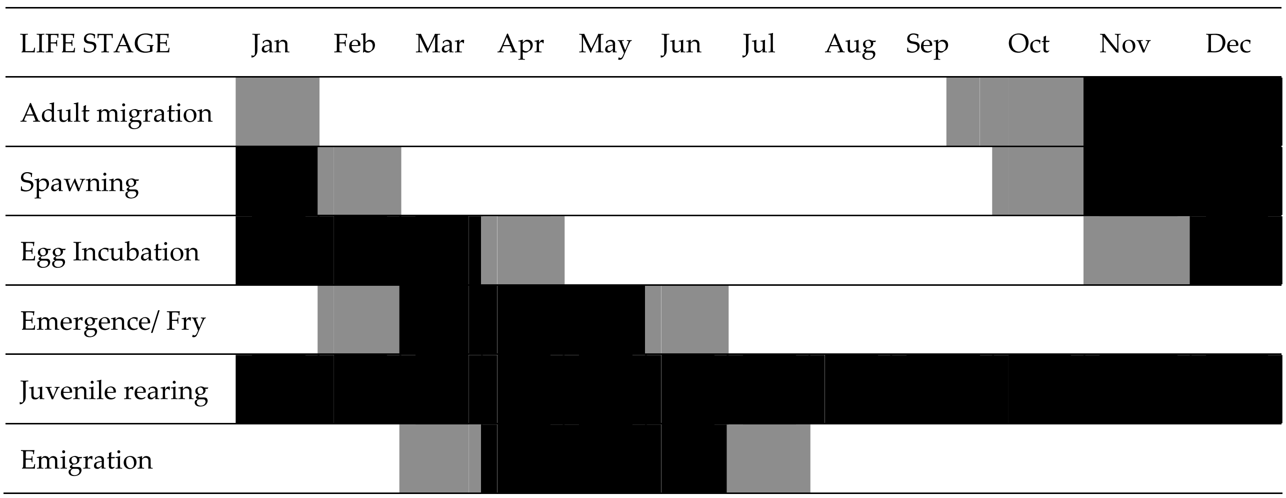


Figure 6: General overview of life stages (modified from Reeves 2009).

Coho salmon exhibit distinct life stages that occur during defined seasons (Table 2). Adult coho salmon migrate from the ocean to natal streams in the fall, generally entering freshwater from September through January and spawning primarily from November to January (DFG 2004). Moving south, the timing of migration occurs later, with fish entering freshwater in the southern portion of the range in November through January and spawning into February or early March (Moyle 2002). The upstream migration typically coincides with large increases in streamflow (Hassler 1987). Coho salmon are often not able to enter freshwater until heavy rains have caused the breaching of sand bars that form at the mouths of many coastal California streams. Spawning occurs primarily in streams with direct flow to the ocean or large river tributaries (Moyle 2002).

Female coho salmon pick a site to spawn at the head of a riffle, just below a pool where water flow changes from slow to turbulent and medium to small size gravel is abundant. Once suitable habitat is located, females fan the gravels with their tails to create nests in the gravel, known as “redds”, where they lay their eggs which are fertilized by accompanying males. The number of eggs a female produces is positively correlated with her size (the larger the female, the more eggs), but in general ranges from 1,400–3000 eggs. The number of eggs deposited per redd is approximately 100 or more. Redd location is chosen to allow good aeration and removal of metabolic waste from the nest. Eggs incubate in redds during November through April, hatching into “alevins” after a period of 35-50 days (Shapovalov & Taft 1954). The period of incubation is inversely related to water temperature (Moyle 2002, DFG 2004). Alevins remain in the gravel for two to ten weeks then emerge into the water column as young juveniles, known as “fry”.

Table 6: Seasonal calendar of coho salmon presence in California’s coastal watersheds. Dark shading indicates months of peak activity for a particular life stage; the lighter shading indicates months of lower activity.



