North Central California Coast Recovery Domain
CCC Coho ESU Recovery Plan

Marine and Climate

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Table of Contents

MARINE HABITAT

"Thus blaming "ocean conditions" for salmon declines is a lot like blaming the iceberg for sinking the Titanic, while ignoring the many human errors that put the ship on course for the fatal collision. Managers have optimistically thought that salmon populations were unsinkable, needing only occasional course corrections such as hatcheries or removal of small dams, to continue to go forward. The listings as endangered species of the winter and spring runs of Central Valley Chinook were warnings of approaching disaster on an even larger scale. "Ocean conditions" may be the potential icebergs for salmon populations but the ship is being steered by us humans. Salmon populations can be managed to avoid an irreversible crash, but continuing on our present course could result in loss of a valuable and iconic fishery."

Peter B. Moyle, Professor of Fish Biology, and University of California

Marine Distribution of CCC coho salmon

CCC coho salmon spend the majority of their lives at sea, therefore evaluating marine distribution and associated stresses and threats is a necessary component for recovery planning. The evaluation is challenging because migration patterns and ecology of coho salmon in the marine environment are highly variable and incompletely understood.

Coho salmon occur in the epipelagic zone (top layer of the water column) in the open ocean, at observed depths of from about 10 to 25 meters (summarized by Quinn 2005). Information from hatchery releases in the range of the CCC coho salmon ESU, found that most individuals were recovered in northern California, followed by southern Oregon, with a small number found in Washington state waters (<1 percent). Based on these data, and assuming a correlation in migration patterns between hatchery and wild populations, it appears the majority of adult CCC coho salmon are located off of California and Oregon. Weitkamp and Neely (2002) found a high diversity of ocean migration patterns which suggests individuals within a population may be widely distributed in the coastal ocean areas.

Marine Phase of the coho salmon life cycle

Two life stages of coho salmon occur in the eastern Pacific Ocean; sub-adults and adults. These life stages occupy different environments and are exposed to different associated stresses and threats encountered within those areas. The sub-adult life stage is defined as individuals inhabiting nearshore marine areas, generally near the continental shelf. The adult life stage is defined as individuals occupying the larger offshore marine environment. Coho salmon utilize nearshore areas of the ocean for a number of months before they enter the open ocean, where they remain for eighteen months or more before they return to their natal streams as spawners. Some coho salmon never move offshore to the open ocean, but instead move north along the continental shelf and grow to adulthood in nearshore areas before returning to spawn (Sandercock 1991). Coho salmon survival in the marine environment is largely affected by individual attributes, such as body size, growth rate, and ocean entry date; as well as environmental conditions, predation and competition (Quinn 2005).

Sub-Adult Life Stage

CCC coho salmon appear to remain in nearshore habitats close to their watershed of origin for the first few months of ocean residency. A life history study by Shapovalov and Taft (1954) on coho salmon in Waddell Creek on the central California coast, showed coho stayed within 150 kilometers of shore for a few months following ocean entry. Other studies using recoveries of coded-wire tags (CWTs) also indicate coho salmon remain in the region of their natal stream during their first summer in the ocean (Fisher and Pearcy 1988). Residency in natal nearshore areas may be linked to smolt density and feeding conditions in those areas and likely varies from year to year (Healey 1980).

The first summer and fall at sea critically influences the likelihood of survival to adulthood (Hartt 1980; Beamish *et al.* 2004). Van Doornik *et al* (2007) and Beamish and Mahnken (2001) correlated the abundance of juveniles caught in September, with adult abundance the following year and determined the success of each year-class was largely set during the first summer in the ocean. The close correlation between jack (two-year old male) abundance and adult abundance further indicates the early ocean period is critical to adult salmon abundance, and that most mortality occurs after the first summer of ocean residency (Quinn 2005). Juvenile salmon that fail to reach a critical size by the end of their first marine summer do not survive the following winter, suggesting that attaining a large size in a short period of time is necessary for survival. Beamish *et al.* (2004) and Holtby *et al.* (1990) found a strong link between growth and survival, with faster growing coho salmon being more likely to survive the winter than slower growing fish, especially in years of low ocean productivity. Increased growth rates are influenced by both genetic disposition (Beamish *et al.* 2004) and feeding opportunities. Upon ocean entry, juvenile coho primarily feed on marine invertebrates, but transition to larger prey (predominantly fish) as they increase in size (Groot and Margolis 1991). Beamish and Mahnken (2001) also found within the first six months of ocean entry, early mortality is influenced by predation, and to a lesser degree a physiologically-based mortality.

Adult Life Stage

Once coho salmon enter the open ocean, they are subject to different food availability, environmental conditions, and stressors than present in the nearshore environment. The growth and survival of adult coho is closely linked to marine productivity, which is controlled by complex physical and biological processes that are dynamic and vary over space and time. Shifts in salmon abundance due to climatic variation can be large and sudden (Beamish *et al.* 1999). Short and long-term cycles in climate (*e.g.*, El Niño/La Niña and the Pacific Decadal Oscillation (PDO)) affect adult size, abundance, and distribution at sea, as does inherent year-to-year variation in environmental conditions not associated with climatic cycles.

Several studies have related ocean conditions specifically to coho salmon production (Cole 2000), ocean survival (Ryding and Skalski 1999; Koslow *et al.* 2002), and spatial and temporal patterns of survival and body size (Hobday and Boehlert 2001; Wells *et al.* 2006). The association between survival and climate operate via the availability of nutrients regulating the food supply and competition for food (Beamish and Mahnken 2001). For example, the 1983 El Niño resulted in increased adult mortality and decreased average size for Oregon's returning coho and Chinook salmon. Juvenile coho salmon entering the ocean in the spring of 1983 had low survival rates, resulting in low adult returns in 1985 (Johnson 1988). Larger-scale decadal to multi-decadal events also have been shown to affect ocean productivity and coho salmon abundance (Pearcy 1992; Lawson 1993; Hare and Francis 1995; Beamish *et al.* 1997; Mantua *et al.* 1997; Beamish *et al.* 1999). Although salmon evolved in this variable environment and are well suited to withstand climactic changes, the resiliency of the adult population has been reduced by the loss of life history diversity, low population abundance, cohort loss, and fragmentation of the spatial population structure. Changes in the freshwater environment have further adversely affected the ability of coho salmon to respond to the natural variability in ocean conditions.

Marine Survival

As noted above, marine survival and successful return as adults to spawn in natal streams is critically dependent on the first few months at sea (Peterman 1992; Unwin and Glova 1997; Ryding and Skalski 1999; Koslow *et al.* 2002). In a detailed study of Puget Sound hatchery coho salmon, Matthews and Buckley (1976), estimated 13 percent survival during the first six months at sea; and after twelve months survival was estimated at nine percent. The survival rate during the second year at sea was 99 percent.

Marine environmental conditions are also a major determinant in adult returns (Bradford 1995; Logerwell *et al*. 2003; Quinn 2005). In general, coho salmon marine survival is about 10 percent (Bradford 1995), although there is a wide range in survival rates (from <1 percent to about 21 percent) depending upon population location and ocean conditions (Beamish *et al*. 2000; Quinn 2005)[1]. Changes in marine survival rates often have large impacts on adult returns (Beamish et al. 2000; Logerwell *et al*. 2003). Recent data from across the range of coho salmon on the coast of California and Oregon reveal a 73 percent decline in returning adults in 2007/08 compared to

[1] Few data exist for coho salmon from California. Most marine survival data reported above are from Oregon, Washington, and Canadian coho populations. NMFS assumes marine survival rates for CCC coho salmon will be similar.

the same cohort in 2004/05 (MacFarlane *et al.* 2008). The Wells Ocean Productivity Index, a measure of Central California ocean productivity, predicted poor conditions during the spring and summer of 2006, when juvenile coho from the 2004/05 cohort entered the ocean (MacFarlane *et al.* 2008). However, strong upwelling in the spring of 2007 may have resulted in better ocean conditions for the 2007 coho salmon cohort.

Stresses

Major stresses identified which potentially affect coho salmon marine survival include: (1) reduced quantity and/or quality of food resources; and (2) reduced genetic and life history diversity. Although poorly understood, the complex physical and biological processes determining feeding opportunities have a large influence on the growth and survival of coho at sea, especially in the first six months of ocean residency. What we do know is that the life history plasticity and genetic diversity of coho salmon entering the ocean environment has been dramatically decreased. The loss of diversity has reduced the growth opportunities, the survival of populations, and the overall resiliency of the ESU. Predation and competition can also influence the size of the population in certain circumstances. An analysis of stresses affecting coho salmon at sea is summarized by life stage below.

Reduced quantity or quality of food

Oceanographic condition (*e.g.*, upwelling rates, sea-surface temperatures, *etc.*) is the major factor influencing salmonid food quantity and quality in the marine environment. The first few months in the ocean are critical for sub-adult coho salmon survival. As previously discussed, sub-adult fish must quickly grow to a large size prior to their first winter in the ocean or be subject to high mortality, thus survival is highly correlated with the amount and type of food available.

The availability and type of food resources in the nearshore environment is dependent upon the location and magnitude of upwelling and its influences on ocean productivity. Upwelling is caused by northerly winds that dominate from spring to early fall along the coastal region of the Pacific Northwest within the California Current marine ecosystem. These winds transport offshore surface water southward, while also transporting surface water away from the coastline (westward). This offshore, southward transport of surface waters is balanced by onshore northward transport (upwelling) of deep, cool, high-salinity, nutrient-rich water (Peterson *et al.* 2006). The shifting of this highly productive water to the surface of the nearshore environment triggers the formation of large phytoplankton blooms. Phytoplankton (minute aquatic plants) form the base of the marine food chain and are eaten by zooplankton (microscopic animals, such as copepods, that move passively with ocean currents). Zooplankton in turn, are preyed upon heavily by forage fish species and sub-adult coho salmon.

Coastal upwelling therefore, is a critical process affecting plankton production, and corresponding food availability. Moreover, the strength and timing of the upwelling event effects salmon survival by influencing the overall abundance and spatial distribution of plankton within the nearshore marine environment. Many studies have demonstrated this direct relationship. For example, Gunsolus (1978) and Nickelson (1986) correlated salmonid marine survival and the strength and/or timing of marine upwelling. Holtby *et al.* (1990) examined the scales of returning adult coho salmon in order to determine growth rates, and found that rapid ocean growth was "positively correlated with ocean conditions indicative of strong upwelling." Better ecosystem productivity is also related to earlier seasonal upwelling events (Peterson *et al.* 2006). Additionally, Cury and Roy (1989) demonstrated a relationship between upwelling and recruitment of several pelagic forage fishes in the Pacific.

The cooler water temperatures resulting from upwelling currents along the eastern Pacific Ocean originating from the subarctic region support high plankton productivity and salmon survival. Marine productivity and salmon survival are typically much lower when warmer, less-saline water upwells from sub-tropic marine regions. Survival is also likely influenced by the species of zooplankton occupying the two water types (cooler subarctic waters, and warmer subtropical waters); sub-arctic copepods are larger and have more fat than sub-tropical ones, promoting better support growth and survival of salmon which prey on them, and on forage species which eat them (Peterson *et al.* 2006). Peterson *et al.* (2006) developed an index to predict salmonid year-class strength based on the species of copepods present over the continental shelf and the inferred source of the water transport.

Unfavorable oceanographic conditions also affect adult coho salmon through their impacts on forage fishes, the primary food of adult coho salmon. For example, Pacific herring recruitment in the Bering Sea and northeast Pacific was accurately forecast based on the air and sea surface temperatures when spawning occurred (Williams and Quinn II 2000), and many Pacific herring starved during a winter of low zooplankton abundance in Prince William Sound, Alaska (Cooney *et al*. 2001).

Reduced genetic and life history diversity

A number of life history and genetic traits also influence coho salmon growth and survival. For sub-adults these include timing of ocean entry, size and age at entry, growth characteristics, migration pathways, feeding behaviors, straying, and age and size at maturity (Quinn 2005). The influence of each of these traits on growth and survival is dependent on ocean conditions, and salmon have a diversity of life history and genetic traits to take advantage of the full range of variability which maximizes their resiliency. Overall, coho salmon have experienced a net loss of diversity and may not be able to exploit the full range of ocean conditions, which may place them at a greater risk of extinction.

