CENTRAL CALIFORNIA COAST COHO SALMON
Oncorhynchus kisutch (Walbaum)

Critical Concern. Status Score = 1.3 out of 5.0. Most or all populations in small coastal streams will be extirpated from California in the next 50 years without increased intervention and protection of watersheds.

Description: Central California Coast coho salmon are morphologically similar to coho salmon in the Southern Oregon-Northern California Coast (SONCC) Evolutionary Significant Unit (ESU). Coho in the two ESUs are so similar that they can only be distinguished by genetic differences (Gilbert-Horvath et al. 2016).

Taxonomic Relationships: California Central Coast (CCC) coho salmon are highly adapted to local environments at the southern end of coho distribution. Bucklin et al. (2007) showed that each population in every stream sampled was distinctive and most closely related to populations in nearby streams. Populations demonstrate concordance between their geographic and genetic differences, with adjacent populations from the Mendocino coast to the Golden Gate generally appearing more closely related to each other (Gilbert-Horvath et al. 2016). Populations further south did not fit this pattern (Good et al. 2005), presumably because movement among these basins is more pervasive than among ones further north; this problem has been enhanced by extirpation of populations from streams between Santa Cruz and Marin counties. There has also been some dispersal by humans through stocking, such as the movement of coho from Scott Creek to Waddell and Gazos creeks (Santa Cruz Co.) (Smith 2015). However, Bucklin et al. (2007) confirmed that planting of coho from outside stocks in the past has had minimal influence on the genetics of local populations within this ESU. A similar genetic and geographic pattern was also observed at the southern end of steelhead range (see south-central coastal and southern steelhead accounts).

Life History: The first comprehensive life history study of coho salmon was done on fish of the CCC ESU, namely the classic studies in Waddell Creek by Shapovalov and Taft (1954). Their life history throughout their range is summarized in Sandercock (1991) while Baker and Reynolds (1986), Moyle (2002), CDFG (2002), and NMFS (2012) review their biology in California. In most respects, the life history of CCC coho is the same as that of SONCC coho, including the presence of small numbers of juveniles that spend two years in the creeks and overwinter and rear in non-natal streams and estuaries during every month of the year (see SONCC coho salmon account). Dr. J. Smith of San Jose State University has in recent years continued the life history and monitoring studies of Shapovalov and Taft (Smith 2015).

Habitat Requirements: Habitat requirements of CCC coho are basically the same as those of SONCC coho, the summary of which is based on Moyle (2002) and DFG (2002, 2004). Smith (2015) notes that success of coho in Scott and Waddell creeks depends on the timing and severity of floods from winter rainstorms and the timing and severity of droughts. Severe high flow events that occur early in the winter (December, January) can scour pools, move large wood, open the mouth of the lagoon for access, and generally improve coho habitat, while similar flood events later in the season (February, March) can scour out redds or flush juvenile coho out of over-wintering habitat (pools, side channels, under large wood). Likewise, severe drought, especially if aggravated by diversions, can dry up stream reaches and confine juvenile coho to pools, which may become too shallow or warm to support them. Smith (2015) notes other CCC coho populations face similar problems.

Distribution: For broad aspects of coho salmon distribution, see the SONCC coho account. CCC coho were historically native to California coastal streams from Punta Gorda (southern Humboldt Co.) down to the San Lorenzo River and (probably) Soquel and Aptos creeks (Santa Cruz Co., Spence et al. 2005, Adams et al. 2007, NMFS 2012), as well as at least four streams tributary to San Francisco Bay (Leidy et al. 2005). It is also possible that a small run once existed in the Sacramento River (Brown et al. 1994). They are currently extirpated from tributaries to San Francisco Bay (NMFS 2012).

The distribution and abundance analysis for California coho salmon of Brown and Moyle (1991) and Brown et al. (1994) was updated by Spence et al. (2005), Bjorkstedt et al. (2005), Spence and Thomas (2011), NMFS (2012), and DFG/W (2002, 2004, 2015), from which this information comes. Bjorkstedt et al (2005) identified 76 streams in the CCC region that likely historically supported populations of coho salmon, based on analysis of historical records, genetic structure, and hydrology. Twelve of these were large enough to support self-sustaining populations through severe environmental conditions ("functionally independent populations"), while the rest presumably required periodic recruitment from permanent populations to be sustained ("functionally dependent"). The 12 main populations were found in the following rivers: Ten Mile, Noyo, Big, Albion, Navarro, Garcia, Gualala, Russian, and San Lorenzo, along with Lagunitas and Pescadero creeks. With a few exceptions, CCC coho distribution is linked to the cool fog belt, close to the ocean; they are also associated with coastal redwood forests in the EPA's West Coast Forest Ecoregion.