Juveniles, or fry, form schools in shallow water along stream margins. Fish feed heavily during this time and as they grow, fish separate and set up individual territories in deep pools with good cover. Juveniles rear in freshwater for about one year with distinct habitat use during summer and winter rearing. In the summer, when flows are low, juvenile coho salmon concentrate in deep pools. In the winter, when stream flows are high, juvenile coho salmon require refuge in habitat such as off channel or backwater pools formed by large woody debris (LWD). After about one year in freshwater juvenile coho salmon undergo transformation into “smolts” in preparation for outmigration to the ocean.

Smoltification is associated with fish age, size, and environmental conditions (Hassler 1987). Smolt outmigration begins in late March or early April, and peaks in California from April to early July (Weitkamp *et al.*, 1995). A period of estuarine residency may occur prior to ocean entry to allow fish to transition to the saline environment. Estuarine use in the CCC coho salmon ESU is quite variable, ranging from substantial juvenile rearing to use only as a migratory corridor.

Ocean adult distribution and behavior are not well studied. After initial entrance to the ocean, smolts concentrate in schools inshore, gradually moving north along the continental shelf (DFG 2004). Ocean residence lasts for two years (except for jacks) until adult fish return to freshwater to spawn and begin the cycle again.

Three-Year Female Life Span

Coho exhibit an almost completely distinct maternal brood year lineage that is a life history trait of significant influence on overall population viability, management, and recovery (DFG 1995). Essentially all wild female CCC coho salmon spawn as three-year olds[9] (Shapovalov and Taft 1954). As a consequence of all wild female coho being three-years old at time of spawning, there are three distinct, separate maternal brood year lineages for the each stream in the ESU (Shapovalov and Taft 1954; DFG 1995). For example, nearly all coho salmon males and females produced in 2008 were the progeny of females produced three years earlier in 2005, which in turn were the progeny of females produced three years earlier in 2001, *etc*. The three maternal brood year lineages are shown in Table 3.

Table 7: Maternal brood year lineage

Lineage: I	2000	2003	2006	2009	2012	2015
Lineage: II	2001	2004	2007	2010	2013	2016
Lineage: III	2002	2005	2008	2011	2014	2017

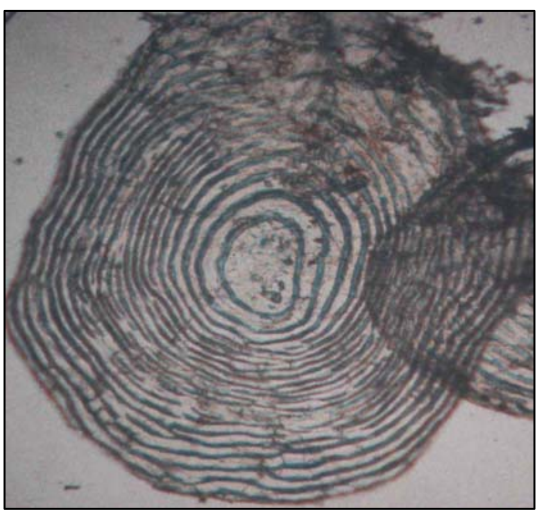


Photo Courtesy: Image of CCC coho salmon scale from 2006, Scott Creek, Santa Cruz, CA. This fish hatched in Spring 2005 and instead of outmigrating in Spring in 2006, it remained in Scott Creek. It would have migrated in 2007. Jerry Smith, San Jose State University.

[9] There is genetic exchange between year classes of a particular stream when two year old precocious males (jacks) of one year class spawns with three year old females of the prior year class. Recent information from California has documented juveniles rearing in freshwater for two years (Bell 2001; Smith pers comm. 2009; Hayes pers. comm. 2009; Wright pers. comm. 2009), and based on documentation of precocious females at the Noyo ECS (DFG 2008 – comments) it appears as though some genetic exchange in maternal brood years is possible.

The overall lack of overlapping maternal generations places brood year lineages (*i.e.*, year classes) at high long-term risk from the adverse effects of stochastic events (such as floods, droughts, *etc*.) This risk is especially high for small, remnant populations. For example, a chemical spill or catastrophic wildfire may eliminate all juveniles in a stream resulting in a complete loss of a year class and, thus, loss of adult spawners three years later. As continuous losses of each year class occurs across generations, extinction becomes imminent. Repopulation is possible by improving freshwater conditions that allow the remnant population to gradually rebound or from pairs straying into neighboring streams to spawn.