As noted above, the timing of ocean entry can affect likelihood of survival. Ryding and Skalski (1999) documented a relationship between the marine survival rate of coded-wire tagged coho salmon released from Washington state and the ocean conditions when released. The authors concluded there are optimal environmental conditions for coho marine survival, and thus optimal dates for ocean-entry, for any given year. Similar patterns have been observed with pink salmon in Alaska (Cooney *et al*. 1995). Research by Mortensen *et al.* (2000) also suggests an indirect relationship between time of ocean entry and growth and vulnerability to predators of sub-adult coho salmon.

Although the date of ocean entry is critical to coho survival, the timing of peak ocean upwelling and productivity is quite variable and cannot be reliably predicted. Between 1967 and 2005, the date of spring transition (the start of upwelling), at 39 degrees North latitude, has varied from January 1 to early April (Bograd *et al.* 2009). Coho salmon migrate to sea over a number of months, which may increase salmonid year class strength because, although the timing of the upwelling event is variable, at least some coho should enter the ocean when conditions were favorable. Size and age variation during outmigration is an important mechanism to improve a population's ability to track environmental change and persist in the marine system[2].

The relationship between size and survival of sub-adult coho salmon has been documented in a number of studies (*e.g.,* Quinn 2005). Size-selective mortality in the ocean (mainly through predation) suggests larger individuals likely experience higher survival rates than smaller individuals (Holtby *et al.* 1990). Some individuals may also have a size advantage due to their genetic disposition, and this, in turn, may translate to increased growth and survival at sea (Beamish *et al.* 2004).

Once coho salmon reach the ocean they are thought to display a range of different migratory pathways depending on their behavior, life history, and genetic makeup (Weitkamp and Neely 2002). A wide distribution allows populations and the ESU to take advantage of numerous feeding opportunities and spreads the risk of isolated mortality events (such as predation,

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[2] In Redwood Creek, California, some coho remain in freshwater for one year before outmigration to the ocean, while a small number remain for an additional year and smolt as two year-olds (Bell and Duffy 2007). In Pudding Creek, California, 12 percent of the smolts were two year-olds (Wright pers. comm. 2009). Two year-old coho salmon migrate at a larger size and may experience higher marine survival than smaller, one year-old fish, but are consequently exposed to an additional year of stresses unique to the freshwater environment. Depending on both ocean conditions and conditions in the freshwater environment, one or both life histories will likely succeed and contribute to the persistence of the population.

fisheries impacts, or ocean conditions). In turn, a wide distribution decreases the risk of any one population being extirpated in concentrated mortality events.

As adults, some coho salmon display a limited range of life history strategies. They either return to their natal streams to spawn after only a few months at sea as two year-olds (called jacks or grilse) or, more typically, after a year at sea as three year olds. Maintaining a healthy abundance of jacks in any population ensures some genetic overlap between brood years and is thought to increase the overall productivity of the population. Also important to the overall health and resilience of the ESU is the presence of strays, which do not return to their natal spawning grounds and consequently help to colonize new spawning areas and re-establish diminished populations.

A diverse array of behaviors and environmental sensitivities, such as those seen in salmon populations, are evolutionary responses to successful adaptation in uncertain environments (*e.g.*, see Independent Science Group 2000). At the metapopulation level, each species of Pacific salmon exhibits many such risk-spreading behaviors via a broad diversity of time-space habitat use by different stocks and substocks of the same species. Through reduced population size, lost connectivity between remaining populations, and the genetic dilution resulting from (past) hatchery use of non-native stock (Weitkamp *et al.* 1995), the CCC ESU has lost much of its historical life history and genetic diversity. The remnant life history characteristics likely limit extant populations from taking full advantage of the range of ocean conditions, diminishing overall productivity. In the marine environment, the impact from lost phenotypic diversity is probably most pronounced at the sub-adult life stage, since success at that life stage is closely correlated with ocean conditions. Because of the importance of maintaining a diverse set of life history strategies and genetic pool to the survival and growth of coho salmon at sea, the loss of these traits is considered a medium to high stress.

Threats

Overview of Threats

Major threats potentially affecting CCC coho salmon in the marine environment include incidental take from commercial and recreational fisheries, aquaculture, predation, harvest of kelp, wave energy generation, management of prey and competitors, hazardous spills, and introduction of non-native species. The threat of climate change also influences ocean productivity, but is discussed separately in the Climate Scenarios section of this appendix.

Commercial and recreational fishery bycatch

Directed commercial and sport fishing take

In 1993, the retention of coho salmon in ocean commercial fisheries was prohibited from Cape Falcon, Oregon south to the U.S.-Mexico border. The following year, coho salmon retention was prohibited in ocean recreational fisheries from Cape Falcon, Oregon to Horse Mountain, California, and expanded to include all California waters in 1995. These prohibitions prohibit direct sport and commercial harvest of coho salmon off the California and Southern Oregon coast, the sole exception being a mark-selective recreational coho salmon fishery that has taken place in recent years in Oregon waters. While the number of CCC coho harvested within the Oregon mark-selective fishery is difficult to determine, the percentage is likely lower than the projected 3.3 percent non-retention exploitation rate for Rogue/Klamath coho salmon (PFMC 2007) due to the more southern marine distribution of CCC coho versus Southern-Oregon Northern California Coast ESU (NMFS 1999a)[3]. Therefore, the primary harvest-related impact on CCC coho salmon likely arises from incidental take through other fisheries. This impact is likely largely restricted to adult fish and has little effect on the sub-adult life stage, which is likely too small to be efficiently captured in this fishery.

[3] NMFS (1999a) suggests exploitation rates for CCC coho salmon may be higher than SONCC coho salmon due to the overwhelming effect of the central and northern California sport and commercial Chinook fishery. However, due to recent declines in Klamath and Sacramento River Chinook salmon populations, Chinook salmon fishing off the California coast has been severely restricted in 2007, 2008, and 2009, and the size and extent of future seasons is uncertain.

The State of California has recently begun implementing a series of underwater parks and reserves along the California coast as part of the Marine Life Protection Act (MLPA) of 1999. The goal of the MLPA is to "protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries (CDFG 2008)". Fishing will be closed or severely restricted in most protected areas, which will ultimately account for approximately 20 percent of state coastal waters (out to three miles off-shore). However, many of the restricted areas coincide with rocky benthic habitat which salmon may inhabit only sporadically, and many of the more popular salmon fishing areas are not expected to be part of the MLPA program. Furthermore, some MLPA areas where fishing is restricted make exceptions with regard to salmon fishing. For these reasons, NMFS does not expect a significant reduction in ocean salmon harvest resulting from the MLPA program.

Bycatch in Federal salmon fisheries

The Pacific Fishery Management Council (PFMC) manages salmonid fisheries in Federal waters. The CCC coho salmon ESU is one component of the Oregon Production Index (OPI) area coho stocks. Because there are insufficient hatchery releases from within the CCC coho ESU to support an estimate of fishery bycatch in the Chinook salmon fishery (CDFG 2002), the projected marine fishery impacts on Rogue/Klamath River (R/K) hatchery coho were used as a surrogate.[4] Coho are intercepted in Chinook-directed fisheries and must be immediately released. However, some will die, as reflected by the 13 percent marine fishery mortality rate allowed for R/K hatchery coho salmon (NMFS 1999a). Given that the estimated discard mortality rate for R/K hatchery coho salmon has been the 13 percent maximum for at least the last three years (PFMC 2007), and prohibitions on take of OPI area coho stocks have not changed, the Federal salmon fishery was determined to pose a low threat to the CCC coho salmon ESU.

[4] The assumption is that exploitation rates of hatchery and wild coho salmon stocks are similar.

<u>Bycatch in State salmon fisheries</u>

All marine fishing occurring within three miles of the California shore is managed by CDFG. Chinook salmon harvest is allowed in California waters and is subject to area restrictions, gear restrictions, seasonal closures, and bag limits (CDFG 2011). Harvest of coho salmon is prohibited in California waters (except Lake Oroville), and any incidentally hooked coho salmon must be immediately released unharmed (CDFG 2011).

The impacts of state-regulated Chinook salmon and steelhead fisheries on CCC coho salmon have not been evaluated but could be significant. Listed salmon and steelhead are likely to occur within the marine environment at the same time, and in the same locations, as non-listed salmonids, and are likely to be captured by the same gear and fishing methods. Bycatch mortality may be enough to hinder recovery due to the extremely low size of the population. In parts of California, ocean fishers use a "drift mooching" method of capturing salmonids, where bait is suspended in the water column and moved by the ocean currents as the boat drifts. Salmon are more likely to swallow the hook when caught using drift mooching than when caught while trolling, and are less likely to survive when released. The survival of Chinook salmon caught and released off Northern California from drift mooching was monitored for four days and compared to a control group (Grover *et al*. 2002). The overall hook-and-release mortality rate for the study was estimated at 42 percent, significantly greater than the 13 percent mortality cap in Federal ocean fisheries. While the study did not evaluate impacts to coho salmon (due to the statewide prohibition on harvest of this species) the impacts between species are likely similar. Given coho occur higher in the water column than Chinook salmon, fishers targeting Chinook salmon may not encounter coho salmon. However, since most of the lifetime mortality suffered by a coho salmon occurs before they reach adulthood (Quinn 2005), an adult coho salmon that has survived at least a year of ocean life and is not far from spawning age is particularly valuable for recovery. The PFMC salmon FMP includes the 42 percent bycatch mortality rate from mooching as part of its recreational bycatch mortality rate for the area south of Point Arena. However, as coho recover, this mortality rate could have a proportionately greater impact on the ESU than it does now, as the rate CCC coho are encountered increases. This fishing method could hinder recovery. Given the impact the state salmonid fishery on CCC coho salmon is unknown but potentially significant; this fishery was determined to pose a medium threat to the recovery of this ESU.

Federal non-salmon fisheries

The PFMC manages four stocks (*aka* stock complexes) in Federal waters potentially affecting CCC coho salmon through fishery bycatch: groundfish, coastal pelagic species (CPS), highly migratory species (HMS), and Pacific halibut. NMFS evaluated the impacts of the groundfish fishery on listed salmon and steelhead and concluded it was not likely to adversely affect salmon or adversely modify critical habitat (NMFS 1999b; NMFS 2005). Salmonids could be accidentally captured in fisheries targeting CPS, but NMFS determined, although some ESUs of coho salmon are captured in CPS fisheries, CCC coho are not captured (PFMC 2005). The HMS fishery targets various species of tunas, sharks, and billfishes as well as mahi-mahi. A 2004 Biological Opinion stated, although all listed salmonid ESUs could occur in the area where HMS fishing occurs, there are no records indicating any instance of take of listed salmon in any HMS fisheries.

Pacific halibut occur on the continental shelf from California to the Bering Sea. Harvest of this species is managed by the International Pacific Halibut Commission (IPHC), which determines allowable catch. Although fishing for this species is allowed in California, in the past ten years only one Pacific halibut was commercially landed in waters off California (Leaman, Executive Director, International Pacific Halibut Commission, personal communication, 2007). Based on surveys from 1200 stations off of Washington and Oregon, an average of less than one salmon is captured per year survey wide (Dykstra, Survey Manager, International Pacific Halibut Commission, personal communication, 2007). The number of salmon caught in the recreational halibut fishery off California appears very small (Palmer-Zwahlen, CDFG, personal communication, 2007).