CCC coho salmon thus were once more or less continuously distributed in coastal streams from Mendocino County south to Santa Cruz County, with extensive inland distributions in the larger river systems such as the Eel. However, the general trend has been downward in the number of wild populations, with individual populations becoming more isolated, the overall distribution becoming fragmented, and fish being extremely rare in the southern two-thirds of the historical range of this ESU (Swales *in prep.*).

Trends in Abundance: Overall historical abundance of coho salmon in California is discussed in the SONCC coho account. There seems to be little doubt that CCC coho are closer to extinction than SONCC coho:

CCC Coho salmon... "are listed as an endangered species... due to a precipitous and ongoing decline in their population. Since their initial listing in 1996...their population has continued to decline and the species is now close to extinction (NMFS 2012, p. v.)."

"Overall, all CCC coho salmon populations remain, at best, a slight fraction of their recovery target levels, and, aside from the Santa Cruz Mountains strata, the continued extirpation of dependent populations continues to threaten the ESU's future survival and recovery." (NMFS 2016, pg. 11).

"...the overall long-term trend in coho salmon populations in most monitored streams in the State remains downward and many populations have either already been extirpated or may be approaching extirpation (Swales *in Prep.*, p. 17)."

Very rough estimates indicate that the number of coho salmon returning to streams in the CCC region 50-60 years ago was somewhere between 50,000 to 100,000 spawners (or more) per year, with 350 or more streams used for spawning and rearing. This suggests a long-term decline in excess of 95% in population size and a decline in number of streams used annually on the order of 50%, although most of the streams with recent records do not have fish every year, and those that do have very small numbers.

In the first statewide assessment of coho status, Brown et al. (1994) considered 5,000-7,000 fish to be a realistic estimate of the total number of naturally spawned adults returning to all California streams each year in 1987-1991 (20% CCC coho, or ca. 1,000 to 1,400 spawners). NMFS (2012) put the estimate at 2,000-3,000 spawners in 2011, with an estimate of less than 500 CCC coho in 2009. The actual number is hard to estimate, and varies with cohort and annual survival in both stream and ocean. Presumably, the actual number varies between 500 and 3,000 per year, depending on conditions in both fresh water and the ocean. Regardless, the number is low and represents a long-term decline from thousands of spawners in the ESU as late as the 1940s.

Mendocino County. Swales (2016) noted that CCC coho were once found in over 200 streams in the county, including most tributaries of Ten Mile, Noyo, Big, and Navarro Rivers. However, a 2002 assessment found that only 62% had signs of still supporting coho salmon. Since that assessment, all streams monitored "have shown a continued downward trend" (Swales 2016, p 16). For example, in the Noyo River, where reasonably good records have been kept since the 1960s (Grass 2008), early counts ranged between 1,200 and 5,000 spawners. Since 1990, most counts have been < 500 fish, with 79 fish in 2005-2006 and 59 in 2006-2007 (Grass 2008). Numbers have continued to remain low but fluctuating since then (Swales 2016).

Sonoma County. Coho salmon are still found in just 5 of 70 streams in Sonoma County, in the Russian River and Gualala River watersheds. In the Russian River, coho are being reared in Russian River Coho Salmon Captive Broodstock Program (RRCSCBP) at Warm Springs Hatchery, on Dry Creek. Outplants of juveniles have been successful, especially in the Austin Creek watershed, resulting in about 200 returning adults in 2010-11, 400 in 2011-12, 500 in 2012-13, 300 in 2013-14, and 400 in 2014-15, up from 2-7 fish 2000-2009 (Swales *in prep*., Higgins 2016) (Figure 1). The increasing trends reflect the success of stocking juveniles in tributary streams to the Russian River. Recent hatchery broodstock introduction efforts from fish from the Russian River and Olema Creek into Salmon Creek have allowed successful spawning, with juveniles captured there for the first time in many years (NOAA Fisheries 2016).

