6.0 POPULATION STRUCTURE & VIABILITY

"In summary, the lack of demonstrably viable populations…and substantial gaps in the distribution of coho salmon throughout the CCC ESU strongly indicate that this ESU is currently in danger of extinction."

Spence et al. 2008

6.1 INTRODUCTION

Salmonid populations have persisted in great abundance for nearly a million years; their persistence contingent on ecological, biological and evolutionary dynamics across both space and time. These historical conditions represent a baseline for population structure and viability with the assumption that as a population departs from its historical baseline, the greater the risk of extinction. For the CCC coho salmon ESU to be removed from the Federal ESA, criteria related to the number, size, trends, structure, *etc.* and the timeframes (*e.g.*, 100 years) to sustain these biological conditions must be met. To inform the recovery or "delisting" criteria, the TRT prepared two NOAA Technical Memoranda characterizing the historical population structure and biological viability criteria for the NCCC Domain salmon and steelhead ESUs/DPSs (Bjorkstedt *et al.*, 2005, Spence *et al.*, 2008). These memoranda provide the fundamental criteria to assess the biological status of populations and their risk of extinction. This chapter provides a summary of these memoranda.

6.2 VIABLE POPULATIONS & HISTORICAL STRUCUTRE

The viable salmonid population (VSP) concept was developed by McElhany *et al.* (2000) and adopted by NMFS as the approach to define viability and determine risk of extinction. This approach evaluates abundance, productivity, spatial structure, and diversity across three levels: ESU or DPS, Diversity Strata, and population. For salmon and steelhead in the NCCC Recovery Domain, the VSP concept was expanded by considering two population characteristics independently: "*…viability, defined in terms of probability of extinction over a specified time frame*

and independence, defined in terms of the influence of immigration on a population's extinction probability" (CDFG 2004).

6.2.1 HISTORICAL POPULATION STRUCTURE

Understanding viability, probabilities of extinction and the influence of immigration on extinction probabilities required some knowledge of, and accounting for, "*characteristics that contribute to a populations' viability and thus their contribution to the persistence of the ESU*" (Bjorkstedt *et al.* 2005). Understanding the historical role these characteristics played for population viability is the underpinning of VSP. Since "*…historical patterns of population abundance, productivity, spatial structure and diversity form the reference conditions about which we have a high confidence that the ESUs…had a high probability of persisting over long periods of time. As populations depart from these historical conditions, their probability of persistence declines and their functional role with respect to ESU viability may be diminished*" (Spence *et al.* 2008).

The development of the historical structure included:

- Modeling the historical intrinsic potential of streams to support adult spawning and juvenile rearing;
- Compilation and review of historical records on population size and distribution;
- Defining populations and their viability in context to the ESU;
- Grouping populations into geographical units within an ESU; and
- Analyzing genetic structure, historical out-of-basin transfers and other information (See Bjorkstedt *et al.* 2005).

6.2.2 MODELING INTRINSIC POTENTIAL OF HISTORICAL HABITATS

Due to a lack of detailed population data, Bjorkstedt *et al.* (2005), used the concept of intrinsic potential (IP) to estimate potential habitat and historical carrying capacity of CCC coho salmon streams. Population size affects a species' viability and extinction risk and size is supported by extent and quality of habitats. Spawning and rearing habitats for adult and juvenile salmon and steelhead are largely determined by the interactions of landform, lithology, and hydrology

relatively constant over long time scales which govern movement and deposition of sediment, large wood and other structural elements along a river network (Agrawal *et al.* 2005). To account for these controls and the differences in habitat suitability across a watershed, three habitat parameters were modeled to serve as a predictor of historical habitat attributes: channel gradient, valley width and mean annual discharge. Each of the three attributes were weighted between zero to one as to their potential to provide quality habitat with lower quality habitats scoring low and higher quality habitats scoring near one. For example, narrow valley widths and steep channel gradients are less likely to provide good spawning habitats while wider valley widths and low gradients are more likely to provide higher quality spawning and rearing habitats. The IP score for each reach in a watershed was multiplied by its respective reach length, and the values summed to estimate IP in km within a watershed that support spawning and rearing. These weighted IP-km, which is not a linear measurement, were used to calculate the likely historical carrying capacity of adult salmonids. Depending on watershed size, 20 to 40 spawners per km were calculated against the amount of IP in a watershed to determine a population size that would represent a low risk of extinction.

