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STATUS REVIEW UPDATE FOR PACIFIC SALMON AND STEELHEAD LISTED UNDER THE ENDANGERED SPECIES ACT: CENTRAL CALIFORNIA COAST COHO SALMON ESU

Brian C. Spence and Thomas H. Williams

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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1 Introduction

The Endangered Species Act (ESA) requires that the National Marine Fisheries Service (NMFS) review the status of listed species under its authority at least every five years to determine whether any species should be removed from the list or have its listing status changed. Previous listing determinations for 16 evolutionarily significant units (ESUs) of Pacific salmon (*Oncorhynchus* spp.) and 10 distinct population segments (DPSs) of steelhead (*O. mykiss*) were issued in June 2005 and January 2006, respectively (70 FR 37160; 71 FR 834). Consequently, NMFS is due to revisit the status of 27 of the 28 currently listed Pacific salmonid ESUs/DPSs of West Coast Pacific salmonids and thus initiated formal status reviews in March 2010 (75 FR 13082). These reviews are being conducted by the NMFS Northwest and Southwest Regions based on scientific summaries of the status of the subject ESUs/DPSs.

Subsequent to a February 2010 request from the Regions to the Northwest and Southwest Fisheries Science Centers to review the status of these ESUs/DPSs, NMFS published a Federal Register notice on 2 April 2010 accepting for review an Endangered Species Act petition (75 FR 16745) to delist coho salmon (*O. kisutch*) in coastal counties south of the ocean entrance to San Francisco Bay (i.e., the Golden Gate), a region that encompasses the southern-most limit of the Central California Coast (CCC) Coho Salmon ESU and the species' geographic range. The petition contended that extant populations south of the Golden Gate were established and have been maintained by introductions of nonnative stock from locations north of San Francisco, and thus argued that the southern boundary of the CCC Coho Salmon ESU should be at or north of the Golden Gate. In response to a request from NMFS' Southwest Region, NMFS Southwest Fisheries Science Center (SWFSC) convened a Biological Review Team (BRT) to review information provided by petitioners, as well as new information concerning the southern boundary of the CCC Coho Salmon ESU. The BRT consisted of representatives from NMFS Southwest and Northwest Fisheries Science Centers, as well as fishery experts from the U.S. Forest Service and U.S. Geological Survey.

The BRT met for several days in July 2010 to specifically address the petitioned action and the appropriate southern boundary for the CCC Coho Salmon ESU. Based on its review, the BRT concluded that the CCC Coho Salmon ESU extends to watersheds south of the entrance to San Francisco Bay. Further, the BRT recommended that the southern boundary of the ESU be extended from its current location at the San Lorenzo River (inclusive) southward to Aptos Creek (Santa Cruz County) (Spence et al. 2011). This recommendation was based on the close proximity and ecological similarities between the Soquel and Aptos creek watersheds and those to the immediate north, coupled with recent (2008) documented natural reproduction of coho salmon in Soquel Creek. In light of the BRT's findings, the Southwest Region requested that the SWFSC review the status of the CCC Coho Salmon ESU, which is currently listed as "endangered" (70 FR 37160), giving consideration to populations south of the current ESU boundary.

This report summarizes the SWFSC's findings regarding the status of CCC Coho Salmon. Specifically, the report evaluates whether there is new biological information since the

2005 BRT review (Good et al. 2005) and subsequent listing determination (70 FR 37160) to suggest that there has been a change in the extinction risk of CCC Coho Salmon based on the boundary definition extending south to Aptos Creek (Santa Cruz County, California). Since publication of Good et al. (2005), Technical Recovery Teams (TRTs) coordinated by NMFS have completed development of viability criteria for all listed Pacific salmonid ESUs/DPSs in the Pacific Northwest and California. These criteria build on the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000). In preparing the current status review for CCC Coho Salmon, we used the conceptual framework developed by the TRT for the North-Central California Coast Recovery Domain, which proposed both historical population structure and viability criteria for CCC Coho Salmon, as well as other ESUs/DPSs in the recovery domain (Bjorkstedt et al. 2005; Spence et al. 2008). This framework is expected to form the basis for future status reviews as well as recovery targets in NMFS' recovery plan for CCC Coho Salmon. We therefore begin the report with a brief overview of the TRT's primary findings before discussing the available biological information regarding the status of the ESU. Because our analysis focuses on the TRT's viability criteria, which require time series of adult abundance estimates at the population level, this status review differs somewhat from that of Good et al. (2005), which relied primarily on presence-absence information, augmented with a very limited number of juvenile, smolt, and adult abundance time series.