Low freshwater survival and reduced population size coupled with poor ocean conditions places further pressure on survival and persistence. This appears to have happened to the lineages of populations in the coho streams south of San Francisco Bay. Lineage I and II have been virtually eliminated but Lineage III persisted in many streams, albeit at a greatly reduced population size. This lineage was generally considered the last strong remaining year class. Unfortunately, poor ocean conditions during 2006/2007 resulted in a catastrophically low rate of adult returns during the winter of 2007/2008 and now, this one strong year class is almost gone (Spence pers. comm. 2009). Further compounding of the risk to coho south of San Francisco Bay occurred with the Lockheed fire in August of 2009. That wildfire burned most of the headwaters of Scott Creek and places this small population at exceptional risk of extirpation due to high rates of sedimentation when the 2009 winter rains begin.

LIFE HISTORY HABITAT REQUIREMENTS

Coho salmon must survive conditions across many different environments between and within freshwater and the ocean. Coho salmon spend the majority of their lives in the ocean, an environment that is difficult to manage and largely subject to environmental events affecting fish outside the control of humans. When environmental conditions are favorable the sub-adult and adult survival rates appear relatively high. Most coho mortality occurs in freshwater and during the rearing stage where the juveniles may be exposed to winter and spring flooding, summer droughts, or lack of rearing or winter refugia space (Sandercock 1991).

In freshwater, coho salmon must have enough energy to migrate (in some cases) long distances, find and fight for mates (males), build redds, survive through winter flows, avoid predators, obtain food, find pools and cool water for summer rearing, access offchannel habitats during outmigration and high winter/spring flows and find refuge in lagoon/estuary habitats for successful saltwater transition to the ocean environment. Environmental conditions influence how much energy coho salmon will need to survive, and whether or not they can survive within the range of available conditions. For example, turbid water beyond a coho salmon's preferred range can increase the energy needed to find food (as prey becomes more difficult to locate). This reduces the energy available to escape predators, and as food input declines, energy for all necessary life functions is further reduced. As environmental conditions become less favorable for coho salmon, fewer will be able to survive (Gregory and Bisson 1997, Lichatowich (1989), Beechie *et al*., 1994). Table 4 summarizes habitat requirements for each life stage.

Table 8: Habitat requirements for each life stage of CCC coho salmon

Freshwater Streams	Eggs: Incubation requires clean water, free of contamination and siltation. Disturbance of a single "redd" (nest of eggs) will result in the death of thousands of salmon embryos.
Freshwater Streams	Alevins: After hatching, alevins remain nestled in the small spaces between the gravels and feed from their attached yolk sacs. They are highly vulnerable to siltation and scour. Once the yolk is absorbed, the young salmon emerge from the gravels.
Freshwater Streams	Juveniles: Deep cool pools for summer rearing juveniles are critical for survival. Riparian vegetation helps support some of the insects consumed by juveniles, provides cover from predators, (when recruited to streams can create wood formed pools) and limits solar radiation to streams keeping water temperatures cool. Tree roots stabilize streambanks and create habitat structure. Downed wood creates cover and refugia for the tiny salmon to reside during high velocity flows. Pools and wetlands provide shelter from high flows and predators.
Freshwater Streams, Estuaries, Ocean	Smolts: Juvenile salmon undergo a physiological change known as "smoltification" that enables them to transition from freshwater to saltwater in the estuaries or lagoons. Smoltification can occur primarily within the freshwater areas, or in the nearshore environment. Smolts need adequate flow from upstream rearing areas to reach these estuaries. Estuaries should provide cover and adequate feeding habitats to facilitate the transition into the ocean. The quality of these areas has implications to survival of smolts as they enter the marine environment.
Ocean	Sub-Adults/Adults: Maturation occurs during ocean residency over a two year period, leading up to the adult salmon's return to streams of their birth. The patterns of migration in the ocean vary and shifts in ocean conditions affect food, migration patterns and survival. Fish in the ocean need adequate supplies of food to facilitate rapid growth. As the salmon return to their natal stream to reproduce, they once again undergo change from saltwater to freshwater; they depend on the nearshore and estuarine environments for this transition.
Ocean, Estuaries, Freshwater Streams	Spawners: Once the adult spawners arrive at their home river they need adequate flows, cool water temperatures, deep pools and cover to rest and hide as they migrate upstream. Females seek clean, loose gravel of a certain size in highly oxygenated water for laying their eggs. The site must remain stable throughout egg incubation and emergence, and allow water to percolate through the gravel to supply oxygen to the developing embryo.