Discrepancies were observed between the predicted IP for CCC coho salmon and historical record accounts. A summer water temperature component was then included to address discrepancies in the model for coho salmon because water temperature is a strong indicator of presence and survival of summer rearing juveniles. Historical records for distribution of CCC coho salmon were reviewed (Spence *et al.* 2005) and a mean August air temperature that exceeded 21.5° C (following isolines) was applied to the model (*i.e.,* temperature mask) to exclude areas where streams were likely too consistently warm for coho salmon (Figure 15). The resulting outputs were more consistent with historical records. The historical abundances are displayed in Bjorkstedt *et al.* 2005 and Spence *et al.* 2008.

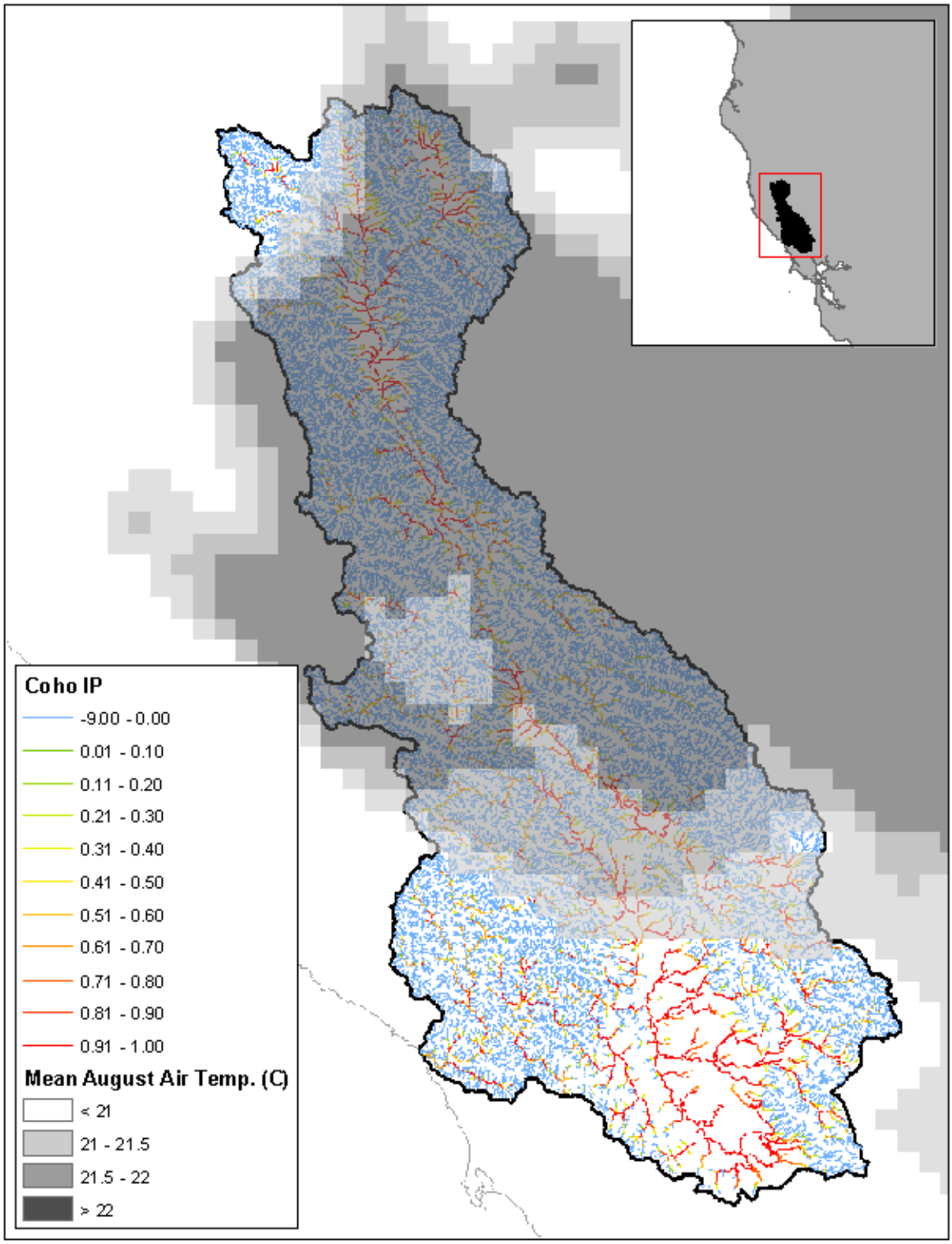

Figure 15: Temperature mask for CCC coho salmon IP in the Russian River. The dark shaded region was excluded due to high mean air temperature.

Uncertainty exists with the IP model outputs, including a likely bias to over or underestimate IP and historical habitat potential. Nonetheless, a benefit of the IP model is that it takes into account differences in intrinsic habitat potential in an objective and transparent manner. This objectivity precluded subjective judgments regarding whether or not habitat historically supported spawning and rearing salmonids, which is often very difficult to determine in light of currently degraded habitat conditions and poor historical records. Comparing modeled IP-based results of spawner abundance to the few historical records of abundance was conducted by Spence (pers. comm. 2008) and indicated, in the majority of cases, that modeled adult abundances were lower than those observed during the 1930s into the 1950s. The conclusion: projected spawner abundance targets did not overestimate natural carrying capacity for most populations within the ESU.

6.2.3 CLASSIFYING POPULATIONS FOR THE CCC COHO SALMON ESU