The information in this update will be used by the Southwest Region to make final determinations about any proposed changes in listing status of the CCC Coho Salmon ESU. The new listing determination will take into account not only biological information but also threats to the species and ongoing or planned protective efforts.

2 Overview of TRT conceptual framework

The CCC Coho Salmon ESU is part of the North-Central California Coast Recovery Domain, which encompasses the geographic region from Redwood Creek (Humboldt County) south to Aptos Creek (Santa Cruz County) inclusive, but excluding California's Central Valley. Two salmon ESUs and two steelhead DPSs lie wholly within this region: California Coastal Chinook Salmon, Central California Coast Coho Salmon, Northern California Steelhead, and Central California Coast Steelhead.

The TRT for the North-Central California Coast Recovery Domain prepared two documents intended to guide recovery planning efforts for the ESA-listed salmonids within the domain. The first of these reports described the historical population structure of the four listed ESUs/DPSs within the recovery domain (Bjorkstedt et al. 2005). Within this document, the TRT categorized each population into one of three distinct types based on its posited historical functional role:

Functionally independent populations: populations with a high likelihood of persisting over 100-year time scales and that conform to the definition of independent "viable salmonid populations" offered by McElhany et al. (2000).

Potentially independent populations: populations with a high likelihood of persisting over 100-year time scales, but that were too strongly influenced by immigration from other populations to exhibit independent dynamics.

Dependent populations: populations that had a substantial likelihood of going extinct within a 100-year time period in isolation, yet received sufficient immigration to alter their dynamics and reduce their risk of extinction.

In addition to categorizing individual populations, the population structure report also placed populations into *diversity strata*, which are groups of populations that likely exhibit genotypic and phenotypic similarity due to exposure to similar environmental conditions or common evolutionary history (Bjorkstedt et al., 2005; revised in Spence et al. 2008). Here, the TRT set the stage for development of viability criteria that consider processes and risks operating at spatial scales larger than those of individual populations.

The second TRT report proposed a framework for assessing viability of populations and ESU/DPSs within the recovery domain (Spence et al. 2008). This report established biological viability criteria, from which delisting criteria are currently being developed by federal recovery planning teams. These criteria consist of both population-level viability criteria and ESU- or DPS-level criteria.

The population viability criteria represent an extension of an approach developed by Allendorf et al. (1997) and include criteria related to population abundance (effective population size), population decline, catastrophic decline, spawner density, and hatchery influence (Table 1). Population viability metrics and methods for estimation are shown in Table 2. In general, the spawner density low-risk criterion, which seeks to ensure a population's viability in terms of its ability to fulfill its historical functional role within the ESU, is the most conservative, and preliminary viability targets for each population were determined by this criterion. The ESU-level criteria are intended to ensure representation of the diversity within an ESU/DPS across much of its historical range, to buffer the ESU/DPS against potential catastrophic risks, and to provide sufficient connectivity among populations to maintain long-term demographic and genetic processes. These criteria are summarized in Table 3.

In the sections that follow, we evaluate the status of the CCC Coho Salmon ESU using the TRT's viability criteria as the framework. Application of these criteria requires time series of adult spawner abundance spanning a minimum of four generations for independent populations. For the vast majority of populations in this CCC Coho Salmon ESU, population-level estimates of abundance are lacking, and only indices of spawner abundance or local population estimates representing only a portion of the population are currently available. In the few cases where population-level estimates do exist, the time series seldom reach the four generations recommended by the TRT for application of the criteria. These data are presented despite the shortcomings, as they provide the only basis for evaluating current status and trends. However, the reader is cautioned that short-term trends in abundance or abundance indices are difficult to interpret against the backdrop of variation in environmental conditions in both the freshwater and marine environments.

Table 1. Criteria for assessing the level of risk of extinction for populations of Pacific salmonids. Overall risk is determined by the highest risk score for any category. N_g = generational sum of abundance; N_e = effective population size; and N_a = annual spawner abundance. From Spence et al. (2008).