Marin County. CCC Coho are present today mainly in two watersheds, Redwood Creek and Lagunitas Creek. They seem to have largely disappeared from Redwood Creek during the 2011-2015 drought years. A significant proportion of the remaining fish are found in Lagunitas Creek and its tributaries. From 1997-98 through 2014-15, Ettlinger et al. (2015) recorded between 26 and 634 coho redds; the average number of redds was about 250, representing about 500 fish assuming one male and one female per redd. The assumption that adult numbers are twice the redd count i.e. two fish per redd, is consistent with the numbers of adults estimated through spawner surveys (Ettlinger et al. 2015).

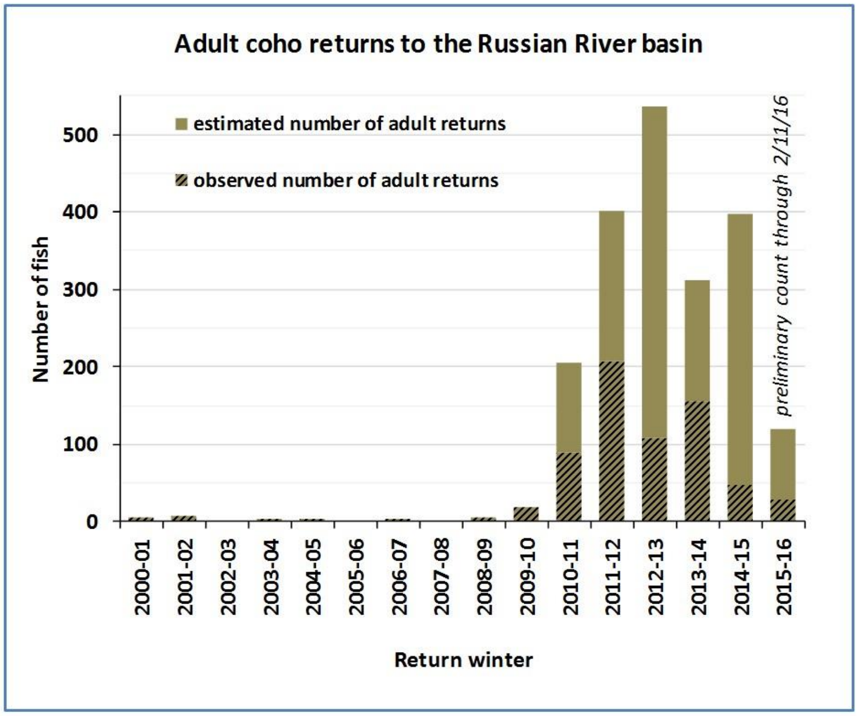

Figure 1. Adult coho salmon returns to the Russian River basin, 2000-2016. Data from UC Davis Cooperative Extension, 2016 (Higgins 2016).

San Francisco Bay tributaries. Coho were historically found in many tributaries to San Francisco Bay, including: San Mateo Creek (San Mateo Co.), Walnut Creek (Contra Costa Co.), San Leandro Creek (Alameda and Contra Costa Co.), San Pablo Creek (Contra Costa Co.), Strawberry Creek (Alameda Co.), Temescal Creek (Alameda Co.), San Lorenzo Creek (Alameda Co.), Alameda Creek (Alameda Co.), Coyote Creek (Santa Clara Co.), Guadalupe River (Santa Clara Co.), San Francisquito Creek (Santa Clara and San Mateo Co.), Corte Madera Creek (Marin Co.), Mill Valley Creek (Marin Co.), and Napa River (Napa Co.), and likely occurred in other tributaries as well, but data are inconclusive (Leidy 1983, Leidy et al. 2005).

San Mateo and Santa Cruz counties. The southernmost populations of coho salmon were originally found in at least 17 streams south of San Francisco Bay (Adams et al. 2007). At present, juveniles survive mainly in Scott, San Vincente, Soquel, and Waddell creeks, although they were present in Gazos Creek until 2005 (Smith 2015). The Scott drainage recorded the highest returns of coho in over a decade during 2014/2015 (NOAA Fisheries 2016). Returns are now entirely dependent on the Kingfisher Flat Restoration Hatchery (Smith 2015). The most recent samplings in Pescadero Creek and the San Lorenzo River indicate that coho have been extirpated in those two independent populations (NOAA Fisheries 2016).