Marine aquaculture

Concerns have been raised over environmental impacts of salmonid culture activities in nearshore or open ocean areas. Potential impacts include disease and parasite transmission, water quality impairment, and genetic interactions. The recovery of CCC coho salmon is unlikely to be hindered by current marine aquaculture activities because, aside from the shellfish farming (*e.g.*, oysters and abalone) occurring in estuaries, marine aquaculture is largely absent from the waters off the California coast where CCC coho salmon spend most of their ocean residency. Further, marine culture of salmonids cannot occur in California's jurisdictional waters, which extend three miles into the Pacific Ocean (see State of California's 2006 Sustainable Oceans Act). In Federal waters (between three and 200 miles from the west coast), the process for obtaining a permit to carry out aquaculture is unwieldy, time consuming, and unattractive to investors (NOAA 2007). A bill to establish Federal guidelines for offshore aquaculture and improve the permitting process was recently considered by congressional committees. This legislation would retain NMFS' review of permit applications to ensure they do not jeopardize the continued existence of CCC coho salmon. Given the low likelihood of any additional aquaculture operations off the California coast in the next five plus years, and the expected close evaluation of any proposals by NMFS, EPA, and other agencies, the threat to listed salmonids from the culture of animals in nearshore and offshore marine areas is rated as low.

Marine mammal predation

Predation by marine mammals (principally seals and sea lions) is of concern in areas experiencing dwindling run sizes of salmon (69 FR 33102). However, salmonids appear to be minor component of the diet of marine mammals (Scheffer and Sperry 1931; Brown and Mate 1983; Hanson 1993; Goley and Gemmer 2000; Williamson and Hillemeier 2001). Harbor seal and California sea lion numbers have increased along the Pacific Coast since passage of the Marine Mammal Protection Act of 1972, but available information indicates salmon are not a principal food source for pinnipeds (Quinn 2005). At the mouth of the Russian River in western

Sonoma County, Hanson (1993) reported foraging behavior of California sea lions and harbor seals with respect to anadromous salmonids was minimal. Hanson (1993) found predation on salmonids coincidental with the salmonid migrations, but the harbor seal population at the mouth of the Russian River was not dependent upon them. Nevertheless, this type of predation may, in some cases, kill a significant fraction of a run and local depletion might occur (NMFS 1997; Quinn 2005). At the ESU level, NMFS considers the threat of marine mammal predation low.

Avian predation

Avian predation is not expected to constitute a significant threat to adult CCC coho salmon because of their relatively large size once in the ocean. All documented incidences of significant effects of avian predation on juvenile salmonids have occurred in estuarine areas near large nesting colonies with high avian densities. While birds are also known to feed on schools of fish in the open ocean (Scheel and Hough 1997), indirect evidence shows salmonids do not generally occur in tight schools. Many salmon probably do not swim in sight of other salmon, and when they have been observed together it is usually in groups of less than four (Quinn 2005). Avian predation is not expected to constitute a significant threat to sub-adult coho salmon when they occur in nearshore oceanic areas used by CCC coho salmon.

Management actions affecting nearshore marine habitat

<u>Harvest of kelp from nearshore marine areas</u>

Both bull and giant kelp are currently harvested from California waters (Spinger *et al.* 2006). Small quantities of each species are currently harvested, due to limited commercial demand. The upper four feet of canopy and leaves of giant kelp are harvested, allowing the plant to continue to grow and reproduce (Spinger *et al.* 2006); therefore, giant kelp are essentially a renewing crop. However, when bull kelp are harvested, the pneumatocyst and associated fronds are removed, which eventually kills the plant. Harvest of bull kelp before it reproduces may destroy beds of this species and reduce the amount of habitat available to juvenile CCC coho salmon. The extent CCC coho salmon utilize kelp is unknown.

Surveys of the fish communities in kelp beds off California south of the CCC coho salmon ESU range are focused on rockfishes and do not mention salmon (*e.g.*, Paddack and Estes 2000). No salmon were found in studies of beds of bull kelp off South-central Alaska (Hamilton and Konar 2007), but salmon were found in beds of brown kelp off Southeastern Alaska (Johnson *et al.* 2003). In Washington's Strait of Juan de Fuca, juvenile Chinook and chum salmon appeared to preferentially use kelp beds (which included both bull kelp and giant kelp) over unvegetated habitats (Shaffer 2004).

The above studies suggest coho salmon could use kelp beds, and some of these kelp beds may be negatively affected by harvest. But at this time, there is no evidence CCC coho salmon rely on kelp beds for shelter in the nearshore marine environment, and no harvest of the kelp beds occurs within the CCC coho salmon ESU range. The threat to CCC coho salmon from the harvest of kelp from nearshore marine waters was rated as Low.

<u>Wave energy generation in the nearshore environment</u>

Wave energy can be harnessed to provide electricity, and there are three proposals to do so in the marine range of the CCC coho salmon ESU (Boehlert *et al.* 2008). The production has a potential to impact CCC coho salmon and their marine habitat. According to the proceedings of a recent workshop on the ecological effects of wave energy generation in the Pacific Northwest (Boehlert *et al.* 2008), the electromagnetic fields and noise associated with wave energy's underwater structures have the most potential of all wave energy efforts to negatively affect salmon. Salmon may avoid the structures due to electromagnetic fields and/or noise, and such avoidance could interfere with the migration of juveniles along the coast, and disrupt adult spawning migrations. The generation of electricity from waves reduces wave energy, changing nearshore wave processes and potentially altering benthic communities where juvenile salmon feed. The harnessing of wave energy may affect transport of zooplankton (Boehlert *et al.* 2008), and so could impact CCC coho salmon's food supply. The workshop participants acknowledged a high degree of uncertainty regarding the actual effects of wave energy generation on salmon, because little data documenting effects exists. Currently, wave energy poses a low threat to sub-adult and adult CCC coho salmon since no operational projects exist at this time. However, thorough research investigating potential adverse impacts on salmon and nearshore habitat should be required before future wave energy projects are permitted.

Management of coho prey and competitors

As coho grow in the ocean, their diet becomes more and more reliant on other fish species. Some concern has been raised over the possibility human harvest of salmon prey species may disrupt the aquatic ecosystem. If enough forage fish were harvested, there may not be enough prey items for higher level predators such as salmon and marine mammals. The effects of forage fish availability on salmonid predator behavior was recognized as a factor influencing the species when CCC coho were listed (69 FR 33102):

> *"The federally-managed fishery with the most potential to impact prey availability for CCC coho salmon is the coastal pelagic species (CPS) fishery. This group includes northern anchovy, market squid, Pacific bonito, Pacific saury, Pacific herring, Pacific sardine, Pacific (chub or blue) mackerel, and jack (Spanish) mackerel. Anchovy and sardine are known as important forage species for predators including salmon and steelhead (PFMC 2005; Quinn 2005). CPS are extremely important links in the marine food chain, and disruptions in their distribution and abundance may impact salmon population dynamics (PFMC 2003)."*

CPS harvest could indirectly affect salmon if it resulted in an inadequate amount of prey species for foraging salmon. The PFMC has adopted a conservative, risk-averse approach to management of CPS that reduces the likelihood of such negative effects. The need to "provide adequate forage for dependent species" is recognized as a goal and objective of the CPS FMP (PFMC 1998). A control rule is a simple formula used by the PFMC in evaluating allowable harvest levels for each of the CPS. The CPS control rules contain measures to prevent excessive harvest, including a continual reduction in the fishing rate if biomass declines. In addition, the control rule adopted for species with significant catch levels explicitly leaves thousands of tons of CPS biomass unharvested and available to predators. No ecosystem model currently exists to calculate the caloric needs of all predators in the ecosystem, so the amount of unharvested CPS biomass is an estimate which may be modified if new information becomes available. Ocean temperature is a factor in the control rule for Pacific sardine, in recognition of the effects of varying ocean conditions on fish production rates. Allowable harvest rates are automatically reduced in years of poor production.

The impacts of these fisheries on Federally-listed ESUs of salmon and steelhead were not evaluated by NMFS. However, due to the conservative control rules used to manage CPS and the preservation of a portion of the biomass for predator consumption, the CPS fishery poses a Low threat to CCC coho salmon recovery.

Transportation-related hazardous spills

Oil spills can have significant, catastrophic effects on aquatic ecosystems (National Research Council 2003), including acute mortality of fishes. The effects of crude oil on pink salmon were studied extensively since the Exxon Valdez oil spill in Prince William Sound, Alaska. Although some researchers found the oil spill affected growth rates of juvenile pink salmon (Moles and Rice 1983; Willette 1996), a review of all research on this topic showed the spill posed a low risk to this species (Brannon and Maki 1996). The relatively low depth of the oil entering the water column and the short time it remained in important natal gravel beds (Brannon and Maki 1996) may account for this effect. Oil spills appear to have the greatest effect on aquatic birds and marine mammals and benthic (bottom-dwelling aquatic) organisms (Boesch *et al.* 1987). The egg, alevin, and fry life stages of salmonids utilize benthic habitat in freshwater and brackish areas, and indeed toxic effects of crude oil were documented on the embryos and larvae of herring on oil-affected beaches (Hose *et al.* 1996). However, none of these salmonid life stages occur in nearshore marine areas or the open ocean, and direct effects of oil spills on salmon occurring in these areas is likely low. Indirect effects could include degradation of submerged aquatic vegetation such as kelp and eelgrass used by some juvenile salmonids in nearshore areas (Thorpe 1994). Disruption of the food web could also be detrimental to these fishes. Although in some circumstances crude oil may inhibit photosynthesis of natural phytoplankton communities, in inland areas of Nova Scotia, Canada, researchers determined that in open marine waters oil did not negatively affect photosynthesis (Gordon and Prouse 1973).

Introduction of non-native species

Some invasive species are detrimental to salmonids, particularly in the freshwater or estuarine environments. Conditions in the open ocean are less hospitable to many invasive species than estuaries[5], and non-marine fish do not tend to survive when released into marine waters. Of 22 fish species successfully introduced into marine waters, all of them came from marine waters, indicating introductions of freshwater or brackish fish species into marine waters were unsuccessful (Hare and Whitfield 2003). All but one of these 22 marine fish species was released from an aquarium or accidentally or intentionally stocked (Hare and Whitfield 2003). Since the sub-adult and adult life stages of CCC coho salmon occur in the ocean, introduction of non-native species is unlikely to affect them because the introduced species are unlikely to survive. Proposed national offshore aquaculture legislation would usually only allow marine culture of native species in Federal waters (NOAA 2007), making it is unlikely further stocking of potentially harmful non-native species will occur in marine waters off California. The threat to sub-adult and adult CCC coho salmon from introduction of additional non-native species was therefore rated low.

Recovery Strategy for CCC coho salmon in the eastern pacific

Marine factors will strongly influence CCC coho salmon recovery, but not solely due to obvious threats such as pollution or over-harvest. Rather, freshwater and marine impacts have reduced CCC coho salmon genetic and life history diversity, leaving the species less equipped to deal

[5] This has led to a requirement to replace ballast water in the ocean before entry into California state waters if the vessel intends to dock at any California port (State of California 2003).

with variable, unpredictable, and often hostile oceanic conditions. The best means to improve CCC coho salmon survival in the marine environment is to preserve and strengthen the existing genetic and life history diversity in the ESU, which will likely improve population abundance over the long-term. In addition, a better understanding of the ocean conditions each year is necessary so that managers could account for periods of poor ocean productivity and high marine mortality when estimating population abundance, harvest levels, and ultimately the progress toward ESU recovery.

Improve the quantity and/or quality of food resources

This is the top-ranked stressor for sub-adult and adult CCC coho salmon, because it results from unfavorable ocean conditions. As ocean conditions are not under human control in the time frame relevant to CCC coho salmon recovery (*e.g.*, 50 years), there are no recovery strategies which could "improve" them. However, strategies which improve genetic and life history diversity in the CCC coho salmon ESU would effectively equip the salmon to better survive an unpredictable ocean environment. Further research is necessary to discern possible connections between global climate change and cyclic patterns of ocean productivity. If a link is found, actions identified to alleviate or diminish global climate change may have value in moderating marine productivity patterns and improving salmon survival.

Increase genetic and life history diversity

Before anthropogenic stressors within the freshwater, estuarine, and marine environment depressed the CCC coho salmon population to a level requiring protection under the ESA, abundant, genetically diverse juvenile salmon entered the ocean each year over a wide range of dates, seasons, and ages from approximately 76 CCC coho salmon populations (Bjorkstedt *et al.* 2005). It is necessary to restore this lost diversity and life-history adaptation to allow CCC coho salmon populations to adapt and persist within the variable ocean environment. To foster greater life history and genetic diversity, recovery actions must be undertaken to improve the various habitats supportive of diverse life history strategies. Management and recovery strategies must adapt to address and conserve the full range of life history potential of a given populations, and hatchery practices must be managed to avoid degrading the genetic diversity of wild stocks.