Population Characteristic	Extinction Risk		
	High	Moderate	Low
Extinction risk from population viability analysis (PVA)	$\geq 20\%$ within 20 yrs	$\geq 5\%$ within 100 yrs but $< 20\%$ within 20 yrs	$< 5\%$ within 100 yrs
	- or any ONE of the following -	- or any ONE of the following -	- or ALL of the following -
Effective population size per generation	$N_e \leq 50$	$50 < N_e < 500$	$N_e \geq 500$
-or-	-or-	-or-	-or-
Total population size per generation	$N_g \leq 250$	$250 < N_g < 2500$	$N_g \geq 2500$
Population decline	Precipitous decline ^a	Chronic decline or depression ^b	No decline apparent or probable
Catastrophic decline	Order of magnitude decline within one generation	Smaller but significant decline ^c	Not apparent
Spawner density	$N_a/IPkm^d \leq 1$	$1 < N_a/IPkm < MRD^e$	$N_a/IPkm \geq MRD^e$
Hatchery influence ^f	Evidence of adverse genetic, demographic, or ecological effects of hatcheries on wild population		No evidence of adverse genetic, demographic, or ecological effects of hatchery fish on wild population

^a Population has declined within the last two generations or is projected to decline within the next two generations (if current trends continue) to annual run size $N_a \leq 500$ spawners (historically small but stable populations not included) *or* $N_a > 500$ but declining at a rate of $\geq 10\%$ per year over the last two-to-four generations.

^b Annual run size N_a has declined to ≤ 500 spawners, but is now stable *or* run size $N_a > 500$ but continued downward trend is evident.

^c Annual run size decline in one generation $< 90\%$ but biologically significant (e.g., loss of year class).

^d $IPkm$ = the estimated aggregate intrinsic habitat potential for a population inhabiting a particular watershed (i.e., total accessible km weighted by reach-level estimates of intrinsic potential; see Bjorkstedt et al. [2005] for greater elaboration).

^e MRD = minimum required spawner density and is dependent on species and the amount of potential habitat available. See Figure 5 in Spence et al. (2008) for illustration of the relationship between spawner density and risk for each species.

^f Risk from hatchery interactions depends on multiple factors related to the level of hatchery influence, the origin of hatchery fish, and the specific hatchery practices employed.

Table 2. Estimation methods and data requirements for population viability metrics. Note that all references to population abundance refer to naturally produced adults (i.e., exclusive of hatchery returns). Modified from Spence et al. (2008).

Population Characteristic	Metric	Estimator	Data Needs
Effective population size per generation -or- Total population size per generation	\bar{N}_e $\bar{N}_{g(harm)}$	Variable: several direct and indirect methods for estimating N_e (see Spence et al. 2008). Harmonic mean of spawner abundance per generation: $\bar{N}_{g(harm)} = \frac{1}{\frac{1}{n} * \sum_{t=1}^n \frac{1}{N_{g(t)}}$ where n is the number of years, where $N_{g(t)}$ is the running sum of adult abundance over period equal to the population's mean generation time (rounded to the nearest whole year) at time t^*	Variable Time series of adult spawner abundance, N_a , for a minimum of 4 generations; demonstration that N_g remains above threshold during periods of low marine survival
Population decline Critical run size	$\bar{N}_{a(geom)}$	Geometric mean annual adult run size: $\bar{N}_{a(geom)} = \left(\prod_{i=1}^n N_{a(i)} \right)^{1/n}$	Time series of adult spawner abundance, N_a , for a minimum of 4 generations; demonstration that N_a remains above threshold during periods of low marine survival
Population trend	T	Slope of natural log of abundance v. time: $\hat{T} = \text{slope } \ln(N_a+1) \text{ v. time}$ where N_a is as defined above	Time series of adult spawner abundance, N_a , for 2-4 generations; demonstration that increasing trend is not result of short-term increases in marine survival
Catastrophic decline	C	Maximum 1-generation decline (proportion) in abundance: $\hat{C} = \text{maximum} \left(1 - \frac{N_{g(t)}}{N_{g(t-2h)}} \right)$ where $N_{g(t)}$ is as defined above, and h is the mean generation time (rounded to the nearest whole year)	Time series of adult spawner abundance, N_a ; minimum of 3 generations to estimate short-term catastrophic risk; for longer time series, need analysis of trends following catastrophic decline and information on marine survival
Population density Depensation	\bar{D}_{dep}	Mean spawner density expressed as spawners per IP kilometer (see text). Arithmetic mean of spawner density for lowest h consecutive years within the last 4 generations where h is mean generation time. $\hat{D}_{dep} = \left(\min \left[\frac{N_{g(t)}}{h} \right] \right) / IPkm$	Time series of adult spawner abundance, N_a , or mean spawner density from randomized survey locations; 4 generations

Table 2. (continued)

Population density Spatial structure and diversity	\bar{D}_{ssd}	Arithmetic mean of spawner density for past 4 generations $\hat{D}_{ssd} = \frac{1}{4h} \sum_{t=1}^{4h} \frac{N_a}{IPkm}$ where <i>IPkm</i> is the sum of available stream kilometers of habitat multiplied by their <i>IP</i> value, and <i>h</i> is mean generation time.	Time series of either adult spawner abundance, <i>N_a</i> , or mean spawner density from randomized survey locations; minimum of 4 generations. <i>IPkm</i> estimates for each population.
Hatchery influence	No specific metrics of estimators proposed. See text for guidance on potentially appropriate analyses.		