Population size (*e.g.,* spawner abundance) and genetic exchange of populations determines ESU viability and extinction risk. A population is "…*a group of fish of the same species that spawns in a particular locality at a particular season and does not interbreed substantially with fish from any other group.*" (Bjorkstedt *et al*., 2005). A "viable" population is "…*a population having a low (<5%) probability of going extinct over a 100-year time frame*" and an "Independent" population "…*as one for which exchanges with other populations have negligible influence on its extinction risk"* (Bjorkstedt *et al*. 2005) or otherwise termed "viable-in-isolation." To distinguish between "viable" and "non-viable" populations the TRT evaluated each populations potential to be "viable-in-isolation" and their measure of "self-recruitment". Self-recruitment "is the proportion of a populations' spawning run that is of native origin" (Bjorkstedt *et al*., 2005). The TRT used the likely historical population abundance as a proxy for assessing viability-in-isolation. The self-recruitment analysis was framed by (1) understanding an individual will attempt to return to its natal watershed and (2) population dynamics are dominated by both internal processes and external dynamics (*e.g.,* straying). This analysis assisted the TRT "…*in identifying the functional role different populations historically played in ESU persistence*" (Bjorkstedt *et al*. 2005 *in* Spence *et al*. 2008).

The TRT determined at least 32 IP-km were required for a population of coho salmon to be viable-in-isolation. This value was selected for consistency with other TRTs in California and Oregon and was based on a simulation analysis of Nickelson and Lawson (1998).

Three types of populations were defined:

- "Functionally Independent Populations" (FIPs): Populations with a high likelihood of persisting over 100-year time scales due to their population size and relatively independent dynamics (*i.e.*, negligible influence of migrants from neighboring populations on extinction risk);
- "Potentially Independent Populations" (PIPs): Populations with a high likelihood of persisting in isolation over 100-year time scales due to large population size, but were likely too strongly influenced by immigration from other populations to exhibit independent dynamics; and
- "Dependent Populations" (DPs): Populations with a substantial likelihood of going extinct within a 100-year time period in isolation due to smaller population size, but receive sufficient immigration to alter their dynamics and reduce extinction risk.