Increase population size

Federal fisheries have been evaluated and appear to pose a low threat to CCC coho salmon, likely due to coho salmon harvest prohibitions in California and a low allowable CCC coho salmon bycatch mortality rate for Federally-managed ocean fisheries. The harvest prohibition extends into ocean waters managed by the state of California. All existing prohibitions and bycatch mortality rates should be retained or made more conservative. Salmonid fisheries in state waters have the potential to negatively impact the ESU and the extent of such impact has not been evaluated. Development of a Fishery Management Evaluation Plan (FMEP) is necessary for NMFS to determine what risk, if any, these fisheries pose to the CCC coho salmon ESU. The effects of drift mooching on CCC coho salmon should be minimized through educating anglers on the use of drift mooch methods that lessen the probability of gut hooking, as suggested in Grover *et al.* (2002).

CLIMATE CHANGE

"There are two key sources of greenhouse gas emissions: fossil fuels and forest change. Any successful climate strategy must address both."

Laurie Wayburn, Pacific Forest Trust

Overview: Climate Change and Pacific Salmon

The best available scientific information indicates the climate is warming, driven by the accumulation of greenhouse gasses (GHGs) in the atmosphere (IPCC 2007). The Intergovernmental Panel on Climate Change (IPCC) concluded in 2007, warming of the climate system is "unequivocal," based on observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. In a recent 2011, report on the Global Climate Change Impacts in the U.S. it was noted, "…salmon in the Northwest are under threat from a variety of human activities, but global warming is a growing source of stress." Salmon and steelhead from northern California to the Pacific Northwest are challenged by a global warming induced alteration of habitat conditions throughout their complex life cycles (Mantua and Francis 2004; Glick 2005; ISAB 2007; Martin and Glick 2008; Glick et al. 2009). Salmon productivity in the Pacific Northwest is sensitive to climate-related changes in stream, estuary, and ocean conditions. Specific characteristics of a population vulnerable to climate change include temperature requirements, reliance on snowpack, suitability of available habitat, and the genetic diversity of the ESU. These changes could alter freshwater habitat conditions and affect the recovery and survival of Pacific salmon stocks.

Climate shifts can affect fisheries, with profound socio-economic and ecological consequences (Osgood 2008). Climate change introduces additional, uncertain impacts to California's ecosystems and species, ranging from changes in the timing of bird migrations in spring, to large-scale movement of species, to increased frequency of forest fires. These are other impacts threaten to disrupt existing current natural communities, and may push many species toward extinction. In addition, climate change will interact with other stressors, such as habitat destruction, that are already threatening species and ecosystems, making it more difficult to achieve conservation goals.

In the Pacific Region, global climate change will lead to major alterations in freshwater environments. The biological implications of physical habitat changes on Pacific salmon are significant. Changes in timing/magnitude of flow and thermal regimes can affect the behavior and physiological responses of salmon during their freshwater life stages. Human activities can affect biophysical changes by imposing additional stressors such as unsustainable exploitation rates on vulnerable populations, and reduced water availability in stressed areas. Threat minimization actions may include adjustment of harvest rates and improved management of freshwater supplies.

Climate variability is an important factor controlling the distribution and abundance of organisms and determining the ecosystem structure. Changes in seasonal temperature regimes affect fish and wildlife (Quinn and Adams 1996; Schneider and Root 2002; Walther et al. 2002). These effects manifest themselves differently in different organisms, some undergo changes in the timing of spring activities, including earlier migration and breeding in birds, butterflies and amphibians, and flowering of plants (Walther *et al.* 2002). In response to warmer water temperatures, a number of fish species shift their distribution to deeper, cooler water, or move pole ward (Osgood 2008). Along with the increase in global temperatures, smaller scale geographic changes in temperature, wind, and precipitation are anticipated (CEPA 2006; Osgood 2008) . Freshwater streams (a key habitat for coho salmon), may experience increased frequencies of floods, droughts, lower summer flows and higher temperatures (Luers *et al*. 2006; Lindley *et al.* 2007; Schneider 2007; Osgood 2008). Estuarine and lagoon habitats are likely to experience a sea level rise and changes in entering stream flow (Scavia *et al.* 2002). The marine environment is important to sub-adult and adult salmonids and is likely to experience changes in temperature, circulation, chemistry, and food supplies (Brewer and Barry 2008; Turley 2008; O'Donnell *et al.* 2009). Because coho salmon depend on freshwater streams and oceans during different stages of their life history cycle, their populations are likely to be affected by many of the climate induced changes shown below in **Figure 1.**

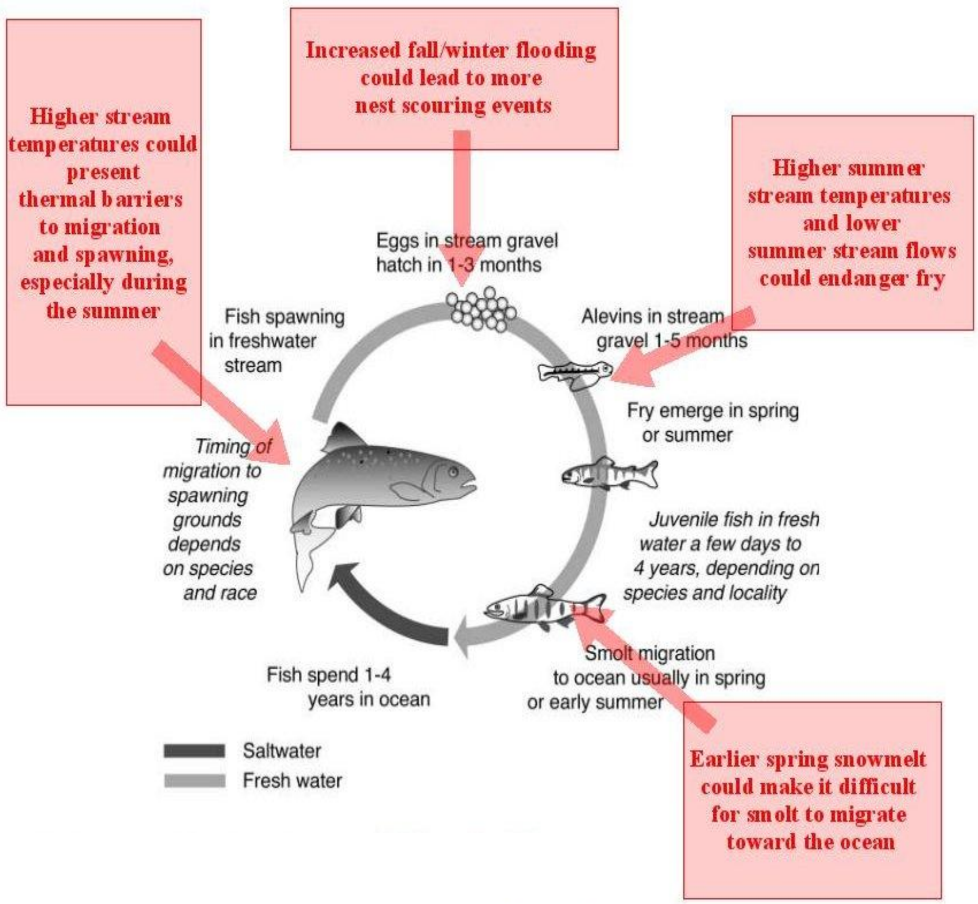

Figure 1: Salmon life history and the impacts of climate change.

Pacific salmon are affected by climate change across a hierarchy of coarse and fine spatial and temporal scales and each of these scales has distinct requirements in the development of policy that will cover climate change effects (Schindler *et al.* 2008). Efforts to minimize the impacts of climate change will take national and international actions beyond the scope of this recovery plan. Although at a local scale, identification and mitigation of impacts from global climate change can help alleviate its effects at (Osgood 2008). Effective management is important and adaptive strategies must consider climate variability. Nearly 75 percent of California's anadromous salmonids are vulnerable to climate change, and future climate change will affect the ability to influence their recovery in most or all of their watersheds (Moyle *et al.* 2008). The following sections describe key issues for consideration regarding impacts of climate change to coho salmon in the CCC ESU.

Climate Change in California

Recent studies call for improved legal and planning protection explicitly accounting for the impacts of climate change in California (Luers and Mastrandrea 2008; Mastrandrea and Luers 2012). A number of climate models evaluate climate change uncertainties and forecast future climate conditions at global and regional scales. Although, studies were conducted to examine the projected impacts of climate change on salmon habitat restoration, specifically Chinook salmon (Battin *et al.* 2007), few studies examine projected impacts to coho salmon.

Integral to understanding climate change effects on salmon is an understanding of how variations in salmon abundance corresponds to climate-related ecosystem regime shifts (Irvine and Fukuwaka 2011). The IPCC-AR4 global climate models (GCMs) do not resolve certain parameters at a fine enough resolution and/or sufficient detail to produce a true forecast, and higher resolution regional climate models (RCMs) are under development (King et al. 2011). Available model predictions show a range of relatively low to high impacts depending on which model is used and the greenhouse gas emissions scenario considered. Even the low impact predictions show changes in California's temperatures, rainfall, snowpack, vegetation, as well as potential changes in ocean conditions likely to have negative impacts on salmonid population numbers, distribution, and reproduction. It is likely, one of the greatest near-term climate challenges California will face are more intense and/or frequent extreme weather events (Meehl *et al.* 2007; Mastrandrea and Luers 2012).

Impacts on Freshwater Streams

Climate change impacts in California suggests average summer air temperatures will increase(Lindley et al. 2007). Heat waves are expected to occur more often, and temperatures peaks are likely to increase (Hayhoe *et al.* 2004). Total precipitation in California may decline and the frequency of critically dry years may increase (Lindley *et al.* 2007; Schneider 2007) which under unimpaired condition would result in decreased stream flow. Wildfires are expected to increase in frequency and magnitude, by as much as 55 percent under the medium emissions scenarios modeled (Luers *et al.* 2006). Vegetative cover may also change, with decreases in evergreen conifer forest and increases in grasslands and mixed evergreen forests. Impacts on forest productivity are less clear. Tree growth may increase under higher CO_2 emissions, but as temperatures increase, the risk of fires and pathogens also increases (CEPA 2006).

Air temperature

According to NOAA's 2008, State of the Climate Report and NASA's 2008, Surface Temperature Analysis, the average surface temperature has warmed about 1° F since the mid-1970's. The Earth's surface is currently warming at a rate of about 0.29° F/decade or 2.9° F/century, and the eight warmest years on record (since 1880) have all occurred since 2001, with the warmest year occurring in 2005. The range of surface water temperatures are likely to shift, resulting in higher high temperatures as well as higher low temperatures in streams. A recent study of the Rogue River basin in Oregon determined annual average temperatures are likely to increase from 1° to 3° F (0.5° to 1.6° C) by around 2040 and 4° to 8° F (2.2° to 4.4° C) by around 2080. Summer temperatures may increase 7° to 15° F (3.8° to 8.3° C) above baseline by 2080, while winter temperatures may increase 3° to 8° F (1.6° to 3.3° C) (Doppelt *et al.* 2008). Temperature changes throughout the NCCC Domains are likely to be similar. A study by Littell *et al.* (2009) suggested one third of the current habitat for listed Pacific salmon species may be unsuitable by the end of this century when temperature thresholds are exceeded.