* In the absence of population-specific information, mean generation time is assumed to be 3 yrs for coho salmon, and 4 yrs for steelhead and Chinook salmon, which constitute the most common ages at spawning for these species within the domain. For more southerly winter steelhead populations, 3 yr-olds may constitute the majority of adult spawners (Busby et al. 1996).

Table 3. ESU-level criteria for assessing the level of risk of extinction for Pacific salmonid ESUs. From Spence et al. (2008).

Criterion	Description
<i>Representation</i>	All identified diversity strata that include historical functionally or potentially independent populations within and ESU/DPS should be represented by viable populations for the ESU/DPS to be considered viable -AND- Within each diversity stratum, all extant phenotypic diversity (i.e., major life history types) should be represented by viable populations
<i>Redundancy and Connectivity</i>	At least 50% of historically independent populations in each diversity stratum must be demonstrated to be at low risk of extinction according to the population viability criteria outlined in Table 1 -AND- Within each diversity stratum, the total aggregate abundance of independent populations selected to satisfy this criterion must meet or exceed 50% of the aggregate viable population abundance (i.e., meeting density-based criteria for low risk) for all independent populations Remaining populations, including historical dependent populations and any historical independent populations that are not expected to attain a viable status must exhibit occupancy patterns consistent with those expected under sufficient immigration subsidy arising from the “core” independent populations selected to satisfy the preceding criterion The distribution of extant populations, regardless of historical status, must maintain connectivity within the diversity stratum, as well as connectivity to neighboring diversity strata

3 Status of the Central California Coast Coho Salmon ESU

3.1 Summary of previous BRT conclusions regarding status

Status reviews by Weitkamp et al. (1995) and Good et al. (2005) both concluded that the CCC Coho Salmon ESU was in danger of extinction. NMFS initially listed CCC Coho Salmon as threatened in 1996, but changed the status to endangered in 2005. In their status reviews, the previous BRTs cited concerns over low abundance and long-term downward trends in abundance throughout the ESU, as well as extirpation or near extirpation of populations across most of the southern two-thirds of the ESU's historical range, including several major river basins. They further cited as risk factors the potential loss of genetic diversity associated with range reductions or loss of one or more brood lineages, coupled with historical influence of hatchery fish (Good et al. 2005).

3.2 Brief review of TRT findings

Bjorkstedt et al. (2005) proposed that the CCC Coho Salmon ESU historically comprised 12 independent populations (11 functionally independent and 1 potentially independent), as well as at least 63 dependent populations. These populations were assigned to five diversity strata, one of which (San Francisco Bay) contained only dependent populations. Spence et al. (2008) developed viability criteria for each independent population; viability targets based on density criteria are shown in Table 4.

The lack of time series of adult abundance estimates for any of the 12 independent populations precluded rigorous application of the criteria (Spence et al. 2008). However, based on ancillary data, the TRT concluded that coho salmon were at high risk of extinction or extinct in the Garcia River, Gualala River, Russian River, Walker Creek, Pescadero Creek, and San Lorenzo River watersheds. The Noyo River population was deemed to be at moderate/high risk. The remaining independent populations (Ten Mile River, Big River, Albion River, Navarro River, and Lagunitas Creek) were considered data deficient. The lack of demonstrably viable populations in any of the diversity strata, the lack of redundancy in viable populations, and substantial spatial gaps in the distribution of coho salmon led the TRT to conclude that the CCC Coho Salmon ESU was in danger of extinction.

3.3 New data and updated analyses

Abundance and Trends

As noted earlier, the status review of Good et al. (2005) relied heavily on non-systematically collected presence-absence information to draw inference about the status of CCC Coho Salmon populations, as only one time series of adult abundance (counts at the Noyo River Egg Collecting Station) spanning more than 10 years was available at the time. Monitoring programs had been initiated on several streams and rivers, but as these time series were of short duration, they were uninformative regarding population trends.