The independence of a population establishes its relative importance to ESU viability. For example, a large population (*e.g.*, Functionally Independent Population) likely functions as a regular source of surplus individuals (through straying) to smaller populations (*e.g.*, Dependent Populations). Straying adds resilience to the ESU when smaller populations are impacted by adverse environmental conditions (*e.g.*, catastrophic wildfire, *etc.*). Surplus individuals from large populations can re-colonize these watersheds overtime. This resilience confers more importance onto large populations for their role in the viability and recovery of the ESU. Notwithstanding, the role of dependent populations are very important in situations where associated historical independent populations are extirpated or at a high risk of extirpation. In these cases, dependent populations can become the vital source of colonizers and genetic diversity to support restoration of the extirpated populations associated with the larger watersheds.

6.2.4 GROUPING POPULATIONS: ESU DIVERSITY STRATA

Diversity Strata, or boundaries that group populations, were delineated for the ESU and are "*geographically proximate populations that reflect the diversity of selective environments, phenotypes and genetic variation across the ESU*" and are "*described in terms of geography and a generally similar set of environmental and ecological conditions*" (Bjorkstedt *et al.*, 2005).

6.2.5 RESULTS FROM HISTORICAL STRUCTURE ANALYSIS

The TRT identified 11 "functionally independent", one "potentially independent" (Figure 16) and 64 "dependent" populations in the CCC coho salmon ESU (Bjorkstedt *et al.*, 2005 with modifications described in Spence *et al.* 2008). The 75 populations were grouped into five Diversity Strata (Figure 16, Figure 17). Five thousand one hundred and ninety four (5,194) IP-km were identified across the historical CCC coho salmon ESU[13]. Watershed boundaries delineate each population for CCC coho salmon ESU.

The advised application of the TRT historical structure is outlined in Bjorkstedt *et al.* (2005): *"Increasing divergence from this baseline almost certainly decreases the ability of the ESU to persist. The functional relationship between departure from historical conditions and extinction risk for the ESU is probably non-linear, such that the loss of a few populations–particularly small populations–from an otherwise intact ESU may not greatly reduce ESU viability, whereas the loss of key populations or the loss of populations from an already diminished ESU will have more profound implications for the persistence of the ESU. Uncertainty associated with the form of this relationship must be accounted for in assessing the viability of any proposed ESU configurations that departs from historical conditions. Understanding the historical population structure of an ESU is essential to reducing the consequences of this uncertainty, as information on the historical role of specific populations in the ESU supports a biologically relevant context for recovery planning.* ***Simply put, populations that were important to ESU persistence in the past, if restored or preserved, are likely to be important to ESU persistence in the future"***(emphasis added). See Bjorkstedt *et al.* (2005) for more information.

[13] The recovery scenario for CCC coho designated 28 focus watersheds and 11 supplemental populations. The total historical IP-km of the 28 watersheds is 1736 km or 33 percent of the historical total.