Increasing air temperatures have the potential to limit the quality and availability of summer rearing habitat for juvenile CCC coho salmon by increasing water temperatures. Increases in fall and winter temperature regimes might shorten incubation and emergence for developing eggs, which Burger *et al*., (1985) predicted would lead to lower survival rates. Increases in summer temperatures will lead to thermal stress, decreased growth and affect survival of out migrating juveniles. For example, modeling results reported by Lindley *et al*. (2007) show, as warming increases, the geographic area experiencing mean August air temperature exceeding 25° C moves further into coastal drainages and closer to the Pacific Ocean. This increase in temperature will likely lead to an increase in stream temperatures in these areas, many of which are areas with focus populations. Many stream temperatures in the CCC coho salmon ESU are at or near the high temperature limit of coho salmon and increasing water temperatures may limit habitat suitability in an unknown number of stream reaches.

Precipitation

Annual precipitation could increase by up to 20% in northern California. Most precipitation will occur during the mid-winter months as intense rainfall events. These weather patterns will likely result in a higher numbers of landslides and greater and more severe floods (Doppelt *et al.* 2008; Luers *et al.* 2006). For the California's North Coast (including the northern part of the NCCC Domain), some models show large increases (75% to 200 %), while other models show decreases of 15 to 30% (Hayhoe 2004) in rainfall events. Increases in rainfall during the winter have the potential to increase the loss of salmon redds via streambed scour from more frequent high stream flows. Reductions in precipitation will likely lower flows in streams during the spring and summer, reducing the availability of flows to support smolt migration to the ocean as well as the availability of summer rearing habitat.

Sea Level Rise

According to the 2002, report released by the U.S. Global Climate Research Program (USGCRP), sea level is expected to rise exponentially over the next 100 years, and is estimated to rise 50-80 cm by the end of the 21st century. Additional research on sea level rise estimates the high end of possible sea level rise by 2200, to be 1.5 m to 3.5 m Vellinga *et al.* (2008). It is predicted that low lying coastal areas will eventually be inundated by seawater or periodically over-washed by waves and storm surges. Coastal wetlands will become increasingly brackish as seawater inundates freshwater wetlands. As a result, new brackish and freshwater wetland areas will be created (Pfeffer *et al.* 2008). Sea level rise will also alter estuarine habitat; which may provide increased opportunity for feeding and growth of salmon, but in some cases sea level rise will lead to the loss of estuarine habitat and a decreased potential for estuarine rearing.

In 2009, The Pacific Institute released a study on the impacts of sea-level rise on the California Coast. The study included a detailed analysis of the current population, infrastructure, and property at risk from projected sea-level rise if no actions are taken to protect the coast, and the cost of building structural measures to reduce that risk. Findings from the report conclude; (1) a sea-level rise of 1.4 m would flood approximately 150 square miles of land immediately adjacent to current wetlands, potentially creating new wetland habitat if those lands are protected from further development; (2) approximately 1,100 miles of new or modified coastal protection structures are needed on the Pacific Coast and San Francisco Bay to protect against coastal flooding, and (3) continued development in vulnerable areas will put additional areas at risk and raise protection costs (Heberger *et al*. 2009). San Francisco Bay is of particular concern, with increased risk to; existing wetlands, unprotected developed areas, and existing levees (Knowles 2010; Cloern *et al.* 2011).

NOAA is developing a strategic approach to integrate its coastal activities, with a specific focus on improving risk assessment and adaptation to climate change in coastal areas. Significant efforts are underway to improve the design, development, and delivery of effective climate services to NOAA and stakeholders through a National Climate Service as part of the National Climate Service Act of 2009. To aid understanding of the impacts of sea level rise on coastal communities, NOAA's Coastal Services Center provides a number of new mapping tools and techniques illustrating the impacts of sea level rise and coastal flooding. One of these tools is the *Sea-level Rise and Coastal Flooding Impacts Viewer* that; (1) displays future sea level rise, (2) provides simulations of sea level rise at local landmarks, (3) communicates the spatial uncertainty of mapped sea level rise, (4) models potential marsh migration, (5) overlays social and economic data on potential sea level rise and (6) examines how tidal flooding will become more frequent with sea level rise. These tools/techniques will increase understanding of the impacts of sea level rise on salmonid habitats and should aid in an adaptive management strategy for coho salmon recovery.

Wildfire

The frequency and magnitude of wildfires are expected to increase in California (Luers *et al.* 2006; Westerling and Bryant 2006). The link between fires and sediment delivery to streams is well known (Wells 1987; Spittler 2005). Fires increase the incidence of erosion by removing vegetative cover from steep slopes. Subsequent rainstorms produce debris flows that carry sediments to streams. Increases in stream sediment can reduce egg to emergence survival and stream invertebrate production, an important food source for rearing salmon and steelhead juveniles (Bjornn and Reiser 1991; Waters 1995).

Vegetative cover

Changes in vegetative cover can impact coho salmon habitat in California by reducing stream shade (thereby promoting higher stream temperatures), and changing the amount and characteristics of woody debris in streams. High quality habitat for most CCC coho salmon streams with extant populations is dependent upon the recruitment of large conifer trees to streams. Once trees fall into streams, their trunks and root balls provide hiding cover for salmonids. In streams, large conifer trees can also interact with stream flows and stream beds and banks, creating deep stream pools needed by salmonids to escape summer high water temperatures. These pools are essential for coho salmon feeding and rearing.

Impacts on the Marine Environment

Marine ecosystems will change as a result of global climate change; many of these changes will likely have deleterious effects on salmon growth and survival while at sea. There is uncertainty about the effects of changing climate on marine ecosystems given the degree of complexity and overlapping climatic shifts currently exist (*e.g.*, El Niño, La Niña, and Pacific Decadal Oscillation). El Niño events and periods of unfavorable ocean conditions threaten the survival of salmonid populations (at low abundance) due to degradation of estuarine habitats and reduced food availability (NMFS 1996). Scientists studying the impacts of global warming on the marine environment predict the coastal waters, estuaries, and lagoons of the West Coast of the will experience increased climate variability, changes in the timing and strength of the spring transition (onset of upwelling), warming and stratification, and changes in ocean circulation and chemistry (Scavia et al. 2002; Diffenbaugh et al. 2003; Feely 2004; Osgood 2008).

Current and projected changes in the North Pacific include: rising sea surface temperatures that increase the stratification of the upper ocean; changes in surface wind patterns impacting the timing and intensity of upwelling of nutrient-rich subsurface water; and increasing ocean acidification which will change plankton community compositions with bottom-up impacts on marine food webs (ISAB 2007). Ocean acidification also has the potential to dramatically change the phytoplankton community due to the likely loss of most calcareous shell-forming species such as pteropods. Recent surveys show ocean acidification is increasing in surface waters off the west coast, and particularly the northern California coast at a more rapid rate than previously estimated (Feely *et al.* 2008). Shifts in prey abundance, composition, and distribution are the indirect effects of these changes.

Direct effects to marine organisms include decreased growth rates due to ocean acidification and increased metabolic costs as sea surface temperatures increase (Portner and Knust 2007). Northwest salmon populations have fared best in periods having high precipitation, cool air and water temperatures, cool coastal ocean temperatures, and abundant north-to-south "upwelling" winds in spring and summer. If conditions are warmer, upwelling may be delayed, and salmon may encounter less food or may have to travel further from to find satisfactory habitat, increasing energy demands, and slowing growth and delaying maturity (ISAB 2007).

Climate Variability and the Spring Transition

Global warming may change the frequency and magnitude of natural climate events that affect the Pacific Ocean (Osgood 2008). For instance, intense winter storms may become more frequent and severe. El Niño events may occur more often and be more severe. The Pacific Decadal Oscillation (PDO) is expected to remain in in warmer ocean conditions in the California current, which may result in reduced marine productivity and salmonid numbers off the coast of California (Mantua *et al*. 1997; Osgood 2008). In addition, the plankton production fueled by coastal upwelling may become more variable than in the past, both in magnitude and timing. While the winds that drive upwelling are likely to increase in magnitude, greater ocean stratification may reduce their effect (Osgood 2008). The strongest upwelling conditions may also occur later in the year (Diffenbaugh *et al.* 2003; Osgood 2008). The length of the winter storm season may also affect coastal upwelling. For example, if the storm season decreases in length, upwelling may start earlier and last longer (Osgood 2008).

Weak early season upwelling can have serious consequences for the marine food web, affecting invertebrates, birds, and potentially other biota (Barth *et al.* 2007). Weak upwelling results in low plankton production early in the spring, when salmonid smolts are entering the ocean. Plankton is the base of the food web off the California Coast, and low levels of plankton reduce food levels throughout the coastal environment. Variations in coho salmon survival and growth in the ocean are similar to copepod (salmonid prey) biomass fluctuations, which are also linked to climate variations (Mackas *et al.* 2007). Salmon smolts entering California coastal waters could be impacted by reduced foraging opportunities, which could lead to lower marine survival rates during the critical first months of their ocean rearing phase (Osgood 2008).

Ocean Warming

Ocean warming has the potential to shift coho salmon ranges northward. Warming of the atmosphere is anticipated to warm the surface layers of the oceans, leading to increased stratification. Many species may move toward the Earth's poles, seeking waters meeting temperature preferences (Osgood 2008; Cheung *et al.* 2009). Salmonid distribution in the ocean is defined by thermal limits and salmonids may move their range in response to changes in temperatures and prey availability (Welch *et al.* 1998). The precise magnitude of species response to ocean warming is unknown, although recent modeling suggests high latitude regions are likely to experience the most species invasions, while local extinctions may be the most common in the tropics; Southern Ocean, North Atlantic, the Northeast Pacific Coast, and enclosed seas (such as the Mediterranean) (Cheung *et al.* 2009).

Ocean Circulation

The California Current brings prey items for salmonids south along the coast. This current, driven by the North Pacific subtropical gyre, starts near the northern tip of Vancouver Island, Canada, flows south near the coast of North America to southern Baja, Mexico (Osgood 2008). Coastal upwelling and the PDO influence both the strength of this current and the types of marine plankton it contains. If upwelling is weakened by climate change, and the PDO tends toward a warm condition, the quantity and quality of salmonid food supplies brought south by the current could decrease (Osgood 2008). However, if rising global temperatures increase the strength of coastal upwelling, cold water fish like salmonids may do well regardless of the PDO phase (Osgood 2008).

Ocean Acidification

Although impacts to coho salmon are difficult to predict, increases in ocean acidity are of concern because they may affect the ocean's food web. The increase in atmospheric CO_2 is changing the acidity of the oceans (Feely 2004; Turley 2008; O'Donnell *et al.* 2009). The world's oceans absorb CO_2 from the atmosphere, and rising levels of atmospheric CO_2 are increasing the amount of CO_2 in seawater (Feely 2004, Turley 2008). Chemical reactions fueled by CO_2 input are increasing ocean acidity at a rate matched only during ancient planet-wide extinction events (Sponberg 2007; Brewer and Barry 2008; Turley 2008). Shelled organisms in the ocean (some species of phytoplankton and zooplankton, and snails, urchins, clams, *etc*.) are likely to have difficulty maintaining and even forming shell material as CO_2 concentrations in the ocean increase (Feely 2004; The Royal Society 2005; Brewer and Barry 2008; O'Donnell et al. 2009). Under worst case scenarios, some shell forming organisms may experience serious impacts by the end of this century (The Royal Society 2005; Sponberg 2007; Turley 2008). In addition, increased CO_2 in the oceans is likely to impact the growth, egg and larval development, nutrient generation, photosynthesis, and other physiological processes of a wide range of ocean life (Turley 2008; O'Donnell *et al*. 2009). However, the magnitude and timing of these impacts on ocean ecosystems from these effects remains uncertain (Turley 2008).

Impacts on Estuarine Environments

Impacts to estuaries and lagoons from global climate change may have greater effects on CCC coho salmon in the northern portion of their range because coho salmon likely use northern estuaries for extended rearing. CCC coho salmon in the southern portion of their range are less dependent on estuaries for rearing. In southern lagoons, observations of coho salmon occurred in April and May (Smith 1990) suggesting these fish were smolts on their way to the ocean. In the northern portion of their range, coho salmon were observed in Albion River estuary from late May through late September, suggesting that some or all of these fish may spend more time rearing in this estuary prior to smolting (Maahs 1998).