Table 4. Projected population abundances (N_a) of CCC Coho Salmon independent populations corresponding to a high-risk (depensation) threshold of 1 spawner/IPkm and low-risk (spatial structure/ diversity=SSD) thresholds based on application of spawner density criteria (see Spence et al. 2008). Values listed under “historical” represent criteria applied to the historical landscape in the absence of dams that block access to anadromous fish. Values listed under “current” exclude areas upstream from impassable dams.

Stratum/ Population	Historical IPkm	Current IPkm	High Risk		Low Risk			
			Historical	Current	Historical SSD		Current SSD	
			Depens. N_a	Depens. N_a	Density spawner/IPkm	N_a	Density spawner/IPkm	N_a
<i>Lost Coast –Navarro Pt.</i>								
Ten Mile R.	105.1	105.1	105	105	34.9	3700	34.9	3700
Noyo R.	119.3	118.0	119	118	33.9	4000	34.0	4000
Big R.	193.7	191.8	194	192	28.8	5600	28.9	5500
Albion R.	59.2	59.2	59	59	38.1	2300	38.1	2300
<i>Navarro Pt. – Gualala Pt.</i>								
Navarro R.	201.0	201.0	201	201	28.3	5700	28.3	5700
Garcia R.	76.0	76.0	76	76	36.9	2800	36.9	2800
Gualala R.	252.2	251.6	252	252	24.7	6200	24.8	6200
<i>Coastal</i>								
Russian R.	779.4	757.4	779	757	20.0	15600	20.0	15100
Walker Cr.	103.7	76.2	104	76	35.0	3600	36.9	2800
Lagunitas Cr.	137.0	70.4	137	70	32.7	4500	37.3	2600
<i>Santa Cruz Mountains</i>								
Pescadero Cr.	60.6	60.6	61	61	38.0	2300	38.0	2300
San Lorenzo R.	135.3	126.4	135	126	32.8	4400	33.4	4200

Several of these monitoring programs have continued and are now approaching the number of years recommended by the TRT (Spence et al. 2008) as the minimum (i.e., four generations) for evaluating population status and trends. New data since publication of the previous status review (Good et al. 2005) thus consist of continuations of a few time series of adult abundance, some of which had only a few years of data at the time of the last status review, and most of which are for dependent populations (see Appendix). The best available data for an independent population are for Lagunitas Creek. Since the 1997–1998 season, redd surveys have been conducted annually in Lagunitas Creek and its major tributaries (San Geronimo, Devils Gulch, Nicasio Creek, and Olema creek) through the combined efforts of the Marin Municipal Water District, the National Park Service, and the Salmon Protection and Watershed Network (Ettlinger et al. 2010; M. Reichmuth, National Park Service, Point Reyes National Seashore, unpublished data). Although these redd counts have not been calibrated to estimate adult population abundance, a rough estimate of spawner abundance can be made by doubling the redd count, which assumes an average of one redd per female and a 1:1 male/female sex ratio. The redd counts also likely provide a reasonable basis for estimating population trends. These redd counts indicate that coho populations within the watershed over the last 12 years have averaged about 527 fish but have declined from a peak observed in 2004 and 2005 (Figure 1a). The negative 12-year trend in redd counts was not statistically significant at $\alpha=0.05$, but was nearly so ($p = 0.098$) (Table 5).