In summary, almost all of the remaining CCC streams with coho have populations of fewer than 100 spawning adults, unless enhanced through hatcheries. These small populations are probably below the minimum population size required to preserve the genetic diversity of the stock and to buffer them from natural environmental disasters. There is every reason, therefore, to think that most CCC coho populations are facing extirpation in the near future, with the exception of populations in Lagunitas Creek, Russian River, and Santa Cruz County drainages, due largely to the heroic efforts by stream managers and conservation hatcheries. In most streams, reliable data on numbers of spawners, especially in recent years, is difficult to come by. The available information indicates that CCC coho salmon live in a small fraction of their historical habitat, with low population sizes. To make matters worse, these fish are mostly in isolated populations that show evidence of genetic and demographic factors that increase the likelihood of extirpation (Bucklin et al. 2007).

In the past 10 years, all CCC coho salmon populations have remained low, with numbers in 2007-08 being exceptionally low. The findings of Bucklin et al. (2007) suggest that most CCC coho populations are in a state of collapse from which recovery will be difficult. The drought has likely also depressed populations somewhat, even if temporarily.

Factors Affecting Status: The same factors that affect SONCC coho populations affect CCC coho populations, only more so. NMFS (2012) notes “Logging, agriculture, mining, urbanization, stream channelization, dams, wetland loss, water withdrawals, and unscreened diversions for irrigation contributed to the decline of the CCC coho salmon ESU” (p 89). As indicated in the SONCC account, the effects of anthropogenic change on coho are particularly severe because of the rigid life-history age-structure. Such stochastic events as floods or severe droughts, when acting on a severely depleted population, can eliminate one or more entire year classes from a stream, although sometimes precocious male parr, one year old jacks, and strays from nearby streams can help to bring back a missing year class. There is good evidence that this has already happened repeatedly in Waddell Creek and other coastal drainages, where the decline of coho is linked to poor stream and watershed management.

Agriculture. Unlike the situation for SONCC coho, many of the heavily logged watersheds in the CCC have not been returned to forest, but have been converted to agricultural lands, especially vineyards. Most of the Navarro River basin, for example, has been converted from dense redwood forest to open farmland, with much of the water diverted for agricultural use. As a result, due to low flows, much of the watershed is largely incapable of supporting *any* salmonids, much less coho salmon (Viers 2008). In the Russian River, the water in the tributaries is all over-allocated and diversion (for frost protection of vineyards) takes place even in winter, leaving little water for fish. A developing and critical issue in coho streams in California is the diversion of water for legal and illegal marijuana growing operations (NMFS 2012), which during summer can desiccate critical rearing habitat.

Dams. The Russian River has two major dams (Warm Springs and Coyote Valley) that have drastically altered its flow regime. In Lagunitas Creek, however, summer flow releases from Peters Dam help to create cold water habitat needed for persistence of juvenile coho. The creek has seven dams on it and is an important source of water for the Marin County Water District.

Urbanization. Another growing problem is urbanization, which has eliminated populations in the San Francisco Bay region and is increasingly contributing to the loss of CCC coho habitat in streams elsewhere. For example, a key tributary to Lagunitas Creek, San Geronimo Creek, is now lined with houses and controversy rages around protecting the creek from encroaching lawns and other issues.

Logging. In CCC coho streams, the most severe damage from logging is a legacy of historical logging practices, as described graphically by NMFS (2012). Starting in the 19th century, unrestricted logging caused massive erosion, removed riparian vegetation and woody debris from channels, caused stream temperatures to increase, filled pools with silt and gravel, altered stream channels, and degraded water quality. The redwood forests were logged off almost completely before 1900. On the Mendocino Coast, the first wave of redwood logging occurred in the late 1800s, and the practices employed severely modified coho habitats. Splash dams were commonly used to get logs from the harvest site down to ports at the mouths of rivers, and crib dams were common on the larger streams. Crib dams impounded water upstream so that logs could be floated downstream, or so water could be released to flush logs that had been dragged into the channel below the dams. Often streams had multiple crib or splash dams left in place on them for many years, preventing upstream migration by salmon. In the Santa Cruz Mountains, virtually all of the redwood forests, with the exception of the headwaters of the San Lorenzo (Big Basin State Park), a small grove near Felton, and some groves in the headwaters of Pescadero Creek were gone before 1900 (B. Spence, pers. comm. 2016). Although splash damming was apparently not used on the San Lorenzo River, mill pond dams were built on most of the major tributaries that would likely have been coho habitat, resulting in early extirpation from the river.