Estuaries are likely to become increasingly vulnerable to eutrophication (excessive nutrient loading and subsequent depletion of oxygen) due to changes in precipitation and freshwater runoff patterns, temperatures, and sea level rise (Scavia *et al.* 2002). These changes may affect water residence time, dilution, vertical stratification, water temperature ranges, and salinity. For example, salinities in San Francisco Bay have already increased because increasing air temperatures have led to earlier snow melt in the Sierra's which reduces freshwater flows into Bay in spring. If this trend continues or strengthens, salinities in San Francisco Bay during the dry season will increase, contributing additional stress to an already altered and highly degraded ecosystem (Scavia *et al.* 2002). If these impacts occur elsewhere, the result may lead to reduced food supplies for coho salmon using estuaries for rearing before going to sea.

Scenarios for Recovery Planning

As described above, climate change is likely to further degrade salmonid habitats. Scientists have developed scenarios, based on reasonable assumptions, using the most up to date scientific data available. These scenarios describe how climate change may affect various aspects of the environment. NMFS has relied mainly on the scenario analysis conducted by the California Environmental Protection Agency (CEPA 2006)[6] to evaluate the impacts of climate change on CCC coho salmon and their habitats. CEPA considered three CO_2 emissions scenarios: high emissions, medium high emissions, and lower emissions. Details of the environmental, population, economic, resource use, and technological assumptions behind each scenario are described in CEPA (2006). These scenarios are among the most accurate predictions of how California will be affected by climate change. It is important to note the scenarios are rough estimates of changes by the end of this century using parameters such as temperature, rainfall, vegetation, *etc*., at a statewide, West Coast, and eco-region scale.

Modeling impacts of climate change is difficult to predict over shorter time scales (Cox and Stephenson 2007). Nonetheless, progress is being made to improve predictions from climate change at shorter time intervals, at the global and regional scales (Smith and Murphy 2007). Unfortunately, predicting impacts on local geographic areas in short time frames, such as the first decade of CCC coho salmon recovery plan implementation, still remains difficult. It is reasonable to assume, given California's complex topography and variety of micro climates, variation within the CCC coho salmon ESU to impacts from climate change[7] are likely.

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[6] These scenarios are being re-evaluated by CEPA based on current information (Franco 2008). When new scenario information becomes available, NMFS will incorporate it into this recovery plan.

[7] For example, a recent article in the Santa Rosa Press Democrat reported the incidence of high temperatures in the Ukiah Valley (which includes a large portion of the mainstem Russian River) has decreased during the last 50 years, while the incidence of high temperatures in Napa Valley have increased (Porter 2008). This information suggests climate change may actually be decreasing the incidence of high temperatures in the vicinity of the Russian River. Due to the absence of peer reviewed climate change models linking global temperature changes to the Russian River watershed, we cannot project cooler temperatures in the Ukiah Valley forward into the future without developing a series of additional scenarios. Ukiah Valley temperatures could continue to drop at the same rate or a different rate, stabilize at some point in time, stabilize and then begin to go up, *etc*.

NMFS considered potential effects of the three scenarios developed by the CEPA (2006) on future habitat conditions and threats for CCC coho salmon in the freshwater environment[8]. We used many of the same habitat attributes, indicators, and threats used to evaluate the current and future condition of coho salmon habitat in this plan. In many cases, scenarios available for California are not specific enough (*i.e.*, watershed scaled) to project changes in habitat indicators or threats with reasonable certainty. Nonetheless, we conclude from the information provided by CEPA (2006) there is a higher probability of greater negative changes to coho salmon habitat under higher CO_2 emissions.

In the following sections we have focused on attributes, indicators, and threats most likely affected by climate change. For example, we considered how passage flows (all life stages), passage at river mouths (adults and smolts) and base flows are impacted by droughts as well as water diversions, impoundments and fire and fuel management. For the threat of increased magnitude and frequency of storms and flooding, we considered how redd scour and pool habitat (shelter, LWD, *etc*.) would be affected. Finally, we also considered the impacts on temperature, riparian species composition, size, and canopy cover, as well as disease, predation, and competition.

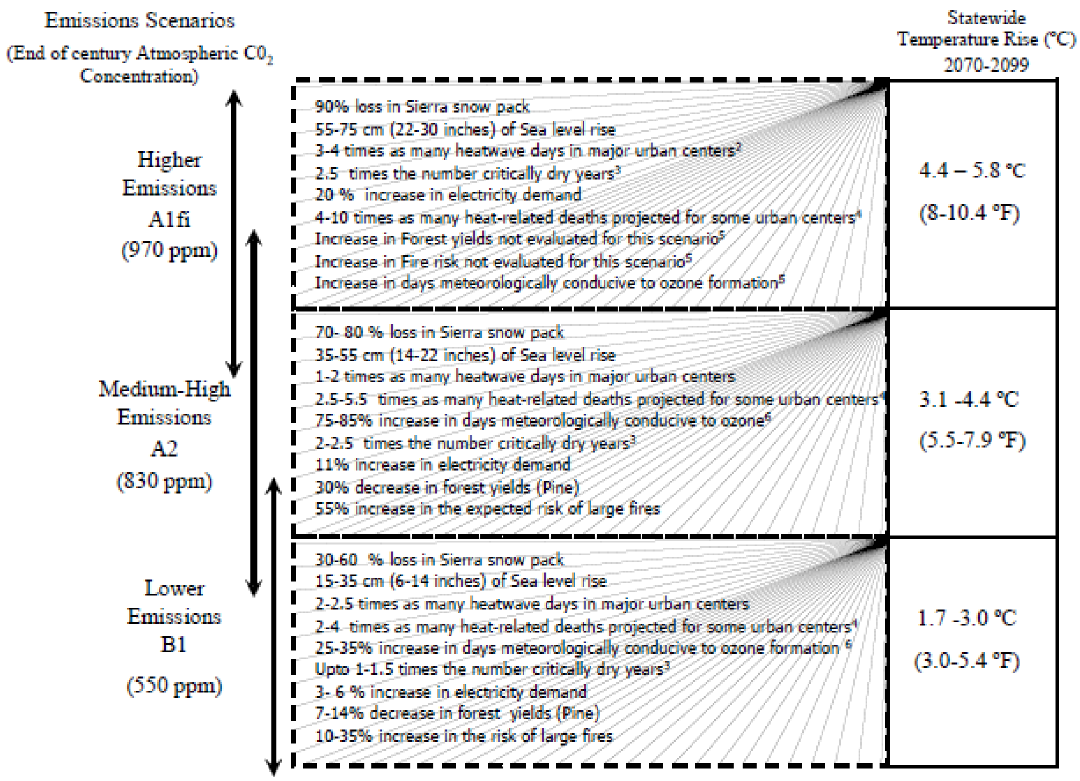
Other habitat attributes were not addressed for CCC coho salmon because: (1) they can be easily linked to changes in the above attributes, or (2) we are unable to make reasonable predictions regarding the impacts of global climate change on these attributes, indicators, or threats based on the available information. For example, agricultural practices, identified as a threat for some populations in the Recovery Plan, can result in sedimentation and turbidity. It is unclear how farmers will respond to increased droughts and changes in vegetation growth patterns, and what resulting impacts on sediment and turbidity would be. Farmers may respond by (1)

[8] We focused on the freshwater environment because more is known about habitat conditions, underlying processes that create and maintain habitat, and there is more information about what may happen due to climate change. Estuarine habitat was not analyzed because available information suggests CCC coho in the southern portion of their range use these habitats for a relatively brief interval as transitional habitat between fresh and saltwater rather than for protracted rearing as do steelhead. However, more studies are necessary from estuaries in the northern portion of the range to determine if this trend holds true throughout the ESU or if it is in response to available habitat conditions.

stopping farming and allowing the land to go fallow, (2) stopping farming and selling the land for residential or urban development, (3) changing or modifying crop rotations, (4) building additional reservoirs and/or, (5) conserving water resources, *etc*.

Emission and Temperature Scenario Overview

The CEPA model consisted of three emissions scenarios; high (970 ppm), medium-high (830 ppm), and low emissions (550 ppm) and predicted condition outcomes (CEPA 2006) (Figure 2). Modeling results indicated minor changes among the environmental impacts for different emissions scenarios between the years 2035-2050. After 2050, the environmental impacts of high emissions scenarios begin to show marked differences from lower emissions scenarios (CEPA 2006; IPCC 2007; Burgett 2009). Emissions and air temperature scenarios from Lindley *et al*. (2007) were used to access the impacts. The Lindley *et al*. (2007) modeling effort focused on Central Valley salmonids, however their analysis was illustrative because their temperature scenario maps included projections for coastal areas used by CCC coho salmon (Figure 3). NMFS recognizes such projections do not provide the level of precision and accuracy needed to determine when air temperatures may reach certain levels in particular streams.



1. Impacts presented relative to 1961–1990.
2. Los Angeles, San Bernardino, San Francisco, Sacramento, and Fresno.
3. Measures for the San Joaquin and Sacramento basins.
4. For Los Angeles, Riverside, and Sacramento.
5. Impacts expected to be more severe as temperatures rise. However, higher temperature scenarios were not assessed for the project.
6. Formation in Los Angeles and the San Joaquin Valley.

Figure 2: Emission scenarios for California for a 30-year period, identifying increased threats associated with average annual air temperature (Lindley *et al.* 2007).

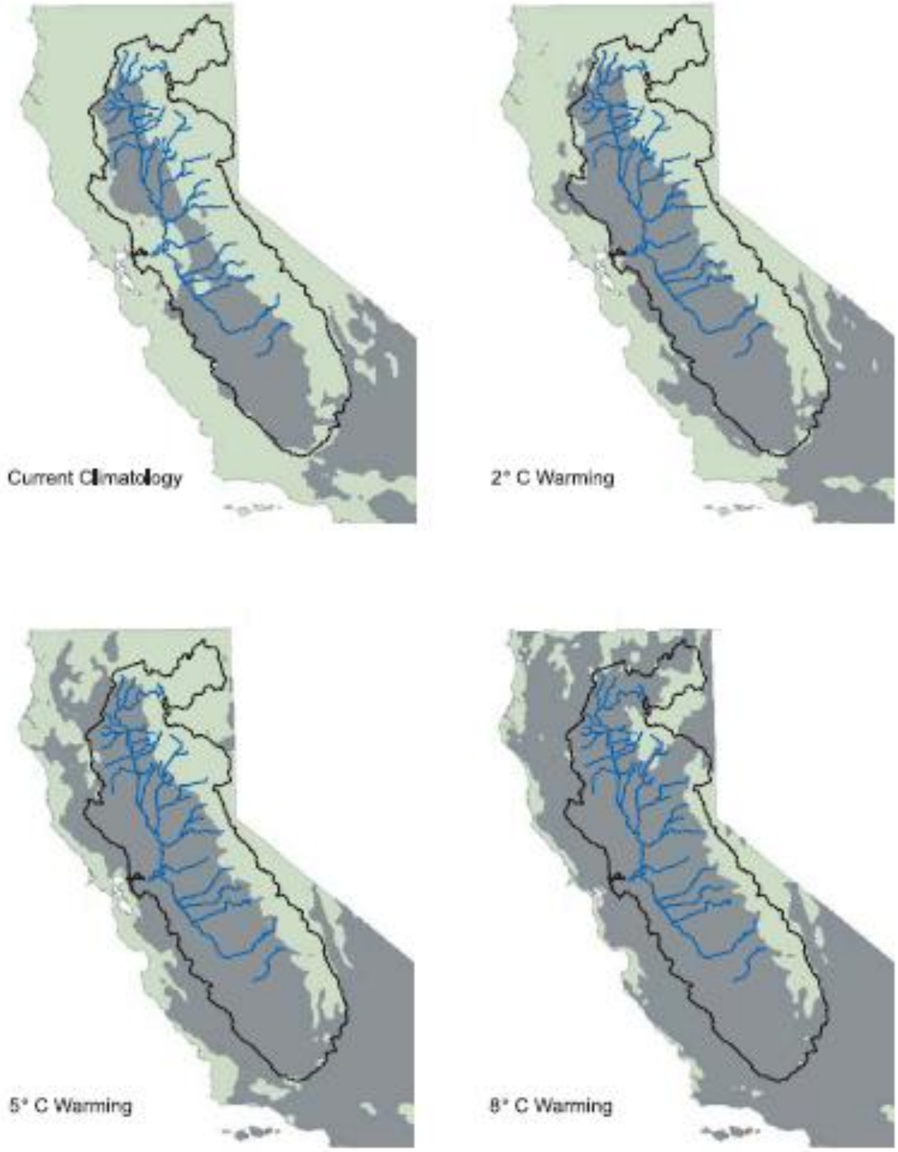


Figure 3: Geographic areas in California experiencing a mean August air temperature >25 °C by year 2100 under different warming scenarios (Lindley *et al.* 2007).