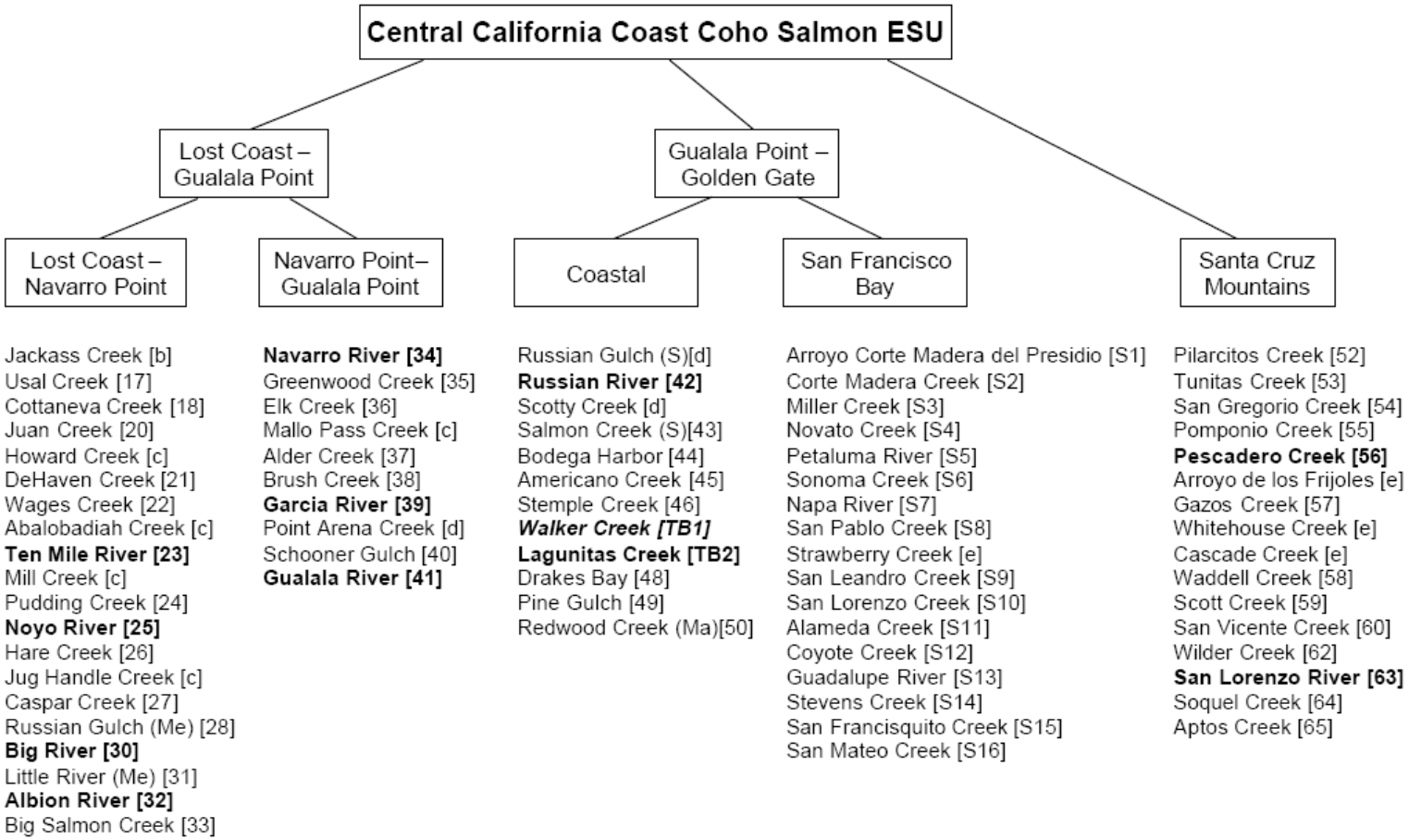

Figure 16: Historical population structure of the CCC coho salmon ESU, arranged by Diversity Strata. Independent population are in bold, potentially independent populations are in italics and dependent populations are all others.

