APPENDIX B

CONSERVATION ACTION PLANNING ATTRIBUTES, STRESSES & THREATS REPORT

North Central California Coast Recovery Domain
CCC Coho ESU Recovery Plan

Conservation Action Planning
Key Attributes, Stresses and Threats Report

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INTRODUCTION

As described in Chapter 7 (Methods) of the Plan, NOAA's National Marine Fisheries Service (NMFS) assessed instream and watershed conditions and threats using a method developed by The Nature Conservancy (TNC) in collaboration with the World Wildlife Fund, Conservation International, Wildlife Conservation Society and others called Conservation Action Planning (CAP). The CAP protocols and standards were developed by the Conservation Measures Partnership, a partnership of ten different non-governmental biodiversity organizations (www.conservationmeasures.org). The method is a "structured approach to assessing threats, sources of threats, and their relative importance to the species' status." The CAP process was adopted as the recovery planning assessment tool for the North Central California Coast (NCCC) Recovery Domain in 2006. CAP is a sophisticated Microsoft Excel-based tool adaptable to the needs of the user. The NMFS application of the CAP protocol included (1) defining current conditions for habitat attributes across freshwater life stages believed essential for the long term survival of Central California Coast (CCC) coho salmon, and (2) identifying activities reasonably expected to continue, or occur, into the future that will have a direct, indirect, or negative effect on life stages, populations and the ESU (*e.g.*, threats). The results of this assessment provided an indication of watershed health and likely threats to coho salmon survival and recovery. These results are used to formulate recovery actions designed to improve current conditions (restoration strategies) and abate future threats (threats strategies). The CAP can also track and summarize large amounts of information for each population over time, and can be adapted and iterative as new information becomes available.

CONSERVATION ACTION PLANNING OVERVIEW

CAP was developed in collaboration with the World Wildlife Fund, Conservation International, Wildlife Conservation Society and others. CAP is a planning tool used to evaluate, prioritize, and address threats to ecosystems and species. CAP is aligned with a set of open standards[1] that were developed by the Conservation Measures Partnership; a partnership of 10 different biodiversity non-governmental organizations. CAP has been applied to more than 400 landscapes in 25 countries, and TNC has officially adopted CAP as its standard conservation planning tool. CAP is also recommended in the NMFS Interim Endangered and Threatened Species Recovery Planning Guidance (Crawford and Rumsey 2011) as a preferred method to assess threats and develop recovery strategies for federally-listed marine and anadromous species.

In 2006, NMFS Southwest Region, Protected Resources Division, North Central Coast Office, partnered with TNC for their assistance and support in applying the CAP framework (*e.g.*, CAP workbook) to NCCC recovery plans. The hands-on training and interactions with TNC staff facilitated development of a customized CAP workbook template used initially for coho salmon, and expanded and modified for the other salmonid species in the NCCC Recovery Domain. Other NMFS recovery domains in California are also using the CAP workbook, or a modified version of the process, to develop their recovery plans.

A CAP workbook was created for each of the 28 focus populations and each workbook has two assessment components: viability (evaluating current conditions) and threats (evaluating future stresses and source of stress). The CAP workbooks provided a foundation to analyze key habitat, landscape and watershed factors relative to specific life stage requirements of salmonids. The CAP workbooks were

[1] More information about the open standards is available at "conservationmeasures.org."

used to identify and analyze current conditions and, ongoing and future stresses and threats to each population. Key attributes define current conditions for each targeted salmonid population, while stresses and threats define current conditions and conditions in the future. The analysis of key attributes is a distinct and separate analysis from the analysis of stresses and threats. The CAP workbooks also provided rationale and transparency in development of specific recovery actions, and prioritization of recovery actions designed to improve habitat attributes ranked as "poor", and reduce stresses and threats ranked as "high" or "very high."

This report provides the rationale, analysis steps, and references behind habitat, landscape and watershed attributes and indicator results and ratings within the CAP workbook viability table. The viability table was used to assess the status of current conditions for CCC coho salmon. This report also provides similar rationale, analysis steps, and references for the stress and threat analysis portion of the CAP workbook.

Assessing Current Conditions: The Viability Table

Viability describes the status or health of a population of a specific plant or animal species (TNC 2007). More generally, viability indicates the ability of a conservation target to withstand or recover from most natural or anthropogenic disturbances and thereby persist for many generations or over long time periods. The viability table within each CAP workbook provides an objective, consistent framework for defining the current status and the desired future condition of a conservation target, while tracking changes in the status of a conservation target over time. The viability table defines specific life stages for each species as "conservation targets", and provides the structure for an assessment of current conditions supported by data from NMFS, other agencies, recovery partners, and the scientific literature.

Conservation Targets

Because salmonid habitat use varies substantially by species and life stage, targets for specific life stages and an additional target to evaluate watershed processes were defined. Discrete life stages were used to assess habitat attributes during critical time frames of the species life history. The targets used in the workbooks and their definitions are described below:

- Spawning Adults – Includes adult fish from the time they enter freshwater, hold or migrate to spawning areas, and complete spawning (September 1 to March 1);
- Eggs – Includes fertilized eggs deposited into redds and the incubation of these eggs through the time of emergence from the gravel (December 1 to April 1);
- Summer Rearing Juveniles – Includes juvenile rearing in streams and estuaries (when applicable) during summer and fall (June-October) prior to the onset of winter rains;
- Winter Rearing Juveniles – Includes rearing of juveniles from onset of winter rains through the winter months up to the initiation of smolt outmigration (November 1 to March 1);
- Smolts – Includes juvenile migration from natal rearing areas until they enter the ocean (March 1 to June 1); and
- Watershed processes - Includes instream habitat, riparian, upslope watershed conditions and landscape scale patterns related to landuse.

Key Attributes

Key attributes are defined as critical components of a conservation target's biology or ecology (TNC 2007). Viable populations result when key attributes function and support transitions between life history stages. By this definition, if attributes are missing, altered, or degraded then it is likely the species will experience more difficulty moving from one life stage to the next. Factors with the greatest potential to impair survival across life stages and limit salmonid production at the population scale were defined as key attributes.

Two categories of attributes describe aspects of the aquatic habitat and watershed processes that affect aquatic and riparian habitats (habitat condition and landscape context attributes), while a third (population size) describes viability parameters (*e.g.*, abundance and distribution) for salmonids. Each attribute is described below.

Indicators and Indicator Ratings

Indicators are a specific habitat, watershed process or population parameter providing a method to assess the status of a key attribute. An attribute may have one or more indicators, and each indicator is an objective, measurable aspect of an attribute (Table 1). Each indicator has a rating which is a reference value describing the conditions of the key attribute as it relates to life stage survival. These conditions are rated as poor, fair, good or very good. Most reference values or indicator ratings were developed using established values from published scientific literature. Measurable quantitative indicators were used for most indicators; however, the formulation of other more qualitative decision making structures were used when data were limited. Qualitative decision structures were used to rate three attributes: instream flow conditions, estuary conditions, and toxicity.