High Emissions Scenario

Under the high emissions scenario, statewide average annual temperature is expected to rise between 4.4° and 5.8° C (Luers *et al.* 2006). The temperature rise is predicted to cause loss of nearly all of the Sierra snowpack (the CCC ESU is not affected by Sierra snowpack), increase in droughts and heat waves, increased fire risk, and changes in vegetation. The North Coast is expected to experience similar effects, although the model appears to differ regarding the incidence of large storms.

Droughts

Natural climate variations such as droughts can dramatically affect habitat conditions for CCC coho salmon. In the high emission scenario, model output from droughts in California, show 2.5 times more critically dry years are possible than have occurred over the recent period (Luers *et al.* 2006). On the North Coast, various modeling efforts have produced varying results for rainfall patterns. Variations in rainfall patterns may produce various effects on CCC coho salmon and their habitat. Nonetheless, due to the uncertainties associated with rainfall on the North Coast, NMFS assumed a "worst case" reduction in precipitation similar to the statewide prediction (*i.e.*, a 2.5 increase in the number of critically dry years). Based on the overall threats ratings for droughts, and water diversions and impoundments outlined in the plan, it is reasonable to assume increases in the level of droughts will dramatically reduce total available freshwater habitat and alter the remaining habitat.

Reductions in freshwater habitat are expected to reduce freshwater survival for CCC coho across their range. The greatest impacts are expected to occur in the Coastal and Santa Cruz Mountains Diversity Strata, where droughts are rated as very high threats in many of the targeted watersheds with focus populations. In these diversity strata, NMFS anticipates severe reductions or elimination of summer rearing habitat due to limited or depleted summer base flows, leading to increased instream temperatures or dewatering. Not only are CCC coho salmon affected during baseflow conditions under this scenario, but migration flows for adults are expected to be severely curtailed, delayed, and/or absent in some years. Adults may experience increased energetic costs during migration because of low flow impediments that are more prevalent during drought than normal water years. NMFS anticipates the greatest negative impacts will be during smolt outmigration because spring flows will decline sooner under drought conditions, reducing migration opportunities. In Northern Coastal watersheds, NMFS expects, under this scenario impacts from increased droughts would be less severe, although some watersheds will exhibit large reductions in the availability of summer rearing habitat due to lack of stream flows.

Key habitat attributes at risk from climate effects were also analyzed. The current condition indicators most likely to worsen due to climate change for each watershed are discussed below. NMFS assumed vulnerability of individual CCC coho salmon populations to increased drought frequency mostly relates to the current condition of specific habitat indicators. For example, San Lorenzo River, Gazos Creek, Pescadero Creeks, Russian River, Gualala River, and Navarro Rivers are likely to be the most vulnerable to reduced adult passage flows due to drought conditions under any emissions scenario.

Fires

Increases in fire frequency or areas affected by fire were not modeled by CEPA (2006) for this scenario; however, the prevalence of fire is expected to increase under higher emission scenarios. NMFS assumes fire frequency and areas affected will be greater than the modeled results for the medium-high emissions scenario described below. Impacts from increased fires are likely to include additional sedimentation to streams. Sedimentation may fill in pools in some areas, decreasing or eliminating the value of in stream restoration efforts to increase the amount of complex habitats available for salmonids.

Storms and Flooding

A worse-case high emissions scenario was assumed which predicts storms and flooding will dramatically increase during the winter months. Increased frequency and magnitude of flows from storms and flooding are likely to increase redd scour and may affect the quantity and quality of spawning gravels, and the amount and quality of pool habitat in many watersheds. Winter rearing populations, without access to velocity refugia, are vulnerable due to increases in flood flows.

In addition, the compounding effects of roads are also a high threat for all targeted populations in the ESU. Therefore, increased magnitudes and frequency of storm and flood events are likely to cause greater sediment output and turbidity due to existing roads. Consequently, these heightened events will overwhelm the drainage capacity of many road crossings, especially under the high emission scenario. Populations most vulnerable to these impacts include the Russian River and San Lorenzo River. Based on the information in the plan, coho populations in the Santa Cruz Mountains Diversity Stratum are the most vulnerable to storms and flooding events.

Temperature

Fish, including salmonids, are sensitive to water temperature changes. Previous sections of this plan explain coho salmon temperature requirements how current stream temperature conditions in the ESU were evaluated. NMFS used, in part, the current condition ratings for temperature to identify populations most susceptible to increases in water temperatures due to climate change. Under the high emissions scenario, a 4.4° C to 5.8° C warming of statewide average annual air temperature was assumed. Figure 4 from Lindley *et al.* (2007) shows areas that may experience August mean air temperature over 25° C. These higher air temperatures are likely to cause an increase in water stream temperatures, unless other factors, such as adequate quantities of cold groundwater input are present. Figure 4 also illustrates where CCC coho salmon may be vulnerable to air temperature increases. According to this map, the interior watershed areas used by the Navarro River, Big River, Garcia River, Gualala River, and Russian River populations may experience high air and water temperatures that dramatically reduce the amount of stream habitat available to coho juveniles during the summers. This impact appears most pronounced in the Russian River, where most of the watershed, except for tributaries near the coast, may experience high temperatures. However, and as noted above, the Ukiah Valley (which contains much of the interior Russian River watershed) currently appears to be cooling, which adds to the degree of uncertainty regarding the impacts of the high temperature scenario for the coast of California.

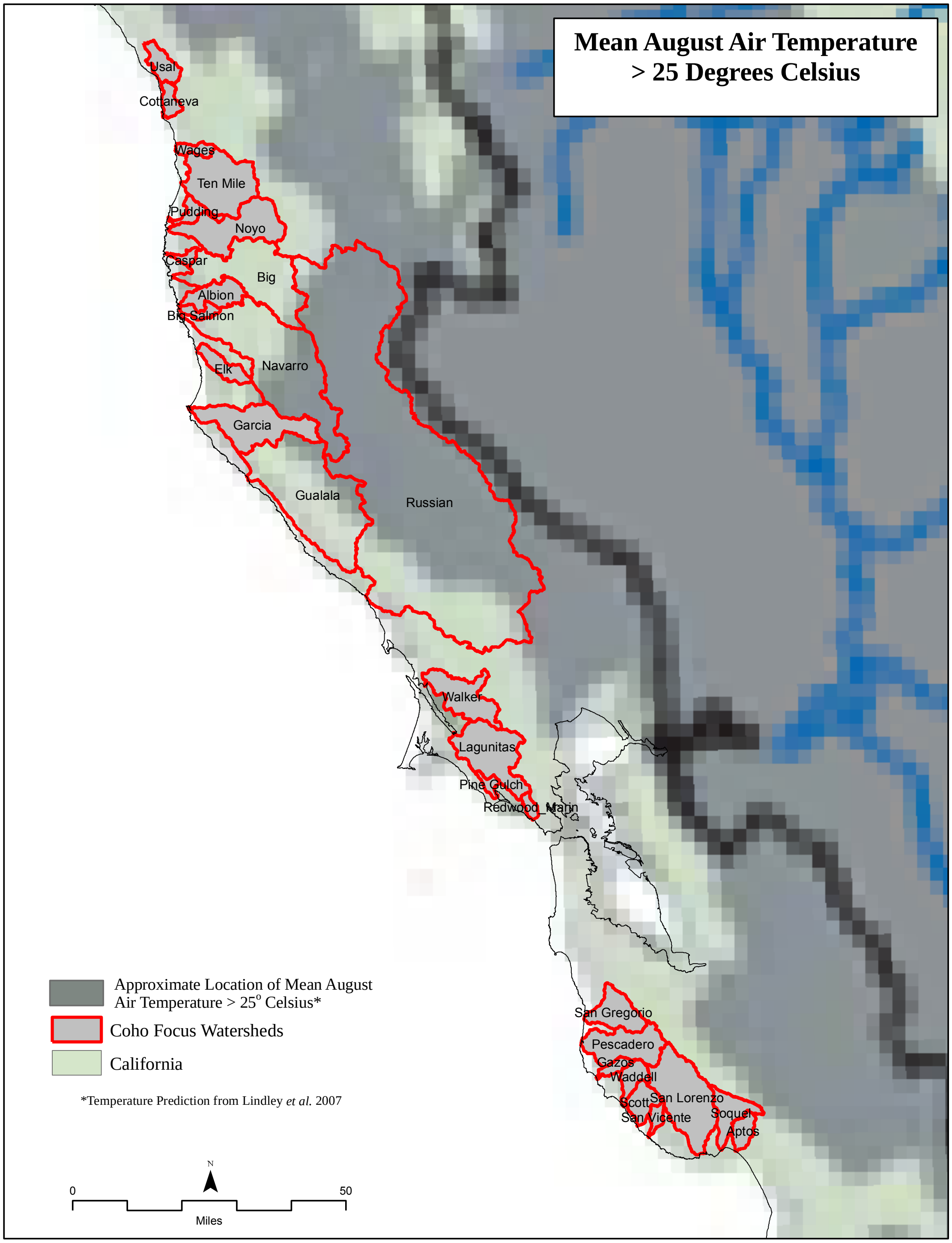


Figure 4: Approximate location of mean August air temperatures greater than 25°C in relation to coho salmon focus populations, under a 5° C warming scenario (modified from (Lindley *et al.* 2007).

Riparian Species Composition, Size, and Canopy Cover

Vegetation near streams provides shade for cooler water temperatures, bank stability, large woody debris to stream channels, and habitat for salmonids prey. Climate change is likely to affect vegetation in California, favoring some vegetation types over others, based on potential changes to air temperatures and rainfall. Scenarios developed for CEPA (2006) concerning vegetation did not include a high emissions scenario. NMFS assumed changes in vegetative cover will be more pronounced than those described under the moderate high emissions scenario. There is uncertainty regarding current information on potential changes in forest productivity. Some studies indicate the potential for increased forest productivity, while others suggest a decline (CEPA 2006). Due to this uncertainty, scenarios for tree size and canopy cover are not included in this discussion[9].

Disease, Predation, and Competition

CEPA (2006) scenarios did not include disease, predation, or competition information directly related to salmonids. However, CEPA and others (Harvell *et al.* 2002) noted that increasing instream temperatures can allow pathogens to spread into areas where they are currently absent because temperature limits their range. In some cases, increasing temperatures may limit or restrict diseases (Harvell *et al.* 2002). However, increasing temperatures likely have a greater potential to increase the susceptibility of coho salmon to disease (coho salmon prefer cooler water temperatures). Given the potential for increasing droughts, disease outbreaks will likely increase if coho salmon are crowded together in areas of low stream flow and higher water temperatures.

[9]Linking tree productivity scenarios to changes in instream habitat will be difficult in this and other scenario exercises. For example, if forest productivity decreases, LWD sizes might decline over time. However, droughts and higher temperatures are likely to raise vulnerability to pests and pathogens, which could increase tree death and thus the contribution of LWD to streams.

Moderate High Emissions Scenario

Under the moderate-high emissions scenario, statewide average annual temperature is expected to rise between 3.1° C and 4.4° C (Luers *et al*. 2006). Statewide, impacts to California's climate are similar to the high emission scenarios and include loss of most of the Sierra snowpack, increase in droughts and heat waves, increase in fire risk, and changes in vegetation.

Droughts

Statewide, there is a 2-2.5 times greater probability of a critical dry year during the medium-high emission scenario (Luers *et al*. 2006). Impacts to CCC coho salmon and their freshwater habitat are likely to be similar to those described in the high emissions scenario.