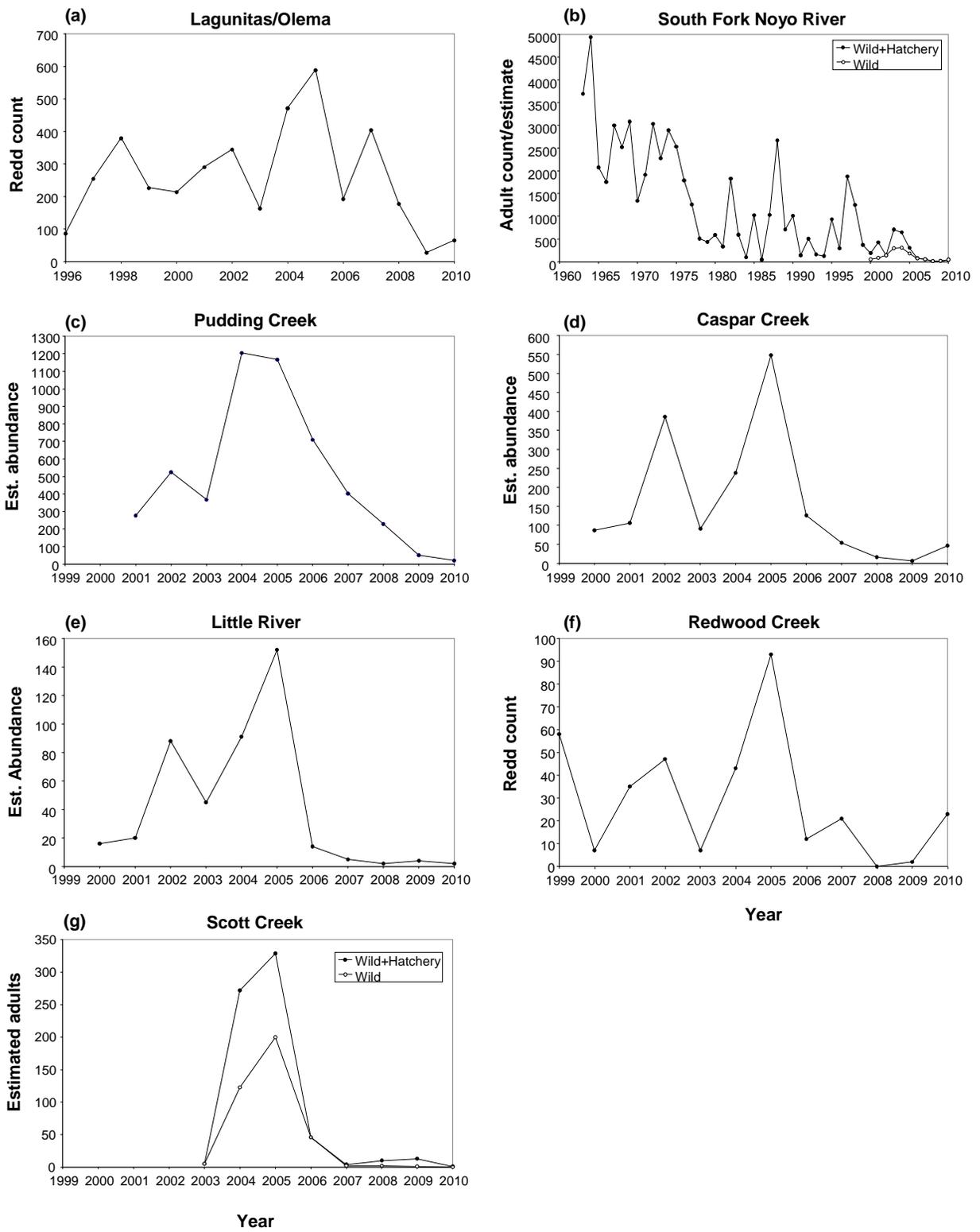


Figure 1. Coho salmon redd counts, weir counts, and abundance estimates for populations in the CCC Coho Salmon ESU.

Table 5. Viability metrics for independent populations of coho salmon in the CCC Coho Salmon ESU. NA indicates not available or applicable.

Population	Years	$\bar{N}_{a(arith)}$	$\bar{N}_{a(geom)}$	$\bar{N}_{g(harm)}$	\hat{T} (95% CI)	\hat{C}	\hat{D}_{dep}	\hat{D}_{ssd}
Noyo River*	8	578	476	NA	NA	NA	2.4	4.8
S. Fk Noyo R.**	12	113	NA	NA	-0.123 (-0.284, 0.038)	NA	NA	NA
Lagunitas Creek†	12	527	408	1450	-0.118 (-0.263, 0.026)	0.72	2.5	7.5

* Data from S. Gallagher, CDFG, unpublished data.

**The S. Fk. Noyo River ECS count represents a partial count of only a portion of the wild Noyo River population. It is provided here to give a general sense of coho numbers in this subbasin relative to the basin as a whole and numbers should not be compared to viability standards. Data are from Harris (2010) and Grass (1999-2009).

† Mean values assume two spawners per redd. Values are based on combined redd counts from Lagunitas Creek and Olema Creek. Lagunitas data are from Ettlinger et al. (2010); Olema Creek data are from M. Reichmuth, National Park Service, Point Reyes National Seashore, unpublished data.