Table 1. CCC coho salmon CAP attributes and indicators by

CCC Coho Population Conditions By Target Life Stage		
Target	Attribute	Indicator
Adults	Habitat Complexity	Large Wood Frequency (BFW 0-10 meters)
		Large Wood Frequency (BFW 10-100 meters)
		Pool/Riffle/Flatwater Ratio
		Shelter Rating
	Hydrology	Passage Flows
	Passage/Migration	Passage at Mouth or Confluence
		Physical Barriers
	Riparian Vegetation	Tree Diameter (North of SF Bay)
		Tree Diameter (South of SF Bay)
	Sediment	Quantity & Distribution of Spawning Gravels
	Velocity Refuge	Floodplain Connectivity
	Water Quality	Toxicity
		Turbidity
	Viability	Density
Eggs	Hydrology	Flow Conditions (Instantaneous Condition)
		Redd Scour
	Sediment	Gravel Quality (Bulk)
		Gravel Quality (Embeddedness)
Summer Rearing Juveniles	Estuary/Lagoon	Quality & Extent
	Habitat Complexity	Large Wood Frequency (Bankfull Width 0-10 meters)
		Large Wood Frequency (Bankfull Width 10-100 meters)
		Percent Primary Pools
		Pool/Riffle/Flatwater Ratio
		Shelter Rating
	Hydrology	Flow Conditions (Baseflow)
		Flow Conditions (Instantaneous Condition)
		Number, Condition and/or Magnitude of Diversions
	Passage/Migration	Passage at Mouth or Confluence
		Physical Barriers
	Riparian Vegetation	Canopy Cover
		Tree Diameter (North of SF Bay)
		Tree Diameter (South of SF Bay)
	Sediment (Food Productivity)	Gravel Quality (Embeddedness)
	Water Quality	Temperature (MWMT)
		Toxicity
		Turbidity
	Viability	Density
		Spatial Structure
Winter Rearing Juveniles	Habitat Complexity	Large Wood Frequency (Bankfull Width 0-10 meters)
		Large Wood Frequency (Bankfull Width 10-100 meters)
		Pool/Riffle/Flatwater Ratio
		Shelter Rating
	Passage/Migration	Physical Barriers
		Tree Diameter (North of SF Bay)
		Tree Diameter (South of SF Bay)
	Sediment (Food Productivity)	Gravel Quality (Embeddedness)
	Velocity Refuge	Floodplain Connectivity
	Water Quality	Toxicity
		Turbidity
Smolts	Estuary/Lagoon	Quality & Extent
	Habitat Complexity	Shelter Rating
	Hydrology	Number, Condition and/or Magnitude of Diversions
		Passage Flows
	Passage/Migration	Passage at Mouth or Confluence
	Smoltification	Temperature
	Water Quality	Toxicity
		Turbidity
	Viability	Abundance
Watershed Processes	Hydrology	Impervious Surfaces
	Landscape Patterns	Agriculture
		Timber Harvest
		Urbanization
	Riparian Vegetation	Species Composition
	Sediment Transport	Road Density
		Streamside Road Density (100 m)

Each indicator has a set of indicator rating criteria representing quantitative or qualitative reference values describing the conditions of the key attribute as it relates to life stage survival and transition. These indicator rating criteria provide an assessment of the current health of each attribute across a population expressed through the most recent measurement for the indicator (TNC 2007). Any given attribute will vary naturally over time, and is considered within an acceptable range when meeting defined critical thresholds (TNC 2007). The status of the attribute can then be expressed in context (when the measurement is compared to indicator rating criteria) which are defined by quantitative thresholds to describe the range of variation. These conditions are rated as poor, fair, good or very good according to the following criteria:

Very Good	The indicator is in an ecologically desirable status, requiring little intervention for maintenance. Very good values were considered fully functional to allow complete life stage function and life stage transition.
Good	The indicator is within an acceptable range of variation, with some intervention required for maintenance. Good values were considered functional but slightly impaired.
Fair	The indicator is outside acceptable range of variation, requiring human intervention. Fair values were considered functional but significantly impaired.
Poor	Restoration is increasingly difficult, and may result in extirpation of the target. Poor values are inadequate for life stage transitions.

In watersheds where the majority of indicators were rated as good or very good, overall conditions were likely to be functional and support transitions between life stages within the historical range of variability.

The quantitative indicator rating criteria boundaries and thresholds vary by indicator and attribute type (*e.g*., condition, landscape or size). NMFS utilized references from the scientific literature and other sources to establish the quantitative ranges and thresholds for each of the rating categories for each indicator. In some cases, only the upward (*e.g*., good) and lower (*e.g*., poor) limits of each indicators' range were available from the scientific literature, so that fair and very good rating boundaries were established via interpolation, or left undefined. Measurable quantitative indicators were used for most indicators; however, the formulation of other more qualitative decision making structures were used when data were limited. Qualitative decision structures were used to rate three attributes: instream flow conditions, estuary conditions, and toxicity. In watersheds where the majority of indicators were rated as good or very good, overall conditions were likely to represent the historical range of variability and supporting transition between life stages.

The scale of available data used for rating an indicator varied by attribute type (*e.g*., condition, landscape and size). For example, landscape attribute data (*e.g*., most land cover data) are available via GIS datasets at the watershed level (*i.e*., population scale), or can be aggregated to a watershed scale. Condition and size attribute data however, are typically collected at much finer scales (*e.g*., site, reach or stream). These data require aggregation at multiple scales to arrive at a population rating. For example, data for many indicators (*e.g*., percent of primary pools) were available at the stream reach (or summarized habitat unit) level and these data must first be aggregated to obtain a stream level rating, then scaled across multiple streams to attain a population or watershed level rating.

Scaled Population Rating Strategy

A scaled population rating strategy was developed within the framework of TNC's CAP process and the intrinsic potential habitat (IP-km) model developed by the Bjorkstedt *et al*. (2005) and Spence *et al*. (2008). The IP-km model used criteria for stream gradient, valley width, and mean annual discharge, to provide quantitative estimates of potential habitat for each population in kilometers (km), with qualitative estimates of the intrinsic potential (IP) weighted (between 0 and 1). These values provided an estimate of the value of each km segment for each species (coho salmon, Chinook salmon, and steelhead) inhabiting a particular watershed. Historical and current IP-km estimates were used to determine historical and current population abundance targets. Known migration barriers were used to evaluate the current extent of IP. In many cases the current IP extent was modified based on the current condition and likely irretrievability of some stream reaches to achieve properly functioning conditions.

Scaled population ratings were based on the relevant contribution each site, reach, and stream makes to the population as a whole. Where data were collected at finer scales, data were aggregated up to arrive at a single rating for a given population. A typical rating scenario involved two to three steps; 1) a rating at the site or reach levels, 2) rating at the stream level, and 3) a rating at the population level, which aggregated multiple stream ratings. Reach and stream level ratings were incorporated into the CAP Workbook analysis for each population.

CDFG stream habitat-typing data, known as the HAB 8 dataset, informed many of the attribute indicators in the CAP Workbook. Data from multiple stream reaches were aggregated to rank each stream based on the criteria for each indicator, and its ability to support a particular life stage or stages. As an example, CDFG considers a primary pool frequency of 50 percent desirable for salmonids (Bleier *et al*. 2003). Primary pool frequency varies by channel depth and stream order[2] therefore, to extrapolate reach scale data upward to the stream scale, rating criteria were established which used a 25 percent boundary from the 50 percent threshold to describe good conditions (*i.e*. the indicator was within acceptable range of variation). Criteria for poor, fair and very good ratings followed the same procedure to establish numeric boundaries for each qualitative category at the stream level scale:

Stream level percent primary pool
Poor = < 25% primary pools;
Fair = 25% to 49% primary pools;
Good = 50% to 74% primary pools; and
Very Good = > 75% primary pools.

Because ratings were ultimately applied at the watershed or population scale, and a population could include multiple streams, stream level ratings were aggregated to obtain a population level rating, and characterize the contribution of each stream/watershed to the population. Good conditions were defined as the level which described an acceptable limit of the variation inherent to each indicator constituting the minimum conditions for persistence of the target. If the indicator measurement lies below this acceptable range, it was considered to be in degraded condition. Specifically, a "good" stream rating was considered the minimum value necessary to complete life stage function and transition. However, all streams cannot be expected to achieve optimal criteria within the entire population, at all places, at all times. To account for natural variation at the population scale, quartile ranges (< 50%, 50-75%, 75-90%, >

[2] Stream order is a hierarchal measure of stream size. First order streams drain into second order streams, and so on. The presence of higher order streams suggests a larger, more complex watershed.