The key to preventing the decline of coho salmon is to protect their spawning and rearing streams and to restore damaged habitat (Moyle 2002). While the ocean environment is where the species spends the majority of its life (and productivity fluctuations in this environment result in changes to coho salmon populations), low ocean returns of adults (escapement) combined with impaired freshwater habitats have a greater negative impact on successful spawning, rearing and outmigration. These factors act synergistically and make it difficult for the population to recover from adverse effects resulting from natural or anthropogenic impacts to ocean cycles. While ocean conditions have fluctuated in the past from poor to excellent for coho salmon, the general trend of freshwater habitat conditions during the 20th and 21st Centuries has been of increasing degradation. Continuing degradation of freshwater habitat impairs the ability of coho to rebound from poor ocean conditions when ocean conditions improve. It is therefore important to restore and protect essential freshwater habitat features.

Conditions in the freshwater environment that ensure the highest likelihood of coho salmon survival through spawning, rearing, and outmigration are varied. Coho salmon are found in a broader diversity of habitats than any of the other anadromous salmonids, from small tributaries of coastal streams to lakes to inland tributaries of major rivers (Meehan & Bjornn 1991). Based on the current status of the population this may seem implausible. However, coho salmon were found throughout their range in California into the mid 1900s. Shapovalov and Taft (1954) reported that coho salmon ascend practically all accessible streams within their range flowing into the Pacific Ocean, from the largest to the very smallest. To emphasize the point they cited Chamberlain (1907) who reported that in southeastern Alaska "(t)he coho is probably less particular (in comparison with the other Pacific salmons) in its requirements. The fry were found, without exception, in every stream and brook examined; even a tiny seepage … which would become dry with the first week of fair summer weather contained its little school of coho fry." Historically, CCC coho salmon inhabited the largest river basins, such as the Russian River, and very small coastal tributaries such as Laguna Creek (Santa Cruz County).

Unfortunately, the habitat requirements for coho salmon in most streams in the CCC ESU are not at properly functioning condition because the natural rates of critical watershed processes (*e.g.,* sediment delivery, hydrology, wood recruitment, temperature regulation, *et cetera*) have been substantially altered by human activities. This is remarkable considering the historically ubiquitous occurrence of coho salmon in the northern coastal streams of North America. The absence of coho salmon in these freshwater habitats is a strong indication that the majority of the watersheds in the CCC ESU are substantially disrupted and degraded. Until these habitats operate at their potential, and the natural processes that form them are restored, streams are unlikely to support viable salmon populations. If ecosystems are allowed to function in a more natural manner, habitat characteristics favorable to salmonids will result, and fish will be able to recolonize and populate historical habitats, recover from earlier stressors, and persist under natural disturbance regimes (Spence 1996). This plan provides strategies to enable the ecosystems where CCC coho salmon once thrived to begin their recovery and ultimately allow the population to reach a recovered status in the same watersheds inhabited by the human population.

<u>Optimal Coho Freshwater Habitat and Current Conditions</u>

When in freshwater, optimal habitats for successful rearing include adequate quantities of: (1) deep complex pools formed by large woody debris, (2) adequate quantities of water, (3) cool water temperatures, (4) unimpeded passage to spawning grounds (adults) and back to the ocean (smolts), (5) adequate quantities of clean spawning gravel, and (6) access to floodplains, side channels and low velocity habitat during high flow events. Numerous other requirements exist (*i.e.*, adequate quantities of food, dissolved oxygen, low turbidity, *etc.*) but in many respects these other needs are generally met when the six freshwater habitat requirements listed above are at a properly functioning condition.