It is hard to overestimate the importance of loss of large wood to coho as the result of historical logging practices. The trunks and large branches of trees provide cover for fish and interact with high flows to create pools and other habitat features. The streams in the Santa Cruz Mountains and Mendocino Coast contain little of the low-gradient, wide-valley streams that tend to be the most productive habitat for coho salmon. Thus, the role of large wood in these steeper streams was, in all likelihood, essential for providing refuge, particularly from high flows, because there were fewer off-channel habitat refuges. Lack of habitat structure is clearly a major problem facing CCC coho, especially in the winter months when refuges from high flows are needed (e.g., Stillwater Sciences 2008). Even in state parks in the region, which often have 100-year old riparian forests, large in-channel wood remains extremely scarce and is present largely as the result of stream enhancement projects (e.g., Ferguson 2005).

The early logging in most CCC coho watersheds was followed by permanent clearing of much of the land for urban and agricultural use, which continued to degrade water quality, quantity, and habitat for coho salmon and other salmonids (NMFS 2012). Thus, Opperman et al. (2005) found that in the Russian River watershed, the pervasive large-scale changes in land use had resulted in high sedimentation that precludes successful salmon spawning. In this way, many CCC coho streams never had the opportunity to recover from earlier damage because of conversion of watersheds to vineyards, farms, suburbs, and towns. As a result, CCC coho are disappearing rapidly.

Estuarine alteration. All CCC coho streams have either estuaries or lagoons at their mouths, which provide important seasonal rearing habitat. The lagoons can close naturally as the result of the combination of low flows and movement of sand by wave and tidal action, keeping adults out and juveniles in at times when both need to migrate. Historically, high stream flows from winter storms would keep the lagoons open to the sea, at least intermittently. Today, lagoons are often opened artificially to prevent flooding of agricultural fields or houses, and they may drain before juveniles are ready to be carried out to sea. The lagoons are also often polluted with agricultural and suburban waste, and can become too warm and anoxic for coho in summer. In addition, marshes that once lined the lagoons on their upper ends have been converted to agriculture or other uses, reducing cover and food supplies.

Harvest. The ocean commercial fishery for coho salmon in California was halted in 1993 and the ocean sport fishery in 1994 and 1995, despite the fact they are mixed stock fisheries, with many of the fish coming from Oregon hatcheries and streams. Sport fishing is now not allowed in streams as a result of listing of coho under the Endangered Species Act. Small numbers are undoubtedly caught and released in both commercial and sport fisheries targeting other species. However, overall, fisheries seem to be having only a minor impact on coho populations today, and the closure of fisheries has presumably helped to protect the dwindling California populations.

Factor	Rating	Explanation
Major dams	Medium	Most streams without dams, but dams affect Russian River, Lagunitas Creek, Mad River, and a few other streams.
Agriculture	Critical	Irrigation diversions in many streams reduce flows; vineyard expansion is a problem. Illegal and unregulated marijuana cultivation is a major and growing issue, especially during drought.
Grazing	Medium	Chronic stream bank alteration.
Rural /residential development	Medium	Many homes along streams.
Urbanization	High	Many important streams flow though urban areas.
Instream mining	Medium	Gravel mining in Russian River reduces habitat.
Mining	Low	Hardrock mining a minor problem, although mercury-laden water affects some streams.
Transportation	Medium	Roads & railroads create sediment and erosion.
Logging	High	A chronic problem related to roads and other impacts; legacy effects a major issue.
Fire	Low	Can cause siltation of coho streams, loss of shade to cool water.
Estuary alteration	High	Most estuaries and lagoons highly altered with reduced rearing habitat.
Recreation	Low	Boating, rafting probably have low impacts.
Harvest	Medium	Mostly protected but still some harvest, including poaching.
Hatcheries	Medium	Conservation hatcheries important for some populations.
Alien species	Low	Few aliens in coho watersheds.

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Central California Coast coho salmon. Factors were rated on a five-level ordinal scale where a factor rated "critical" could push a species to extinction in 3 generations or 10 years, whichever is less; a factor rated "high" could push the species to extinction in 10 generations or 50 years, whichever is less; a factor rated "medium" is unlikely to drive a species to extinction by itself but contributes to increased extinction risk; a factor rated "low" may reduce populations but extinction is unlikely as a result. A factor rated "n/a" has no known negative impact. Certainty of these judgments is high. See methods for explanation.