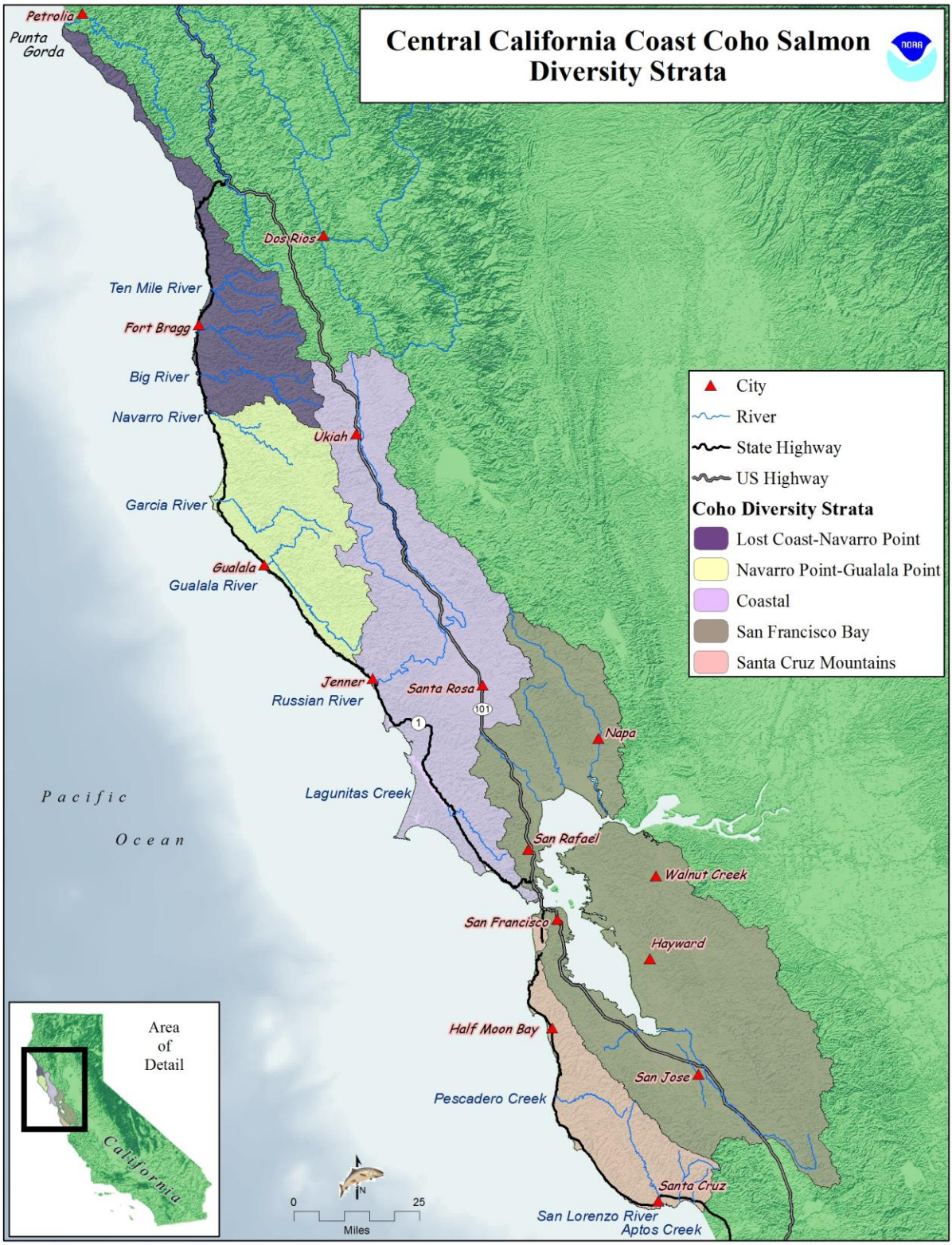

Figure 17: CCC coho salmon Diversity Strata

6.2.6 BIOLOGICAL VIABILITY CRITERIA

Spence *et al.* (2008) developed biological viability criteria for the ESU, Diversity Strata and populations consistent with the three levels of biological organization outlined by Bjorkstedt *et al.* (2005) important for the long term persistence of CCC coho salmon. These criteria are described in the two categories of: "Population Viability Criteria" and "ESU Viability Criteria". The biological viability criteria "*…defines sets of conditions or rules that, if satisfied, would suggest that the ESU is at low risk of extinction*" (Spence *et al.* 2008). These general conditions require: (1) achieving population viability across selected populations and (2) attaining the necessary number and configuration of these viable populations across the landscape. ESU and population viability was considered by (Spence *et al.* 2008) using "*two distinct but equally important perspectives*": (1) population viability in relation to its historical function and (2) minimum population size.