Deep complex pools formed by wood. Large woody debris originating from riparian trees is a form of cover in many streams and its importance is widely recognized (Bisson *et al.* 1987; Holtby 1988). When riparian trees fall into water courses they create conditions which scour the gravel bottoms of streambeds and create deep pools. These pools are the preferred habitat of coho salmon. Coho prefer the slower moving areas of a stream, provided by pools, as feeding habitat and cover from predators. Slow moving water allows coho to capture food with the minimum expenditure of energy. Pools also provide an increase in the volume of rearing habitat which allows a greater density of juveniles than an equivalent length of stream without pool habitats. For example, in British Columbia, juvenile coho salmon abundance was five times higher in streams with large amounts of LWD (Fausch and Northcote 1992 in Bilby and Bisson 1998).

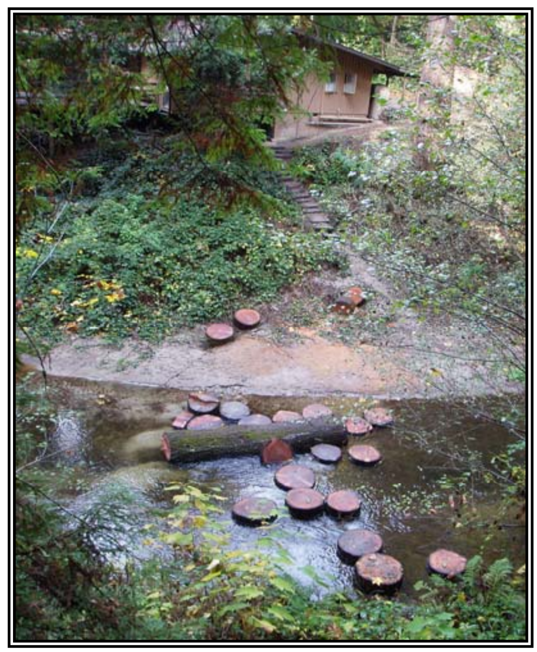


Photo Courtesy: These recent photographs (and the one on the following page) illustrate the practice of removing one of the most essential structural components of coho salmon habitat, large woody debris. These trees were cut up into small pieces on the San Lorenzo River in Santa Cruz County. Cutting these trees rendered them useless in future pool formation due to the wide width of the river. Large trees are needed because they tend to remain stable during high flows and help create deep scour holes that provide summer rearing habitat as well as high flow refugia during winter floods. Photographs courtesy of Chris Berry, Santa Cruz Water Department.

In many streams, these essential pool and complex habitats have been altered or lost due to reduced water flows, large woody debris removal activities, increased rates of sedimentation, and loss, alteration and simplification of riparian forests which leads to a lack of significant large wood recruitment. Lack of recruitment is due in large part to the much younger age of current riparian forests which generally lack older trees that fall into the stream as they age and die. The absence of large wood in the stream, in particular, has had major impacts to coho salmon because of its role in physical habitat formation, in sediment and organic-matter storage, and in maintaining a high degree of spatial heterogeneity (habitat complexity) in stream channels {NAP, 1996}. Decreases in coho abundances following LWD removal or loss have been documented in streams in the Pacific North West and Alaska (Bryant 1983; Dollof 1986; Reeves et al 1993). The loss of pools formed by large woody debris is indicative of past and present management practices as well as altered natural processes. Maintaining pool habitats, reversing the mechanisms leading to their loss, and adding wood will be necessary to ensure adequate summer and winter rearing habitat in every stream designated for recovery.

Photo Courtesy: Caspar Creek, Mendocino County, CA. Prime CCC coho salmon summer rearing habitat. Photo courtesy of Rick Macedo, DFG.

Water.

Fish need water and adequate water quantity and quality are essential for CCC coho salmon survival and persistence. Coho salmon populations need enough aquatic space for large numbers of juveniles to find food and escape from predators. Appropriate flows are needed for migration to and from the ocean, for habitat connectivity during the low flow summer season, for spawning, and for egg and alevin survival.