90%) were used for population level rankings to extrapolate stream level data upward to the population scale:

Population level percent primary pool rating criteria
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75% to 90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Represented schematically, Figure 1 illustrates this stepwise aggregation of data to arrive at a watershed level rating for each attribute.

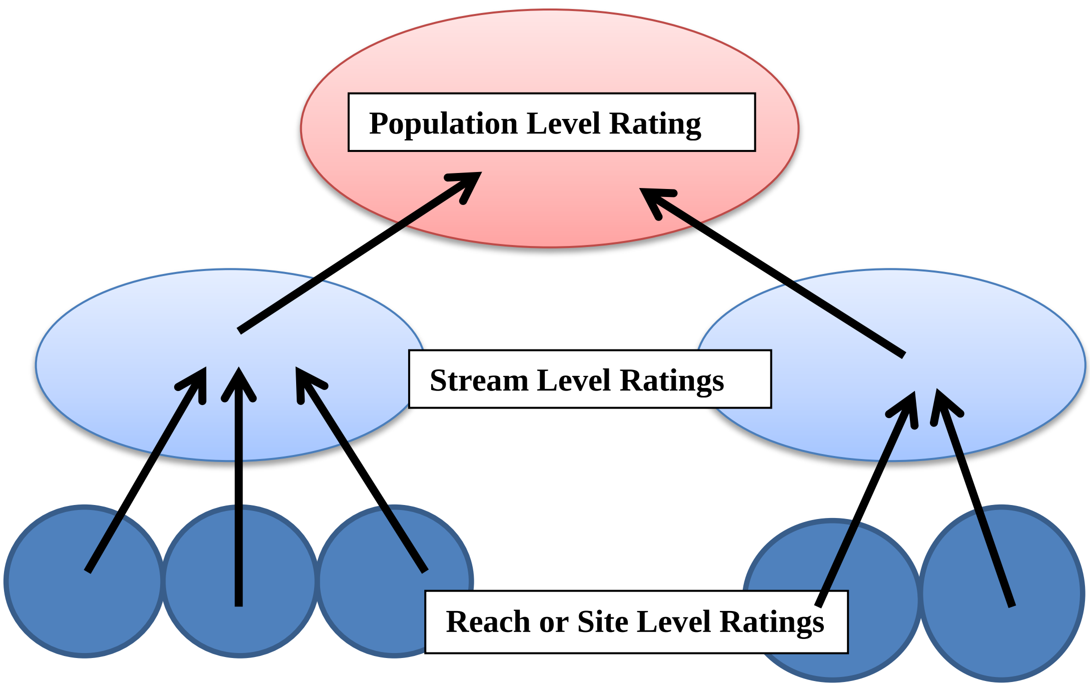

Figure 1. Schematic representation of stepwise aggregation of data, beginning with site or reach specific data, to arrive at a single population or watershed level attribute rating.

Stream attributes are unlikely to meet good conditions across 100 percent of a watershed/population, given the natural variability in geomorphic variables such as reach type, stream order, stream width and gradient, hydrologic variables such as rainfall, biologic factors such as vegetation, and the varying degree of natural disturbances such as fire, flood or drought.

Spatial Analysis

In situations where the percent-of-streams metric deviated from the percent IP-km metric or where the rating criteria is not consistent (*e.g.*, poor vs. good in different streams within the same watershed), the percent IP-km rating criteria was used as the default. In these cases, map based (GIS and Google Earth) analysis tools were used to visually evaluate each streams' contribution to the universe of good quality habitat for each population. Where quantitative measurements were lacking, a qualitative estimate was used based on best available literature, spatial data and IP-km extent and ranges (discussed below). Population level ratings are presented within each population profile (see Volume II) to summarize conditions and for comparative purposes across the ESU.

NMFS GIS staff mapped IP-km extent and value utilizing Google Earth (.kml files) to provide spatial representation of the historical intrinsic potential in for various data layers and analysis. These data were used in combination with the HAB 8 layer (#4 below), to compare the current condition of a given habitat segment to its historical expectation/performance/contribution. The following criteria were used:

1. IP extent and value per Calwater/sub-watershed unit GIS map for each recovery population/watershed provided spatial representation of each streams/sub-watersheds highest percentage IP-km values. IP-km valued habitats were color coded within each Calwater/sub-watershed unit;
2. IP numeric extent and rank per Calwater/sub-watershed unit Excel spreadsheet for each recovery population/watershed provided the numeric information corresponding to the Calwater/sub-watershed highest percentage maps. This spreadsheet included a breakdown of the ratio of IP-km valued habitat within each Calwater/sub-watershed unit; the extent (km) of each IP-km valued habitat within each Calwater/sub-watershed unit; and the total (km) of IP-km valued habitat within a given Calwater/sub-watershed unit;
3. CDFG surveyed reaches (HAB 8 data) were overlaid on Google Earth providing spatial representation of the extent of HAB 8 data. This was utilized in combination with the IP-km layer (#1) to aid the viewer in making a determination of the extent in which a given populations IP-modeled habitat had been surveyed; and
4. Reach scale HAB 8 survey extent overlaid on IP-km modeled habitat on maps to evaluate discrepancies between percent of stream and percent of IP-km rating criteria for a particular indicator. Maps also displayed IP-km modeled habitat color coded by value (high, medium, low) and specific HAB 8 surveyed reach locations.

Confidence Ratings

The assessment of watershed conditions for the indicators defined below relied heavily on CDFG's stream habitat-typing data (HAB 8 dataset[3]). While this dataset provided the best available coverage throughout the NCCC Recovery Domain, it did not cover all IP-km or all watersheds, and in some cases covered only small portions of a watershed.

We analyzed the variable coverage of HAB 8 data across watersheds to measure the confidence in our conclusions at the population scale. Two measures were investigated; 1) the percent of IP-km covered by HAB 8 surveys, and 2) the relative distribution of IP-km values within the surveyed areas compared to the population as a whole.

The percent of IP-km covered gave a measure of sample size. For example, confidence might be low if less than 20 percent of all IP-km in the population were surveyed, which could be significant if this indicator alone characterized the population as a whole. Table 2 shows how confidence increased as a function of increased coverage.

Table 2. Confidence ratings for HAB 8 data as a function of percent of IP-km surveyed.

Confidence	Low	Fair	High	Very High
% Coverage	< 20	20-50	50-80	> 80

[3]Methods for Hab-8 surveys are described in Flosi *et al*. (2004).

To determine whether surveyed areas were representative of habitat throughout the population, we the distribution of IP-km values (between 0 and 1) were compared within the surveyed reaches to the overall distribution of IP-km values in the population. For both sets the average IP-km value and standard deviations (SD) was calculated. The Albion River population for example, had an average IP-km value of 0.58 (SD 0.28). This Albion River comparison provides a relative indication of total surveyed areas compared to other watersheds (0.71 (SD 0.39)).

Putting it all together: Attributes, Indicators and Ratings

This section details all key attributes, indicators, and ratings used in the CAP workbooks and describes methods used to inform those ratings.

Attribute: Estuary/Lagoon

Estuaries and lagoons provide important habitat for the physiological changes young salmonids undergo as they prepare to enter the ocean (smoltification), and provides important habitat for some rearing salmonids.