6.2.7 POPULATION VIABILITY CRITERIA

Criteria were developed that constitute a viable population (Table 7) and categorized into extinction risk categories of abundance, population growth rate, population spatial structure and population diversity (McElhany *et al.* 2000):

- Abundance is the number of adult spawners measured over a time based on life history;
- Population growth rate (*i.e.*, productivity) is a measure of a populations' ability to sustain itself overtime (*e.g.*, returns per spawner);
- Population spatial structure describes how populations are arranged geographically based on dispersal factors and quality of habitats; and
- Population diversity is the underlying genetic and life history characteristic providing for population resilience and persistence across space and time.

For a population to be viable it must be large enough to (1) have a high probability of surviving environmental variation, (2) compensate for disturbances, (3) maintain genetic diversity, and (4) functionally contribute to associated ecosystems. The criteria provides information on (1)

likelihood of extinction, (2) effective population size or total population size, (3) population decline, (4) catastrophic decline, (5) spawner density, and (6) hatchery influence (Table 7).

Table 7: Population Extinction Risk Criteria (Spence *et al.* 2008)

Population Characteristic	Extinction Risk		
	High	**Moderate**	**Low**
Extinction risk from population viability analysis (PVA)	≥ 20% within 20 yrs	≥ 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 *-or-* Total population size per generation	$N_e \leq 50$ *-or-* $N_g \leq 250$	$50 < N_e < 500$ *-or-* $250 < N_g < 2500$	$N_e \geq 500$ *-or-* $N_g \geq 2500$
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] ≤ 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) <u>*or*</u> $N_a > 500$ but declining at a rate of ≥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. Figure 5 summarizes 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.

6.2.8 ESU VIABILITY CRITERIA

Four criteria were developed that, collectively, constitute a configuration in the number and distribution of viable and non-viable populations likely providing for ESU persistence over 100 year time frame (*i.e.*, viable). There may be several plausible scenarios of population viability that could satisfy ESU-level criteria (Spence *et al.*, 2008). The goals of the ESU criteria are to reduce the risk of extinction by ensuring: (1) connectivity between populations, (2) representation of ecological, morphological, and genetic diversity, and (3) redundancy in populations to minimize risks associated with catastrophic events.

In characterizing a viable ESU the TRT applied the hypothesis that populations, as they functioned in their historical context, were highly likely to persist and that "…*increasing departure from historical characteristics logically requires a greater degree of proof that a population is indeed viable*" (Spence *et al.* 2008). Due to the likely historical roles of functionally independent or potentially independent populations, these populations form the foundation of the ESU viability criteria. Dependent population criteria were also developed to ensure reservoirs of genetic diversity, account for the extirpation of FIPs in the ESU, connectivity between FIPs, reduced risk of ESU extinction, to provide a vital source of colonizers for extirpated populations and to buffer impacts resulting from poor ocean conditions and disturbances to independent populations.

The four ESU viability criteria are:

(1) Representation Criteria;

1. a. All identified Diversity Strata that include historical FIPs or PIPs within an ESU should be represented by viable population for the ESU to be considered viable.

-AND-

1. b. Within each Diversity Stratum, all extant phenotypic diversity (*i.e.*, major life-history types) should be represented by viable populations.

(2) Redundancy and Connectivity;

2.a. At least fifty percent of historically independent populations (FIPs or PIPs) in each Diversity Stratum must be demonstrated to be at low risk of extinction according to population viability criteria. For strata with three or fewer independent populations, at least two populations must be viable.

-AND-

2.b. 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 FIPs and PIPs.

(3) Remaining populations, including historically dependent populations or any historical FIPs or PIPs not expected to attain a viable status, must exhibit occupancy patterns consistent with those expected under sufficient immigration subsidy arising from the 'focus' Independent populations selected to satisfy the preceding criterion.

(4) The distribution of extant populations, regardless of historical status, must maintain connectivity within the Diversity Stratum, as well as connectivity to neighboring Diversity Strata.