The only other independent population for which information is available is the Noyo River. Here, two separate time series of abundance are available. Counts of coho salmon have been made annually at the Noyo Egg Collecting Station (ECS) on the South Fork Noyo River since the 1960s (Grass 1999–2009; Harris 2010). These data represent only a portion of the Noyo population (roughly one-third of the watershed lies upstream of the ECS), and interpretation of the data is confounded by three complications: (1) counts from 1963 to 1998 consist of a mix of hatchery and wild fish, which were not discriminated during counting; (2) the station was not operated continuously during most years prior to 1998, so the counts underestimate the total number of fish that passed upstream; and (3) some fish are able to pass over the weir without being counted, also leading to underestimation of population size above the weir. Beginning with the 1997–1998 spawning year class, hatchery fish were marked, allowing hatchery and wild fish to be tallied separately, though releases of hatchery fish ceased in the early 2000s and the last hatchery-origin fish were captured in 2006. Despite these limitations, it is clear that adult returns to the South Fork Noyo River have declined substantially since the 1960s and 1970s and have continued to decline in recent years, with fewer than 80 fish being recorded at the weir in each of the last 5 years (Figure 1b). The 12-year trend in number of wild fish was negative, though not statistically significant ($p = 0.119$) (Table 5). A shorter time series of adult abundance for the entire Noyo Basin, which combines several methods of estimation and includes hatchery fish (see Appendix), indicates that the average annual abundance declined from an estimated 668 fish between 2001–2003 to 513 fish from 2006–2010 (S. Gallagher, California Department of Fish and Game, Fort Bragg, unpublished data). No trend was calculated for this time series as there were two years without population estimates.

Monitoring of coho salmon has also been ongoing for five dependent populations of coho salmon in the ESU. For three of these (Pudding Creek, Caspar Creek, and Little River), adult abundance estimates based on redd counts assuming one redd per female, mark-recapture estimates, or a combination of the two have been made since 2000 or 2001 (S.

Table 6. Estimated population abundance and trends for dependent populations of coho salmon in the CCC Coho Salmon ESU. NA indicates not available or applicable.

Population	Years of data	$N_{a(arith)}$	$N_{a(geom)}$	$N_{g(harm)}$	T (95% CI)
Pudding Creek*	10	494	272	980	-0.318 (-0.620, -0.016)
Caspar Creek*	11	155	83	217	-0.228 (-0.463, 0.007)
Little River*	11	40	16	30	-0.277 (-0.521, -0.033)
Redwood Creek	12	29**	NA	NA	-0.159 (-0.3935, 0.075)
Scott creek	8	47 [†]	NA	NA	NA

* Data from Gallagher and Wright (2008) and S. Gallagher, CDFG, Fort Bragg, unpublished data.

** Value is average redd count, not a population estimate.

[†] Data in several years of extremely low abundance were insufficient to produce reliable population estimates; thus, actual counts were used. The mean value reported likely represents a slight underestimate.

Gallagher, California Department of Fish and Game, Fort Bragg, unpublished data; see Appendix). In all three cases, population trends have been downward (Figures 1c, 1d, and 1e), significantly so for Pudding Creek (slope = -0.318; $p = 0.041$) and Little River (slope = -0.277; $p = 0.031$), and marginally so for Caspar Creek (slope = -0.228; $p = 0.0561$) (Table 6). Pudding Creek is the largest of these populations, with an estimated average of 494 spawners annually. Caspar Creek averaged 155 spawners over 11 years, and Little River approximately 40 (Table 6). Coho redd counts have been made by the National Park Service in Redwood Creek (Marin County) annually since 1999 (M. Reichmuth, National Park Service, Point Reyes National Seashore, unpublished data). Counts have ranged from 0 to 93 during this 12-year period and trended downward (Figure 1f), though the decline is not statistically significant (slope = -0.159; $p = 0.162$). And finally, counts of adult coho salmon have been made at the Scott Creek weir (Santa Cruz County) since 2003 (S. Hayes, National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division, Santa Cruz, unpublished data). In 5 of 8 years, counts have been too low (fewer than 15 fish) to produce reliable estimates of abundance; however, the population has declined precipitously since the 2003-2004 and 2004-2005 spawning seasons when an estimated 272 and 329 adults returned, respectively (Figure 1g). During those two seasons, slightly more than half the returning fish were of hatchery origin. In the last four years, only 5 of 28 adults (including jacks) captured have been of wild origin.