Fires

Fires are also expected to increase under this scenario. The model predicts an overall 55% increase in the risk of large fires in California (Luers *et al*. 2006). In particular, Northern California modeling results predict an overall 90% increased risk of fires (Westerling and Bryant 2006). By the end of the century the risk of fire occurrences will likely increase, even in some coastal areas that currently experience fog and cool temperatures in the summers (Westerling and Bryant 2006). Similar to the high emission scenario, impacts from increased fires are likely to include additional sedimentation in streams potentially decreasing or eliminating the amount of complex habitat for coho salmon.

Storms and Flooding

Scenarios for increased magnitudes and frequencies for storm and flood events were not modeled for Northern California. A worse-case moderate-high emissions scenario was assumed where storms and flooding dramatically increase during the winter months. Impacts under this scenario are likely similar to those expected for the high emissions scenario, although the magnitude and frequency of storm flows may be less. Similar to the high-emission scenarios, coho populations in the Santa Cruz Mountains Diversity Stratum are the most vulnerable to storms and flooding events.

Temperature

As with the high emissions scenario, NMFS used the 5° C warming-map from Lindley *et al.* (2007), which shows areas that may experience August mean air temperature over 25° C (Figure 4) as a predictor of potential change in the ESU. The higher air temperatures are likely to increase stream temperatures (unless other factors, such as cold groundwater input, are present). Impacts to coho salmon and their freshwater habitats are likely to be similar, while somewhat less than, the impacts described under the high emissions scenario.

Riparian Species Composition, Size, and Canopy Cover

Climate change will likely affect vegetation patterns in California by favoring some vegetation types over others based on potential changes to air temperatures and rainfall. Based on the maps produced by CEPA for the California moderate high emissions scenario for tree species distribution (Lenihan *et al.* 2006), NMFS inferred mixed evergreen forest (Douglas-fir, tanoak, madrone, oak) may expand toward the coast and into areas currently dominated by evergreen conifer forest (coastal redwoods) by the end of the century. Increases in tanoak, a hardwood, in coastal riparian areas could ultimately decrease the value of future LWD (although this would likely take a considerable time to actually occur due to the longevity of redwood). Streams in riparian forests composed of hardwood species generally have less LWD volume than streams in conifer riparian forests (Gurnell 2003). LWD is an important component of pool formation in some streams, and large decreases in conifer LWD could reduce the number, depths, and longevity of pools in IP-km, ultimately reducing the amount of high quality rearing and over wintering habitat available for CCC coho salmon.

Disease, Predation, and Competition

Similar to the high emission scenario, CEPA scenarios do not include disease, predation, or competition information regarding salmonids. NMFS assumed increasing temperatures may increase exposure risk, given the potential for increasing frequency of droughts. If drought frequency increases, disease outbreaks will likely increase if coho salmon are crowded together in smaller amounts of wetted habitats as well as increased competition for food and rearing resources. Potential impacts are expected to be somewhat less in severity for the moderate high emissions scenario than in the high emissions scenario.

Low Emissions Scenario

Under a low emissions scenario, statewide average annual temperature is expected to rise between 1.7° C and 3.0° C (Luers *et al.* 2006). Statewide, one-third to one-half of the Sierra snowpack is expected to be lost (although this will have little impact to the CCC ESU); there will be an increase in droughts and heat waves, increase fire risk, and changes in vegetation type and composition. Changes for the North Coast are likely to be similar, although model results appear to differ regarding the incidence of large storms, as described above in the high scenario.

Droughts

Statewide the probability of critically dry years increases 1-1.5 times for the low emission scenario (Luers *et al.* 2006). Due to the uncertainties associated with rainfall on the North Coast, a worse-case reduction in precipitation (similar to the statewide prediction) was assumed; yielding a 1-1.5 increase in the number of critically dry years. In comparison to the high and medium emission scenarios, CCC coho salmon and their freshwater habitat are less likely to be adversely affected. Impacts will most likely affect the Coastal and Santa Cruz Mountains Diversity Strata under this scenario

Fires

Fires are expected to increase under this scenario with an overall 10% to 35% increase in the risk of large fires in California (Luers *et al.* 2006). For northern California, modeling results predicted an overall 40% increase in fire risk (Westerling and Bryant 2006). By the end of the century, based upon the fire risk maps provided by Westerling and Bryant (2006), the risk of fire near the coast may increase, although the magnitude of the increase appears limited. Impacts from increased fires are likely to include additional sedimentation in streams and increased turbidity. Sedimentation may fill in pools in some areas, decreasing or eliminating the value of instream restoration efforts to increase the amount of complex habitats available.

Storms and Flooding

Scenarios for increases in storms and flooding are not available because variation in model results for climate change impacts on precipitation in Northern California. For storms and flooding, a worse case lower emissions scenario was assumed where storms and flooding increase during the winter months. Based on threat rankings, Santa Cruz Mountain Diversity Stratum coho populations are likely, the most vulnerable to storms and flooding. Impacts under this scenario are likely to be less than those expected for the moderate high and medium emissions scenarios described above.

Temperature

Current condition ratings for temperature were used to identify populations susceptible to increases in water temperatures from climate change. Under low emissions scenario, a 1.7° to 3.0° C warming of statewide average annual air temperature was assumed likely to occur. The 2° C warming-map from Lindley *et al.* (2007), was used to predict potential changes to the CCC ESU (Figure 4). According to results presented on the map, the interior Russian River and Navarro River are the areas affected by air temperature increases. However, fewer subbasins within these watersheds are more affected than in the other emission scenarios.

Riparian Species Composition, Size, and Canopy cover

See discussion in moderate high emissions scenario. These potential impacts are likely to be less than those in the moderate high emissions and high emissions scenarios.

Disease, Predation, and Competition

See discussion in the moderate high emissions scenario. These potential impacts are likely to be less than those in the moderate high emissions and high emissions scenarios.

Most Vulnerable Populations

Using the best available scientific data and information compiled in the Plan, NMFS found the following populations to be a high or very high risk of threat from climate: Pudding, Big River, Navarro River, Russian River, Lagunitas Creek, San Lorenzo River and Soquel Creek.

Recovery Planning and Climate Change

The effects of climate variability on Pacific salmon abundance are uncertain because historical records are short and abundance estimates are complicated by commercial harvesting and habitat alternation. We cannot currently predict the precise magnitude, timing, and location of impacts from climate change on coho salmon populations or their habitat. Some CCC coho salmon populations are likely to be more vulnerable than others, and these populations are identified in the plan. Monitoring and evaluating changes across the CCC coho salmon ESU on a long-term scale is critical for devising better scenarios and adjusting recovery strategies.

Survival and recovery of CCC coho salmon under any climate change scenario depends on securing and expanding viable CCC coho salmon populations. Viable populations have a better chance of surviving loss of habitat, and can likely persist in the advent of range contraction, if habitat conditions in inland and at the southern extent of the range become more tenuous. Major differences in environmental impacts of high, medium, and low emissions scenarios may not become evident until about mid-century.

A number of federal, state and local adaptive/action plans have been developed for the U.S. and the State of California. For example, in 2010, NOAA released the *Adapting to Climate Change: A Planning Guide for State Coastal Managers* document and sea level inundation toolkit, to help U.S. state and territorial (states) coastal managers develop and implement adaptation plans to reduce the risks associated with climate change impacts (NOAA 2010). In 2008, under the Executive Order S-13-08 signed by the Governor of California, the State of California began to develop state-wide and local climate adaption/action plans that focus on topics such as: the economy, ecosystem/natural resources, human health, infrastructure, society and water resources. In 2009, the California Natural Resources Agency released the *California Climate Adaptation Strategy* document. Many of the issues discussed in this document address the impacts of sea level rise, drought, flooding, air temperature and precipitation on the topics mentioned above. In the NCCC Recovery Domain, climate adaption/action plans have been developed for the San Francisco Bay (SPUR 2011); the City of San Rafael (City of San Rafael Climate Change Action Plan (City of San Rafael 2009)); and the City of Berkeley (Berkeley Climate Action Plan (City of Berkeley 2009)). At present, the state of California is the only state in U.S. to develop a cap-and-trade program on GHGs. The program is a central element of California's Global Warming Solutions Act (AB 32) and covers major sources of GHG emissions in the State such as refineries, power plants, industrial facilities, and transportation fuels. Implementation of the cap-and-trade program will be an essential component in minimizing the impacts describe above to CCC coho salmon ESU.

In the future, climate change will likely surpass habitat loss as the primary threat to the conservation of most salmonid species (Thomas *et al.* 2004). Climate change will continue to pose a continued threat to salmonids in the foreseeable future throughout the Pacific Northwest (Battin *et al.* 2007). Overall, climate change is believed to represent a growing threat to CCC coho ESU. Understanding and successfully adapting to these changes will require additional knowledge of the likely consequences and the types of actions required.

Recommended Actions and Options for Adaptive Management:

Information from federal, state, private, and public entities was used to compile specific recommended actions and options for management for climate change which include but are not limited to:

- 2010 Interagency Climate Change Adaptation Task Force Progress Report to the President;
- 2010 National Park Service's Climate Change Response Strategy;
- 2010 U.S. Fish and Wildlife Service's Strategic Plan for Responding to Accelerating Climate Change;
- 2009 U.S. Global Climate Research Program Change (USGCRP) Climate Change Impacts in the United States Report;
- 2008 U.S. Forest Service's Strategic Framework for Responding to Climate Change; and
- 2007 IPCC Fourth Assessment Report Summary.

Although options for resource managers to minimize the harm to aquatic and terrestrial resources from climate change are limited, there are several management options that can help protect and recovery coho salmon.

Stewardship and Outreach

- Actively engage stakeholders and the public regarding climate change impacts to coho salmon recovery. The website **http://www.ipcc.ch** summarizes of climate change issues for North America and the suite of actions from the IPCC to be considered for ecosystem and human health.
- Work with staff, and other entities to encourage and incorporate climate change vulnerability assessments and climate change scenarios in consultations, permitting, and restoration projects to access the impacts on coho salmon.

Research and Monitoring

- Expand research and monitoring to improve climate change predictions and effects to salmon recovery. For example, investing in marine climate change research will facilitate improved decision making by resource managers and society. Improved predictions will help ensure the future utility, protection, and enjoyment of coastal and marine ecosystems. See Appendix K for specific research needs and strategies.
- Use existing models, tools and techniques (*i.e.*, Regional Climate System Model, Sea level Rise and Coastal Flooding Impacts Viewer) to improve accuracy of ecological forecasting in order to anticipate and offset impacts related to global human population growth and development, to salmon viability and habitat.
- Support development and application of GCMs and RCMs to support research and monitoring activities listed in the recovery plan.

- Model stream flows (ranging from critical dry to wet years) to identify, prioritize, and protect areas of cool water input vulnerable to ongoing and future increases in diversion.

Protection, Minimization, Mitigation and Restoration

- Minimize increases in water temperatures by maintaining well-shaded riparian areas.
- Ensure road drainages are disconnected from the stream network to reduce the effects of discharge peaks during intense rain events.
- Protect springs and large groundwater seeps from development and water diversion. Subterranean water sources that provide cool water inflow will be increasing important in watersheds with ongoing water diversions.
- Ensure fish have access to seasonal habitats such as off-channel wintering areas and summer thermal refugia.
- Promote and maintain forest stand structures promoting fog drip.
- Promote and support policies that (a) explicitly maintain instream flow by limiting water withdrawals, (b) enhance flood-plain connectivity by opening historically flooded areas where possible, (c) remove anthropogenic barriers for fish passage, and (d) expand riparian forests to increase habitat resilience.
- Encourage and increase voluntary carbon accounting in the forest sector through certification with the California Climate Action Registry and their Forest Protocols.
- Promote land management practices that enhance carbon storage. For example, promote biological carbon sequestration best management practices (BMPs). Focus on forestlands to store carbon and reduce greenhouse gasses (See also Logging and Wood Harvesting Strategies) by working with appropriate entities to prevent forest loss, conserve and manage for older forest, and restore forests where converted to other land uses.

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