Condition Indicator: Estuary/Lagoon Quality & Extent for Sumer Rearing and Smolt Targets

Many estuaries and lagoons across the NCCC Domain have been degraded by management actions such as channelization, artificial breeching, encroachment of infrastructure such as highways, bridges, residential and commercial development, and sediment deposition. These and other anthropogenic effects have reduced estuary and lagoon habitat quality and extent.

Ratings:

An estuary protocol was developed using a variety of components of estuary/lagoon habitat using a qualitative decision structure. Rating thresholds were defined in the following manner:

Poor = Impaired/nonfunctional;
Fair = Impaired but functioning;
Good = Properly functioning conditions; and
Very good = Unimpaired conditions.

Methods:

Because data were lacking in many populations a qualitative decision structure was developed to derive ratings for the estuary/lagoon indicator. The protocol provided a structured process to capture and evaluate diverse types of data where it was available, and to apply qualitative assessments where data were lacking. It included three major components:

- General rating parameters applied to all estuaries and lagoons to evaluate the current extent and adverse alterations to the river mouth, hydrodynamics (wetland and freshwater inflow), and artificial breeching;
- Rating parameters for estuaries functioning or managed as open systems from March 15 to November 15 (to include the pre-smolt timing of the summer rearing period); and
- Rating parameters for lagoons currently functioning or managed as close systems from March 15 to November 15 (to include the pre-smolt timing of the summer rearing period).

I. General Rating Parameters for Estuaries and Lagoons

***Includes the pre-smolt timing of the summer rearing period.**

Criteria	Population Name	Confidence/Source
1. Current Extent: Fraction of the Estuary/Lagoon in Natural Conditions		
2. Alteration to River Mouth Dynamics (Estuary Opening Patterns)		
3. Alterations to Hydrodynamics: Inner Estuary/Lagoon Wetlands		
4. Frequency of Artificial Breaching (Seasonal)		
5. Alterations to Freshwater Inflow (refer to Instream Flow Protocol)		
Overall ranking		

1. **Current Extent: Fraction of the estuary and/or lagoon in natural conditions (prior to European settlement); including tracts of salt and freshwater marshes, sloughs, tidal channels, including all other tidal and lagoon inundated areas:**

Very Good	Good	Fair	Poor
≥ 95%	95-67%	66-33%	< 33%

2. **Alteration to river mouth dynamics leading to changes in estuary opening patterns due to jetties, tide gates, roads/railroads, bridge abutments, dredging, and artificial breaching, *etc*.:**

Very Good	Good	Fair	Poor
No modification	Slight modification to estuary entrance, but still properly functioning	Some modification altering the estuary entrance from naturally functioning	Major modification restricting the estuary entrance from properly functioning

3. **Alterations to *INNER* estuary/lagoon hydrodynamics (upstream of the river mouth) due to construction of barriers (dikes, culverts, tide gates, roads/railroads, *etc*.):**

Very Good	Good	Fair	Poor
No impairments	Some impairments; 95-67% of the estuary/lagoon remains hydrologically connected	Impairments, but 66-33% of the estuary/lagoon remains hydrologically connected	Extensive impairments, with <33% of the estuary/lagoon hydrologically connected

4. Frequency of artificial breaching events:

Very Good	Good	Fair	Poor
No artificial breaching occurs: natural variability	<1 artificial breaching event immediately following a rain event; no artificial breaching during the rearing season (March 15 – November 15)	Artificial breaching events only occur prior to significant storm events	Winter and summer breaching events independent of rain events

5. Alterations to freshwater inflow (refer to Instream Flow Protocol for guidance):

Very Good	Good	Fair	Poor
No impoundments within the watershed	Total impoundment volume <20% median annual flow	Total impoundment volume 20-50% median annual flow	Total impoundment volume 51-100% median annual flow

II. **Estuary:** ***Currently Functioning or Managed as an Open System (*Rearing Season: March 15 – November 15)***
***Includes the pre-smolt timing of the summer rearing period.**

Criteria	Population Name	Confidence/Source
Tidal Prism: Estuarine Habitat Zones		
Tidal Range (Flushing Rate)		
Temperature (C): Estuarine Habitat Zones		
Dissolved Oxygen (mg/L): Estuarine Habitat Zones		
Macro-Invertebrates Abundance and Taxa Richness: Estuarine Habitat Zones		
Habitat Elements and Complexity		
Toxicity (Metal, Pesticides, Pollution, *etc*.)		
Exotic Pest Species		
Overall ranking		

1. **Estuarine Habitats Zones: Marine salinity zone (33 to 18 ppt); mixing/transitional zone (18 to 5 ppt); and riverine/freshwater tidal zone (5 to 0 ppt):**

Very Good	Good	Fair	Poor
All zones are present and are relatively equal in total area - natural tidal prism (33.3% ea.)	Any approximate percentage ratio with a 40/40/20 combination (example: 20% MSZ; 40% MZ; 40% RTZ)	Any approximate percentage ratio with a 45/45/10 combination	Any approximate percentage ratio with <10% of any one zone represented

2. **Tidal Range (flushing rate):**

Very Good	Good	Fair	Poor
Estuary reach very well flushed (macro-tidal); excellent vertical mixing	Estuary reach moderately well flushed (meso-tidal); good vertical mixing	Estuary reach is moderately flushed (micro-tidal); some vertical mixing occurs, but some areas remain stagnant (not mixed or flushed)	Estuary reach very poorly flushed (ultra micro-tidal); poor vertical mixing resulting in reduced water quality (low DO)

3. **Relative temperature within each Estuarine Habitat Zones (marine salinity zone, mixing/transitional zone, and riverine tidal zone):**

   a. **Temperature: Marine Salinity Zone (33 to 18 ppt) -** Immediately inside the mouth of the estuary to the start of the mixing/transitional zone:

Very Good	Good	Fair	Poor
< 14.0° C	14.1-16.5° C	16.6-18.0° C	> 18.0° C

   b. **Temperature: Mixing/Transitional Zone (18 – 5 ppt) –** Area where the salinity within the Estuarine Habitat Zone ranges from 18 to 5 ppt:

Very Good	Good	Fair	Poor
< 16.0° C	16.1°-18.0° C	18.1°-20.0° C	> 20.1° C

   c. **Temperature: Riverine or Freshwater Tidal Zone (<5 ppt) –** Area from the mixing/transitional zone to the head-of-tide:

Very Good	Good	Fair	Poor
< 17° C	17.1°-19.0° C	19.1°-21.5° C	> 21.6° C

4. **Relative Dissolved Oxygen (mg/L) for a given duration within each Estuarine Habitat Zones (marine salinity zone, mixing/transitional zone, and riverine tidal zone):**

   a. **Dissolved Oxygen (mg/L): Marine Salinity Zone -** Immediately inside the mouth of the estuary to the beginning of the mixing/transitional zone:

Very Good	Good	Fair	Poor
>7.75 mg/L at all times	7.74-6.5 mg/L at all times	Fall below 6.4 mg/L, but stays above 5.0 mg/L for < 24hrs	Falls below 5.0 mg/L for periods > 24 hours

b. **Dissolved Oxygen (mg/L): Mixing/Transitional Zone –** Area where the Estuarine Habitat Zone ranges from 18 to 5 ppt:

Very Good	Good	Fair	Poor
>7.75 mg/L at all times	7.74-6.5 mg/L at all times	Fall below 6.4 mg/L, but stays above 5.0 mg/L for < 24hrs	Falls below 5.0 mg/L for periods > 24 hours

c. **Dissolved Oxygen (mg/L): Riverine or Freshwater Tidal Zone –** Area from the mixing/transitional zone to the head-of-tide:

Very Good	Good	Fair	Poor
> 7.75 mg/L at all times	7.74-6.5 mg/L at all times	Fall below 6.4 mg/L, but stays above 5.0 mg/L for < 24hrs	Falls below 5.0 mg/L for periods > 24 hours

5. **Relative Macro- Invertebrate Abundance and Taxa Richness within each Estuary Habitat Zone –** Macro-invertebrates that are known or would be considered to be available prey items for juvenile salmonids:

a. **Relative Macro- Invertebrate Abundance and Taxa Richness): Marine Salinity Zone -** Immediately inside the mouth of the estuary to the start of the mixing zone:

Very Good	Good	Fair	Poor
Abundance and taxa richness are considered to be high	Abundance of prey items is high, but taxa richness is relatively low	Abundance is of prey items and/or taxa richness are moderate	Abundance of prey items and/or taxa richness are low

b. **Relative Macro- Invertebrate Abundance and Taxa Richness Mixing/Transitional Zone –** Area where the salinity zone ranges from 18 to 5 ppt:

Very Good	Good	Fair	Poor
Abundance and taxa richness are considered to be high	Abundance of prey items is high, but taxa richness is relatively low	Abundance is of prey items and/or taxa richness are moderate	Abundance of prey items and/or taxa richness is low

c. **Relative Macro- Invertebrate Abundance and Taxa Richness: Riverine or Freshwater Tidal Zone –** Area from the mixing/transitional zone to the head-of-tide**:**

Very Good	Good	Fair	Poor
Abundance and taxa richness are considered to be high	Abundance of prey items is high, but taxa richness is relatively low	Abundance is of prey items and/or taxa richness are moderate	Abundance of prey items and/or taxa richness is low

6. **Habitat Elements and Complexity -** % area containing SAV, large or small WD, emergent and/or riparian vegetation, marshes, sloughs, tidal wetlands, pools > 2 meters, *etc*.:

Very Good	Good	Fair	Poor
> 70%	70-45%	45-20%	<20%

7. **Toxicity - Toxicity -** % of area where containments are detected (metals, pesticides, and pollution that are impacting the estuary ecosystem, *etc*.):

Very Good	Good	Fair	Poor
Not detected	< 2%	2.1-5%	> 5%

8. **Exotic Pest Species -** Number of exotic pest species that alter the estuary ecosystem and significantly impact salmonids (please note how exotic pest species impacts salmonids - *i.e.*, stripers - predation):

Very Good	Good	Fair	Poor
No exotic pest species known to be present	One or more pest species present but there are **no major** impacts to salmonids and the estuary ecosystem	One or more pest species present and at least one is having a **moderate** impact to salmonids and the estuary ecosystem	One or more pest species present and at least one is having a **major** impact to salmonids and the estuary ecosystem

9. **Quantity of Rearing Habitat (Life Stage and Species) = OVERALL**

   a. **Quantity of rearing habitat for young-of-year coho and/or *NON-osmoregulating* salmonids (refer to rating listed above for guidance – Estuarine Habitat Zones, water quality parameters, etc.):**

Very Good	Good	Fair	Poor

   b. **Quantity of rearing habitat for osmoregulating salmonids (refer to rating listed above for guidance – Estuarine Habitat Zones, water quality parameters, *etc*.):**

Very Good	Good	Fair	Poor

III. **Lagoon: *Currently Functioning or Managed as a Closed System (*Rearing Season: March 15 – November 15)***

***Includes the pre-smolt timing of the summer rearing period.**

Criteria	**Population Name**	**Confidence/Source**
Seasonal Closure (date/month)		
Freshwater Conversion (d)		
Lagoon Elevation – NGVD (ft.)		
Temperature (C): Lagoon Habitat Zones		
Dissolved Oxygen (mg/L): Lagoon Habitat Zones		
Macro-Invertebrates Abundance and Taxa Richness: Lagoon Habitat Zones		
Habitat Elements and Complexity		
Toxicity (Metal, Pesticides, Pollution, etc.)		
Exotic Pest Species		
Overall ranking		

1. **Seasonal Closure –** Timing of sandbar formation creating a summer rearing lagoon (date/month):

Very Good	Good	Fair	Poor
April 15 – May 7	**May 7 – June 1**	**June 1 – June 21**	**Later than June 21st**

2. **Freshwater Conversion –** number of days required to complete freshwater transformation:

Very Good	Good	Fair	Poor
1 to 3	**3 to 7**	**7 to 14**	**>14**

3. **Freshwater Lagoon Elevation during seasonal closure (NGVD):**

Very Good	Good	Fair	Poor
> 5 feet	**> 4 feet**	**> 3 feet**	**< 3 feet**

4. **Relative temperature within each Lagoon Habitat Zone (Lower, Middle, Upper):**

   a. **Temperature: Lower Lagoon Habitat Zone -** Immediately inside the sandbar to approximately the middle reach of the lagoon:

Very Good	Good	Fair	Poor
< 16.0° C	16.1°-18.0° C	18.1°-20.0° C	> 20.1° C

b. Temperature: Middle Lagoon Habitat Zone:

Very Good	Good	Fair	Poor
< 17° C	17.1°-19.0° C	19.1°-21.5° C	> 21.6° C

c. Temperature: Upper Lagoon Habitat Zone:

Very Good	Good	Fair	Poor
< 17° C	17.1°-19.0° C	19.1°-21.5° C	> 21.6° C

5. Relative Dissolved Oxygen (mg/L) for a given duration within each of the Lagoon Habitat Zones (Lower, Middle, Upper):

a. Dissolved Oxygen (mg/L): Lower Lagoon Habitat Zone - Immediately inside the mouth of the estuary to the start of the mixing/transitional zone:

Very Good	Good	Fair	Poor
> 7.75 mg/L at all times	7.74-6.5 mg/L at all times	Fall below 6.4 mg/L, but stays above 5.0 mg/L for <24hrs	Falls below 5.0 mg/L for periods > 24 hours

b. Dissolved Oxygen (mg/L): Middle Habitat Zone:

Very Good	Good	Fair	Poor
> 7.75 mg/L at all times	7.74-6.5 mg/L at all times	Fall below 6.4 mg/L, but stays above 5.0 mg/L for < 24hrs	Falls below 5.0 mg/L for periods > 24 hours

c. Dissolved Oxygen (mg/L): Upper Lagoon Habitat Zone:

Very Good	Good	Fair	Poor
> 7.75 mg/L at all times	7.74-6.5 mg/L at all times	Fall below 6.4 mg/L, but stays above 5.0 mg/L for < 24hrs	Falls below 5.0 mg/L for periods > 24 hours

6. Relative Macro- Invertebrate Abundance and Taxa Richness within each Lagoon Habitat Zone – Macro-invertebrates that are known or would be considered to be available prey items for juvenile salmonids:

a. Relative Macro- Invertebrate Abundance and Taxa Richness: Lower Lagoon Habitat Zone:

Very Good	Good	Fair	Poor
Abundance and taxa richness are considered to be high	Abundance of prey items is high, but taxa richness is relatively low	Abundance is of prey items and/or taxa richness are moderate	Abundance of prey items and/or taxa richness are low

b. Relative Macro- Invertebrate Abundance and Taxa Richness: Middle Lagoon Habitat Zone:

Very Good	Good	Fair	Poor
Abundance and taxa richness are considered to be high	Abundance of prey items is high, but taxa richness is relatively low	Abundance is of prey items and/or taxa richness are moderate	Abundance of prey items and/or taxa richness is low

c. Relative Macro- Invertebrate Abundance and Taxa Richness: Upper Lagoon Habitat Zone:

Very Good	Good	Fair	Poor
Abundance and taxa richness are considered to be high	Abundance of prey items is high, but taxa richness is relatively low	Abundance is of prey items and/or taxa richness are moderate	Abundance of prey items and/or taxa richness is low

7. **Habitat Elements and Complexity -** % area containing SAV, large or small WD, emergent and/or riparian vegetation, marshes, sloughs, tidal wetlands, pools > 2 meters, etc.:

Very Good	Good	Fair	Poor
> 70%	70-45%	45-20%	< 20%

8. **Toxicity -** % of area where containments are detected (metals, pesticides, and pollution that are impacting the estuary ecosystem, etc.):

Very Good	Good	Fair	Poor
Not detected	< 2%	2.1-5%	> 5%

9. **Exotic Pest Species -** Number of exotic pest species that alter the estuary ecosystem and significantly impact salmonids (please note how exotic pest species impacts salmonids - *i.e.*, stripers - predation):

Very Good	Good	Fair	Poor
No exotic pest species known to be present	One or more pest species present but there are **no major** impacts to salmonids and the estuary ecosystem	One or more pest species present and at least one is having a **moderate** impact to salmonids and the estuary ecosystem	One or more pest species present and at least one is having a **major** impact to salmonids and the estuary ecosystem

10. Quantity of Rearing Habitat (Life Stage and Species) = OVERALL

a. Quantity of rearing habitat for young-of-year coho and/or *NON-osmoregulating* salmonids (refer to rating listed above for guidance – Lagoon Habitat Zones, water quality parameters, *etc*.):

Very Good	Good	Fair	Poor

b. Quantity of rearing habitat for osmoregulating salmonids (refer to rating listed above for guidance – Lagoon Habitat Zones, water quality parameters, *etc*.):

Very Good	Good	Fair	Poor

Attribute: Habitat Complexity

Habitat complexity is critically important for salmonids because complex habitats are typically highly productive, offer velocity refuges, places to hide, and lower temperatures. This attribute encompasses specific elements, such as large woody debris (LWD), and multi-faceted features such as shelter rating and the ratio of pools to riffles and flatwater. To capture the diversity and importance of this attribute, NMFS identified five different indicators for habitat complexity.

Condition Indicator: Large Woody Debris (LWD) BFW 0-10 and LWD BFW 10-100 for Adult, Summer and Winter Rearing Targets

Instream large wood has been linked to overall salmonid production in streams with positive correlations between large wood and salmonid abundance, distribution, and survival (Sharma and Hilborn 2001). Salmonids appear to have a strong preference for pools created by LWD (Bisson *et al*. 1982) and their populations are typically larger in streams with abundant wood (Naimen and Bilby 1998). Decreases in fish abundance occur following wood removal (Lestelle 1978; Bryant 1983; Bisson and Sedell 1984; Lestelle and Cederholm 1984; Dolloff 1986; Elliott 1986; Murphy et al. 1986; Hicks *et al*. 1991a) while increases in fish abundance have been found following deliberate additions of LWD (Ward and Slaney 1979; House and Boehne 1986; Crispin *et al*. 1993; Reeves *et al*. 1993; Naimen and Bilby 1998; Roni and Quinn 2001).

The LWD indicator is defined as the number of key pieces of large wood per 100 meters of stream. Separate rating criteria were developed for channels with bankfull width (BFW) less than 10 meters and greater than 10 meters. Key pieces are logs or rootwads that: (1) are independently stable within the bankfull width and not functionally held by another factor, and (2) can retain other pieces of organic debris (WFPB 1997). Key pieces also meet the following size criteria: (1) for bankfull channels 10 meters wide or less, a minimum diameter 0.55 meters and length of 10 meters, or a volume 2.5 cubic meter or greater, (2) for channels between 10 and 100 meters, a minimum diameter of 0.65 meters and length of 19 meters, or a volume six cubic meters or greater (Schuett-Hames *et al.* 1999). Key pieces in channels with a bankfull width of > 30 meters pieces only qualify if they have a rootwad associated with them (Fox and Bolton 2007).

Ratings: Number of LWD key pieces per 100 meters of stream length (BFW 0-10 and BFW 10-100)

The frequency of key pieces of LWD influences development and maintenance of pool habitat for multiple life stages of salmonids. LWD is the number of pieces (frequency) per stream length (100 meters) within each reach. Rating criteria were based on the observed distribution of key pieces of LWD in unmanaged forests in the Western Washington eco-region developed by Fox and Bolton (2007). Fox and Bolton's (2007) recommendations were followed using the top 75 percentile to represent a very good condition for LWD frequency. The California North Coast Regional Water Quality Control Board (NCRWQCB 2006) used similar information to develop indices for LWD associated with freshwater salmonid habitat conditions. Rating thresholds are as follows:

For smaller channels (0-10 meters BFW):

Poor = < 4 key pieces/100 meters;
Fair = 4 to 6 key pieces/100 meters;
Good = 6 to 11 key pieces/100 meters; and
Very Good = > 11 key pieces/100 meters.

For larger channels (10-100 meters BFW):

Poor = < 1 key pieces/100 meters;
Fair = 1 to 1.3 key pieces/100 meters;
Good = 1.3 to 4 key pieces/100 meters; and
Very Good = > 4 key pieces/100 meters.

Methods:
Assessing population condition with these criteria proved problematic due to the paucity of absence of adequate LWD surveys in most areas in the CCC ESU. For those populations without LWD survey data, SEC queried the percent LWD Dominant Pools attribute from HAB 8 data. SEC also queried percent pools with LWD and percent shelter that is LWD from the HAB 8 data, but percent LWD dominant pools produced discernible breaks in the distribution of observed values consistent with expected results. Therefore, the percent of LWD dominated pools was used as a proxy to evaluate LWD key piece frequency.

CDFG (2004) habitat typing survey methods follow a random sampling protocol stratified by stream reach (*i.e.*, Rosgen Channel type) used to assess stream habitat conditions from the mouth to the end of anadromy. Habitat data can be used to characterize each reach of stream, and these data were averaged over the surveyed reaches to characterize the stream. LWD is counted in shelter value rating as one of the components of shelter.

Assigning rating to LWD was complicated due to variability in assessment techniques, descriptions, and timing. It is possible that pieces of LWD recorded on some streams would not meet our criteria set for key pieces by this analysis. For example, in some cases, the criteria were not included in the stream inventories; in others, size classifications did not correlate well with our rating system (for example, 1-2 foot diameter and more than 20 foot long versus 0.55 meters in diameter and 10 meters long).

Reach distances and bankfull widths were converted to meters. Some dataset documented LWD per 100 feet and was provided for the habitat elements of riffles, pools, and flat water. In this case the percentage and length of each element given for a particular reach, was back calculated to estimate LWD density in that reach (

Table 3). SEC queried the stream summary database for LWD counts for each stream reach and extrapolated the data to characterize each population stream, for all populations where the data existed. Where HAB 8 data was lacking, a qualitative approach was used and based on the best available information (watershed assessments, *etc*.), spatial data and IP-Km habitat potential to inform Best Professional Judgment ratings.

Table 3. Categories used as rough equivalencies to key pieces of LWD.