Other data

From 2006 to 2008, researchers at the Fisheries Ecology Division of NMFS Southwest Fisheries Science Center undertook a study of juvenile coho salmon distribution and abundance in coastal streams of Santa Cruz and San Mateo counties at the southern end of the CCC Coho Salmon ESU's range. During each year of the three-year study, 46–47 randomly selected 1-kilometer reaches (approximately 13–15% of the accessible stream kilometers) were surveyed using mask and snorkel. In 2006, juvenile coho salmon were found at 2 of 46 sites (San Vicente and Scott creeks). In 2007, coho salmon were not

detected at any of the 47 sites surveyed. In 2008, coho salmon were found at 5 of 46 sites surveyed, with each site occurring in a different watershed (San Gregorio, Waddell, Scott, San Vicente, and Soquel creeks); however, in all cases, the numbers of coho were small, with fewer than 180 individuals total observed in any one stream (B. Spence, National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division, Santa Cruz, unpublished data). Genetic analysis of fish from the three sites with the largest numbers of fish in 2008 indicated that the juveniles observed were likely the result of no more than one or two successful spawning pairs in each case (Spence et al. 2011). Other juvenile sampling efforts in the area reported a similar scarcity of coho salmon in streams south of San Francisco since 2005 (Smith 2009, 2010). These observations confirm that all natural populations south of San Francisco are extinct or nearly so.

3.4 Discussion

Although long-term data on adult abundance for populations within the CCC Coho Salmon ESU remain scarce, all available evidence from shorter-term research and monitoring efforts indicate that conditions have worsened for populations in this ESU since the last formal status review was published (Good et al. 2005). For all available time series, recent population trends have been downward, in about half the cases significantly so, with particularly poor returns during the period 2006 to 2010. Additionally, it is evident that many independent populations are well below low-risk abundance targets, and several are, if not extinct, likely below their high-risk depensation thresholds (e.g., San Lorenzo River, Pescadero Creek, Russian River, Gualala River, Garcia River) specified by the TRT (Table 4). Though population-level estimates of abundance for most independent populations are lacking, it does not appear that any of the five diversity strata currently supports a single viable population as defined by the TRT's viability criteria. In summary, the risk of extinction for CCC Coho Salmon ESU appears to have increased since 2005, when Good et al. (2005) concluded that the ESU was in danger of extinction.

The inclusion of Aptos and Soquel creek populations in the definition of this ESU does little to affect the interpretation of the status of the ESU as a whole. The recent observation of juvenile coho salmon in Soquel Creek adds an additional watershed within the Santa Cruz Mountain diversity stratum for which recent successful reproduction has been documented; however, it remains clear that all extant populations south of the Golden Gate are at precariously low numbers and that this stratum is at high risk of extinction.

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Appendix. Population data for independent and dependent populations of coho salmon in the CCC Coho Salmon ESU from the 1998–1999 spawning season through the 2009–2010 season. Data sources include Sean Hayes, NMFS Southwest Fisheries Science Center, unpub. data (Scott Creek); Michael Reichmuth, National Park Service, Point Reyes National Seashore, unpub. data (Redwood Creek); MMWD (2010) and M. Reichmuth (Lagunitas Creek); Sean Gallagher, CDFG, unpub. data (Little River, Caspar Creek, Pudding Creek, Noyo River); Grass 1999-2009 and Harris 2010 (S. Fk Noyo River ECS).

Year	Population/Method							
	Scott Cr.	Redwood Cr.	Lagunitas Cr. ^b	Little R.	Caspar Cr.	Noyo R.	S. Fk. Noyo R.	Pudding Cr.
	mark-recapture estimate	redd count	redd count	estimate: one redd/female	estimate: one redd/female	redd count w/ spawner:redd expansion	weir count	mark-recapture estimate
1998-1999		58	226				70	
1999-2000		7	213	16	87		58	
2000-2001		35	290	20	106	950	86	279 ^d
2001-2002		47	344	88	386	568	144	524 ^d
2002-2003	5 ^a	7	163	45	91	487 ^c	297	367 ^d
2003-2004	123	43	471	91	238	no data	310	1204
2004-2005	200	93	588	152	548 ^c	no data	183	1167
2005-2006	46	12	192	14	126 ^c	1394	74	709
2006-2007	2	21	404	5	54	330	59	401
2007-2008	2 ^a	0	177	2	16	259	15	228
2008-2009	1 ^a	2	27	4	6	294	19	50
2009-2010	0 ^a	23	65	2	46	286	46	9 ^d

^a Values for indicated years are weir counts; too few fish were captured to generate reliable population estimates.

^b Redd totals included combined counts from Lagunitas, Devils Gulch, Nicasio, San Geronimo, and Olema creeks.

^c Estimates based on live fish mark-recapture

^d Estimates based on assumption of one redd per female.

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