Lack of water is a severe limiting factor for coho salmon in many watersheds in the CCC ESU. Impacts from ongoing water diversions are most severe in the more urbanized watersheds and watersheds with significant agriculture diversions. California's Mediterranean climate results in low flow conditions during the summer and late fall rearing periods. Water diversions during the summer rearing period magnify the impact of natural low flows with pronounced impacts to juvenile survival. Frost protection for vineyards can create instantaneous flow reductions that leave salmon stranded on a drying stream bed. Additionally, in urbanized areas water runs off more quickly due to increased impervious surfaces resulting in higher winter flows and lower summer baseflow. DFG has noted that undocumented and illegal summer and fall water diversions are a serious concern and many previously perennial streams are now dry in late summer (Harris, S. pers. comm. 2009). Strategies to address this limiting factor are often difficult to implement but will be necessary to begin coho salmon recovery in many of the targeted watersheds in the ESU.

Instream temperature. Summer rearing coho salmon are sensitive to warm water temperatures. Optimal growth occurs when instream temperatures average 12-14° C. When maximum weekly average temperatures exceed 18° C coho salmon are absent from otherwise suitable rearing habitat (Welsh *et al.*, 2001). Temperatures exceeding 25-26° C are lethal. Altered thermal regimes change many characteristics of stream habitat through altering the structure of plant and invertebrate communities (Bisson & Davis 1976) and adverse interspecfic interactions between salmon and non-salmon fishes through increased competition and predation (Reeves *et al.,* 1987).

One of the more important factors contributing to optimal stream temperature is intact riparian buffers. Retention of wide riparian buffers with adequate riparian canopy, formed by mature native trees, moderates water temperature. Riparian canopy intercepts solar radiation, particularly in the smaller tributary streams where coho juveniles rear, and moderates the effects of warm summer temperatures.

Photo Courtesy: Coho smolt with parr marks fading and fish turning silver. San Vicente Creek, Santa Cruz, CA. Chris Berry, City of Santa Cruz Water Department.

Passage. Coho salmon require adequate passage conditions from the ocean to spawning areas for adults and from rearing areas to the ocean for smolts. Reduced flows, debris jams, plugged or improperly placed/sized culverts, excessive water velocities, closed sandbars and other conditions impede migrating adults. Unscreened diversions can impede smolt outmigration, particularly during low flow conditions. Typically, adult coho salmon do not migrate to the higher gradient stream reaches that steelhead are able to access. Many of the more significant barriers to adult migration in the CCC ESU have been addressed because a large proportion of past restoration projects have been directed at fixing passage problems. Barriers formed by large wood were removed at considerable effort by DFG in the past[10].

Spawning gravel. Adult coho females typically choose a spawning site near the head of a riffle, just below a pool, where water changes from smooth to turbulent flow and where there is abundant medium to small gravel. Most females dig at least three to four nests (redds) and deposit eggs in each {Godfrey, 1965}. The eggs will incubate an average of 38 days at 10.7° C (Shapovalov & Taft 1954) or longer at cooler water temperatures. Depth of egg burial varies substantially within and between salmon populations (Burner, 1951; van den Berghe and Gross, 1984; Tripp and Poulin, 1986). In some cases, larger females deposit eggs at greater depth than their smaller counterparts (van den Berghe and Gross, 1984), reducing the probability egg loss due to streambed scour during high flow conditions. Physical factors such as water velocity, the size of substrate and compaction of the stream bed also influence the depth of egg burial (Burner, 1951). Upon hatching the sac fry (alevins) remain in the gravel from one to five months. To ensure survival from spawning to emergence the gravels must be clean of fine sediment in order to supply, via intragravel flow, the eggs and newly hatched sac fry with oxygen rich water and to remove metabolic waste.

Photo Courtesy: A coho salmon redd and spawning gravel on the South Fork Noyo River, Jackson Demonstration State Forest, Mendocino County, CA. Rick Macedo, DFG.