TERM	**POTENTIAL ERROR** and/or Comment	**LOCATION(S)** (unless noted, includes subbasins)
"Debris Jams"	Underestimates # key pieces of LWD. Uncertainty was too high, so no rating was given.	Ten Mile River.
"Key LWD"	Criteria may not match	Noyo River Albion River
"Key pieces"	Criteria may not match	San Gregorio Creek
"LGWDDEB_NO" (Number of large woody debris)	Criteria may not match	Lagunitas Creek San Geronimo Creek
"LWD Forced Pool"	underestimates # of key pieces of LWD	Russian River subbasins: Willow Creek (Russian River) Freezeout Creek (Russian River) Unnamed tributaries (Russian River) Cottaneva Creek
"LWD per 100 ft" for: "Riffles," "Pools," and "Flat."	(1)Where percent of each element was recorded, LWD per 100m was calculated.	Pudding Creek Big Salmon Creek Walker Creek
"Number of pieces per 100 linear feet of stream within the bankfull channel"	Criteria may not match. Live trees included in total were subtracted before calculating	Caspar Creek
"Pieces of large wood"	Criteria may not match	Soquel Creek Gazos Creek
"Total # LWD"	Different criteria for LWD than for key pieces of LWD	Pescadero Creek
"Total Logs w/Estimates from LDA's (# per mile)"	Criteria may not match	Aptos Creek
"Key LWD Pieces/328 ft. w/Debris Jams"	Criteria may not match.	Navarro River Big River Russian River subbasins: Ackerman Creek Alder Creek Jack Smith Creek

"Total # of Debris Jams" + "Key LWD Pieces/100m w/o Debris Jams	Criteria may not match. Two totals were added (see comment for Navarro) Debris jams only recorded for 3 out of 22 reaches. In only one case did it change the rating—from fair to good.	Garcia River

Condition Indicator: Percent Primary Pools for Summer Rearing Target

Pools provide hydraulic and other environmental conditions favoring presence of summer rearing juvenile salmonids (Bisson *et al.* 1988). During high flow events, pools are usually scoured, leaving a coarse gravel channel armor and depositing material on the riffles (Florsheim *et al.* 2001). The percentage of pools within a stream is a common indicator for estimating amount of rearing habitat available for juvenile salmonids. The pool:riffle:flatwater ratio indicator (described below) describes the frequency of all pool habitat types (mid-channel, scour and backwater pools) relative to other habitat types across each population. However, quantitative information on pool frequency without accompanying qualitative information such as depth or shelter indicators and criteria, can give a false impression of habitat conditions (if, for example, there are numerous, shallow, short simple pools which are a common occurrence in aggraded streams). This indicator describes pool quality by assessing primary pools. These are the larger deeper pools preferentially occupied by juveniles and adults respectively, have specific depth criteria, and are a subset of all pool habitat types.

Deeper larger pools have larger volume and as such have a larger juvenile rearing carrying capacity. The frequency of these larger deep pools provides a conservative measure of the quality of significant rearing habitat and staging habitat. CDFG combined measures of pool depth and frequency in their watershed assessments by reporting the frequency of primary pools stratified by stream order. Primary pools in first and second order streams are two feet deep or more, while primary pools in third and fourth order streams were are three feet deep or more (Bleier *et al*. 2003).

Ratings: Percent of primary pools at the reach, stream and population scale

Juvenile salmonids prefer well shaded pools at least three feet deep with dense overhead cover or abundant submerged cover composed of undercut banks, logs, roots, and other woody material. Pool depths of three feet are commonly used as a reference for fully functional salmonid habitat (Overton *et al*. 1993; Brown *et al*. 1994; Baker and Smith 1998; Bauer and Ralph 1999).

Maximum pool depth is partially a function of channel size, and is highly affected by the physical properties that affect stream energy such as gradient, entrenchment, width, and sediment load. The Washington State Fish and Wildlife Commission (1997) recommended the following pool frequencies by length: "(f)or streams less than 15 meters wide, the percent pools should be greater than 55 percent, greater than 40 percent and greater than 30 percent for streams with gradients less than 2 percent, 2-5 percent and more than 5 percent, respectively."

Pool depths and volume can be impaired by sediment over-supply related to land management (Knopp 1993). Reeves *et al*. (1993) found diminished pool frequency in intensively managed watersheds. Streams in Oregon coastal basins with low timber harvest rates (< 25 percent) had 10-47 percent more pools per 100 meters than streams in high harvest basins (> 25 percent). Peterson *et al*. (1992) used 50 percent pools as a reference for good salmonid habitat and recognized streams with less than 38 percent pools by length as impaired, though Alaska studies showed ranges of 39-67 percent pools by length (Murphy *et al*. 1984).

The CDFG Watershed Assessment Field Reference (CDFG 1999) states good salmonid streams have more than 50 percent of their total available fish habitat in adequately deep and complex pools, though CDFG considers a primary pool frequency of less than 40 percent inadequate for salmonids (Bleier *et al*. 2003). Knopp (1993) summarized pool frequency in disturbed streams in northern California, and found a pool frequency average of 42 percent. Due to the number of variables influencing pool depth (stream order, gradient, entrenchment, substrate) a quartile approach was established to extrapolate up to a stream scale (versus a reach scale). The quartile approach set a 25 percent boundary from a 50 percent threshold to describe good conditions for primary pools to account for bias due to stream order and the natural range of variability.

The resulting criteria for primary pools are:

Stream level percent primary pool rating criteria
Poor = < 25% primary pools;
Fair = 25% to 49% primary pools;
Good = 50% to 74% primary pools; and
Very Good = > 75% primary pools.

Population scale encompasses multiple streams (including mainstem channels which cannot always be expected to achieve optimal criteria across all stream orders). Therefore stream level data were evaluated according to the following criteria:

Population level percent primary pool rating criteria
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75-90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Methods:
The CDFG habitat typing procedure evaluates pools by classifying 100 percent of the wetted channel by habitat type from the mouth to the end of anadromy (Flosi *et al*. 2004). The method is used in wadeable streams (stream orders 1-4). CDFG follows a random sampling protocol stratified by stream reach (*i.e*., Rosgen Channel type) to measure conditions within habitat types for variables such as width and depth. Typically, depth is recorded for every third habitat unit in addition to every fully-described unit. This provides an approximate 30 percent sub-sample for all habitat units. Habitat data can be used to characterize each reach of stream, and data can be averaged over the collection of reaches to characterize the stream. Habitat typing surveys (Flosi *et al.* 2004) provide a measure of pool frequency defined as the percentage of stream reaches in pools. This sub-sample is expressed as an average for each stream reach. SEC queried the stream summary database for the mean of each variable for each stream reach and then extrapolated the data to characterize each stream, for all streams within each population where the data existed. Rating each population for this variable required two steps; calculation of the mean values at the stream scale from reach scale data, then calculating the percentage of streams/IP-km meeting optimal criteria, at the population scale.

The CDFG reach summary output summarizes the frequency of primary pool indicator for the proportion of pools two feet deep or greater in first and second order streams, and three feet deep or greater in third and fourth order streams. For populations where SEC had access to the stream summary database (Russian River, Salmon Creek, Lagunitas Creek), the amount of primary pool from stream habitat data was calculated. Where data were lacking, other datasets and best professional judgment were utilized.

Condition Indicator: Frequency of Pools, Riffles, and Flatwater for Adult, Summer and Winter Rearing Targets

Pools provide hydraulic and other environmental conditions necessary for summer rearing of juvenile salmonids, and resting cover for adults; riffles provide hydraulic and environmental conditions critical for spawning adults and incubating eggs; while adjoining flatwater provide habitats for a diversity of life stages. In general, winter habitat is lacking where flatwater habitats dominate the channel, because they lack elements (velocity refuge, scour elements, cover and shelter) for fish to maintain residency under high flow conditions. The average frequency of pools:riffles:flatwater across all IP-km provides an indication of the habitat diversity available for various species and life stages.