Effects of Climate Change. Moyle et al. (2013) rated CCC coho salmon as "critically vulnerable" to climate change, indicating it could be the final blow driving it to extinction. This is a result of low populations, stream flow, and highly damaged watersheds. Predicted effects on coho habitat include increases in stream temperatures, variability in flows (including greatly reduced summer flows), and changed ocean conditions that dictate coho growth and survival. Increased frequency of wildfires may increase erosion and reduce shading of already warming streams. These ongoing changes are being superimposed on the other threats to coho, increasing the likelihood of rapid extirpation as time passes. Without dramatic action to protect and enhance habitats, especially at the southern end of their range, CCC coho are likely to continue to decline.

Status Score = 1.3 out of 5.0. Critical Concern. Highly vulnerable to extinction within next 50 years. This score is the result of the precarious state of all populations and the 95% plus decline in abundance from 50-60 years ago. Present trends suggest that most or all populations in small coastal streams will disappear in the next 50 years without increased intervention and protection of watersheds. NMFS (Good et al. 2005, NMFS 2012), DFG (2002), and Swales (2016) agree that coho salmon are in danger of extirpation from the southern end of their range in the near future, and that the condition of CCC coho populations continues to deteriorate. CCC coho are listed as endangered by both state and federal governments (1996). The federal status was reaffirmed in 2016.

Metric	Score	Justification
Area occupied	2	Most populations not self-sustaining in long run.
Estimated adult abundance	2	All populations are small, isolated, and may function independently. Most are <100 in most years.
Intervention dependence	1	All populations require intervention to persist and most have intensive management in place or proposed.
Environmental tolerance	1	Coho are among the most sensitive salmonids to environmental conditions.
Genetic risk	1	Populations small and isolated.
Climate change	1	At southern end of range so exceptionally vulnerable.
Anthropogenic effects	1	1 Critical, 3 High factors.
Average	1.3	9/7.
Certainty (1-4)	4	Well documented.

Table 2. Metrics for determining the status of CCC coho salmon, where 1 is a major negative factor contributing to status, 5 is a factor with no or positive effects on status, and 2-4 are intermediate values. Certainty of these judgments is high. See methods for explanation.

Management Recommendations: Many of the conservation measures discussed for SONCC coho salmon are important for CCC coho as well. However, given the extreme, largely irreversible alteration of many, if not most, CCC coho watersheds, it is clear that keeping the ESU from extinction will require special, high energy/cost efforts, many of which are underway (NOAA Fisheries 2016).

- Protect the few watersheds that have the potential to support coho in the future, such as Scott and Waddell creeks, Lagunitas Creek, and the Garcia, Noyo, and Gualala rivers. They require protection from further degradation and large-scale restoration efforts.
- Develop and maintain restoration hatcheries where they can be used in conjunction with habitat improvement and evaluation measures. The captive broodstock and rearing program on the Russian River seems to be producing successful results, but it is not certain if coho populations, even in restored habitats, can survive without supplementation. Populations in Scott and Wadell creeks appear to be totally reliant on production from the conservation hatchery. However, more monitoring is needed of genetic and demographic effects on both source and receiving populations.
- Resolve all the complex water allocation issues in the watersheds to make sure adequate

water is left to support coho salmon.

- Work with vineyard owners to reduce the impact of vineyards on coho. Viers et al. (2013) indicate that there are a number of strategies than can work well. Similar actions are needed to work with marijuana growers.
- Focus on Lagunitas Creek as a demonstration stream to publicize the plight of the coho and to demonstrate restoration techniques, such as placement of large woody debris (Ferguson 2005). Spawning coho are already a major public attraction in the lower creek (in Samuel P. Taylor State Park) but more could be done to enhance their numbers and to protect habitat. In particular, housing developments along San Geronimo Creek must be constructed in such as way as to do no damage to the creek or to increase its sediment flow into Lagunitas Creek.
- Provide additional special status and protection to the Santa Cruz County CCC coho, as the southernmost populations of the species. The entire watersheds should be managed with coho salmon as the highest priority.

Other management actions put forward by CDFG (2004) and NMFS (2006, 2012, 2016) could go a long ways towards reversing the trends if properly implemented, but they also will require increased funding, increased interagency cooperation, mobilization of public opinion, and development of an extensive monitoring program. Finding a way to work with the numerous private owners of land along coho streams is critical. Monitoring the populations is a necessity; spawning streams should be identified and populations should be sampled annually.

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