Gravels with high concentrations of fine sediment can substantially reduce egg survival. Phillips *et al.*, (1975) found survival to emergence was only eight percent where gravel/sand mixtures were 70 percent (particle size < 3.3 mm). Fine sediment originates from many anthropogenic activities including agriculture, livestock grazing, urbanization, roads, forestry, mining as well as natural processes such as landslides, streambank erosion, and fire. Minimizing anthropogenic sources of fine sediment is readily achievable when riparian buffers of sufficient size persist along stream channels, culverts are adequately sized and properly located, development or extractive land management practices are avoided on unstable areas, cover crops are left during the winter, roads are properly maintained, *etc.*

[10] Today a lack of wood exists in many streams due to some of the large wood removal activities that were conducted for the purpose of passage improvement and channel improvement. Reduced large wood frequencies in most streams is now recognized as a key habitat limiting factor of for coho habitat across the CCC ESU.

Photo courtesy: This series of photographs illustrates the consequences of a massive land slide at the headwaters of Soldier Creek, tributary to Usal Creek in Mendocino County, California. The slide may have delivered up to one million cubic yards of sediment into the watershed. Sediment from this slide buried the coho salmon spawning and rearing habitat in Soldier Creek rendering it unsuitable for coho salmon for many years afterwards. Picture at bottom left illustrates the lower portion of Soldier Creek that changed from a system with abundant diversity of instream habitat to a greatly simplified stream that was essentially one long continuous riffle, unsuitable for juvenile rearing. Picture at bottom right illustrates the sediment plume from Soldier Creek as it enters North Fork Usal Creek. Twelve years after the slide stream conditions are improving. Photos courtesy of David Hines and Jonathan Ambrose, NMFS.

Floodplains. Survival and distribution of juvenile coho salmon are associated with available winter habitat (Bustard & Narver 1975; Peterson 1982; Tschaplinski & Hartman 1983; Nickelson *et al.* 1992; Quinn & Peterson 1996, Bell 2001). During winter, juvenile coho salmon select habitats with low velocity water such as alcoves, side-channels, backwaters, riverine ponds, and deep pools formed by rootwads (Bustard & Narver 1975; Tschaplinski & Hartman 1983; Nickelson *et al.* 1992). These habitat features provide cover from predators and protection from high discharge, factors that cause premature emigration and/or mortality of over-wintering salmonids (Bustard & Narver 1975; McMahon & Hartman 1989; Sandercock 1991; Erman *et al.*, 1988). These habitat features often occur at the greatest frequency on floodplains.

Cottaneva Creek, Mendocino County, CA. Photo courtesy of Matt Goldsworthy, MRC

Because survival and growth are often better in floodplain habitats, maintenance and restoration of these areas may be of exceptional importance for coho salmon recovery. However, floodplains are frequently locations of human development and as the name implies, are areas prone to flooding. Many floodplain habitats in the CCC ESU are heavy altered and channelized (for flood control and as a matter or routine maintenance practices) and no longer maintain alcoves, side-channels, backwaters, *etc.* Restoring floodplain habitats, wherever feasible and beneficial, would have a significant benefit to over-winter survival of juvenile coho salmon.

For more extensive discussion of and data supporting the relationship between changes in habitat variables and the status and trends of fish and wildlife populations, readers should refer to the work of Fiedler and Jain (1992), Gentry (1986), Gilpin and Soule (1986), Nicholson (1954), Odum (1971, 1989), and Soulè (1986). For detailed discussions of the relationship between habitat variables and the status and trends of salmon populations, readers should refer to the work of FEMAT (1993), Gregory and Bisson (1997), Hicks *et al*., (1991), Murphy (1995), National Research Council (1996), Nehlsen *et al*., (1991), Spence *et al*., (1996), Thomas *et al*., (1993), and The Wilderness Society (1993).

Photo courtesy: Branciforte Creek on the San Lorenzo River, Santa Cruz County, CA. This picture illustrates permanent impacts to a riparian zone on a floodplain due to bank hardening and stabilization actions. This urbanized stream bank no longer provides shade or any potential for future wood recruitment. The rip rap on the streambank will act to increase water velocity rending the habitat much less suitable for rearing and migration. Jon Ambrose, NMFS.

<u>Marine Environment</u>

The marine life stage of CCC coho salmon is not well studied. After initial entrance to the ocean, smolts concentrate in schools inshore, gradually moving north along the continental shelf (DFG 2004). As described above, ocean residence typically lasts for two years, when adult fish return to freshwater to spawn and begin the cycle again. Some precocious males (jacks) return after only six months of ocean residence.

Long-term trends in marine productivity associated with atmospheric conditions in the North Pacific Ocean have a major influence on coho salmon production. Natural climatic conditions may have exacerbated or mitigated the problems associated with degraded and altered riverine and estuarine habitats (69 FR 33102). Coho salmon have evolved behaviors and life history traits allowing them to survive a variety of environmental conditions. When populations are fragmented or reduced in size and range, however, they are more vulnerable to extinction by natural events.

Poor ocean conditions are believed to have a prominent role in the recent decline of coho salmon populations in California. Unusually warm ocean surface temperatures and associated changes in coastal currents and upwelling, known as El Niño conditions result in ecosystem alterations such as reductions in primary and secondary productivity and changes in prey and predator species distributions. More significantly, poor ocean conditions that affect the biological productivity are the result of interdecadal climate variability in the northeast Pacific (Beamish and Boullion 1993, Hollowed and Wooster 1994). Regimes shifts in the ocean have likely significantly adversely affected overall CCC coho salmon production.

El Niño is often cited as a cause for the decline of West Coast salmonids. Near-shore conditions during the spring and summer months along the California coast may have dramatically affected year-class strength of salmonids (Kruzic *et al.,* 2001). Coho salmon along the California coast may be especially sensitive to upwelling patterns because of the lack of other coastal habitat types that normally buffer adverse oceanographic effects (*i.e.* extensive bays, straits, and estuaries). The paucity of high quality near-shore habitat, coupled with variable ocean conditions, makes freshwater rearing habitat more crucial for the survival and persistence of many coho salmon populations. Of greatest importance is not how salmonids perform during periods of high marine survival, but how prolonged periods of poor marine survival affect population viability. Salmonid populations have persisted through many such cycles. It is less certain how they will fare in periods of poor ocean survival when freshwater, estuary, and nearshore marine habitats are degraded (Good *et al.,* 2005). Recovery of coho salmon in the NCCC Domain will depend on populations robust and resilient enough to withstand natural changes in ocean productivity.

El Nino events are interannual variations in ocean conditions that decrease the abundance of salmonid prey items in the ocean, and while they tend to occur more frequently in particular longer term ocean environmental regimes they are not necessary for poor marine survival. The changes to Pacific Decadal Oscillation (PDO) are more long lasting and more profound. Synthesis of climate and fishery data from the North Pacific sector highlights the existence of this very large scale, interdecadal, coherent pattern of environmental and biotic changes. The marine ecological response to the PDO-related environmental changes starts with phytoplankton and zooplankton at the base of the food chain and works its way up to higher level predators like salmon (Venrick *et al.,* 1992, Roemmich and McGowan 1995, Hare 1996, Brodeur *et al.,* 1996, Francis *et al.,* 1997). This "bottom-up" enhancement of overall productivity appears to be closely related to upper ocean changes that are characteristic of the positive polarity of the PDO. PDO reversals occurred in 1925, 1947, and 1977 (Mantua *et al*., 1997, Mantua and Hare 2002). The results of these reversals were significantly changed harvest patterns between Alaskan fisheries and fisheries in Washington, Oregon, and California (WOC). Of note however, Mantua *et al*., (1997) observed a weaker connection between harvest records for the WOC salmonids than the Alaskan fisheries. They indicated that climatic influences on salmon in their southern ranges may also be masked or overwhelmed by anthropogenic impacts: Alaskan stocks are predominantly wild spawners in pristine watersheds, while the WOC coho and Columbia River spring Chinook salmon are mostly of hatchery origin and originate in watersheds that have been significantly altered by human activities.

For more information on marine conditions please see Appendix A.

Photo Courtesy: Hatchery adult (from the Broodstock Program) CCC coho salmon, Scott Creek, Santa Cruz County, CA. Morgan Bond, SWFSC