Developing or enhancing pools habitats for rearing and riffle habitats for spawning are a common focus of restoration activities. When pools lacking depth or shelter, actions are typically recommended to deepen pools by adding instream complexity. This ultimately shortens adjoining flatwater types, or converts flatwater habitat types to pools. Conversely, when spawning gravels are lacking, actions are typically recommended to add instream structures as a technique to flatten the gradient and retain gravels. This ultimately shortens adjoining flatwaters or converts flatwater habitat types to riffles. In this case, the length or frequency of flatwater types are decreased in favor of increasing the percent length of pools/riffles or the frequency of pools/riffles respectively.

Ratings: Frequency of pools:riffles:flatwater at the reach, stream and population scale

As noted above, Reeves *et al*. (1993) found pools diminished in frequency in intensively managed watersheds. Streams in Oregon coastal basins with low timber harvest rates (< 25 percent) had 10-47 percent more pools per 100 m than did streams in high harvest basins (> 25 percent). The CDFG Watershed Assessment Field Reference (CDFG 1999) states good salmonid streams have more than 50 percent of their total available fish habitat in adequately deep and complex pools; and have at least 30 percent in riffles. Knopp (1993) summarized pool frequency in disturbed streams in Northern California, and found pool frequency averaged 42 percent.

CDFG considers a primary pool frequency of less than 40 percent, and riffle frequency less than 30 percent inadequate for salmonids (Bleier *et al.* 2003). Based on this consideration NMFS established rating criteria (discussed previously) using a 10 percent boundary from the target threshold for subsequent ratings for pools and riffles.

The resulting criteria are:

Stream level pool:riffle:flatwater frequency rating

Poor = < 20% pools and < 10% riffles;
Fair = 20% to 29% pools and > 10% to 19% riffles;
Good = > 30% to 39% pools and = >20% to 29% riffles; and
Very Good = > 40% pools and = > 30% riffles.

To extrapolate stream level data upward to the population scale, we then rated each population on the following criteria.

Population level pool:riffle:flatwater frequency rating
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75% to 90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Methods:
CDFG habitat typing is a standardized method that physically classifies 100 percent of the wetted channel by habitat type from the mouth to the end of anadromy (Flosi *et al.* 2004). The attributes distinguishing the various habitat types include stream order, over-all channel gradient, velocity, depth, substrate, and the channel type features responsible for the unit's formation. Level I categorizes habitat into riffles or pools. Level II categorizes riffles into riffle or flatwater habitat types, for a total of three types (riffle, pool, and flatwater). Level III further differentiates riffle types on the basis of water surface gradient, and pool types according to location in the stream channel. At Level IV, pools are categorized by the cause of formation; riffles are categorized by gradient; and flatwaters are categorized by depth and velocity. Typically, habitats are described according to location, orientation, and water flow at the Level IV scale. However, habitat can be summarized at any habitat scale and used to characterize each reach of stream, as well as the stream as a whole.

The length and frequencies of a habitat type depends on stream size and order. Generally a stream will not contain all habitat types, as the mix of habitat types reflects the overall channel gradient, flow regime, cross-sectional profile, and substrate particle size. Therefore collapsing the habitat types at the Level II scale provides a reasonable measure of diversity to describe the complexity of habitats that occur across watersheds, which also describes the critical habitat needs across species in a population. SEC calculated the calculated the frequency of Level II habitats (pools, riffles and flatwater) from the database of streams where surveys are available.

SEC queried the stream summary database for pool:riffle:flatwater frequency for each stream reach and extrapolated the data to characterize each stream, for all streams within each population where the data existed. As with other data collected at smaller scales, rating each population required two steps; calculation of the mean at the stream scale from reach scale data, then determining the percentage of streams/IP-km meeting optimal criteria, at the population scale.

<u>Condition Indicator: Shelter Ratings for Adult, Summer and Winter Rearing, and Smolt Targets</u>
Depending on spring flow conditions, salmonids require pool habitats with adequate complexity and cover for multiple life stages, including rearing and smolt outmigration. Winter habitat is considered impaired in habitats lacking velocity refuge, cover and shelter during period of high stream flow. Pool shelter rating was used to evaluate the ability of pool habitat to provide adequate cover for salmonid survival throughout the population.

Shelter rating is a measure of the amount, and diversity, of cover elements in pools. Shelter rating is used by CDFG in their stream habitat-typing protocol (Flosi *et al.* 2004). It is an useful indicator of pool complexity. Shelter/cover elements include undercut bank, large and small woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain, boulders, and bedrock ledges (Bleier *et al*. 2003).

Ratings: Pool shelter averaged at the reach, stream and population scales
Bleier *et al*. (2003) identified a shelter rating value of < 60 as being inadequate, and > 80-100 as good for salmonids. Average shelter value below 80 was rated fair; average shelter value above 100 was rated to identify high value refugia areas. The stream level criteria are:

Stream level shelter rating
Poor = < 60 average shelter value;
Fair = 60 to 79 average shelter value;
Good = 80 to 100 average shelter value; and
Very Good = > 100 average shelter value.

Given that the population scale encompasses multiple streams, the following ratings were used to extrapolate shelter conditions for each population:

Population level shelter rating
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75% to 90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Methods:
The CDFG (2004) habitat typing survey method estimates shelter ratings in all pool habitats measured. Typically, pool habitats are described in every third habitat unit in addition to every fully-described unit which provides an approximate 30 percent sub-sample. Habitat data were used to characterize each reach of stream, and data were averaged over the collection of reaches to characterize the entire stream.

Shelter rating values were generated by multiplying instream shelter complexity values by estimated percent area of pool covered. Scores were obtained by assigning an integer value between 0 and 3 to characterize type and diversity of cover elements and multiplying that value by the percent cover (Table 4). A shelter rating between 0 and 300 is derived, with 300 being equal to 100% cover with maximum diversity (Flosi *et al.* 2004).

SEC calculated average shelter rating across all reaches using HAB 8 reach summation information. This sub-sample is expressed as an average for each stream reach. SEC queried the stream summary database for mean percent shelter ratings for each stream reach and extrapolated the data to characterize each stream, within each population (where data were available). As with other reach level data, deriving ratings for the each population required two steps; calculation of shelter value at the stream scale from reach scale data, then determining the percentage of streams/IP-km meeting optimal criteria at the population scale. A bias analysis was also conducted for the population shelter rating value reflecting the percent of potential IP-km evaluated.

Table 4. Values and examples of instream shelter complexity. Values represent a relative measure of the quality and composition of the instream shelter. Adapted from Flosi *et al.*, 2004.

Value	Instream Shelter Complexity
0	No Shelter
1	1-5 boulders
	Bare undercut bank or bedrock ledge
	Single piece of LWD (>12" diameter and 6' long)
2	1-2 pieces of LWD associated with any amount of small woody debris (SWD) (<12" diameter)
	6 or more boulders per 50 feet
	Stable undercut bank with root mass, and less than 12" undercut
	A single root wad lacking complexity
	Branches in or near the water
	Limited submersed vegetative fish cover
	Bubble curtain
3 (Combinations of at least 2 cover types)	LWD/boulders/root wads
	3 or more pieces of LWD combined with SWD
	3 or more boulders combined with LWD/SWD
	Bubble curtain combined with LWD or boulders
	Stable undercut bank with greater than 12" undercut, with root mass or LWD
	Extensive submerged vegetative fish cover

Attribute: Hydrology

Hydrology, as a key attribute, includes all aspects of the hydrologic cycle relevant to the spawning, incubation, rearing and migration of salmonids. The magnitude, timing, and seasonality of local precipitation and geology determine a watershed's historical discharge patterns. These patterns however, can be modified by individual and cumulative water use practices to interfere with a salmonids' ability to complete their life cycle. Because stream flow is rarely measured throughout a watershed (*i.e.*, in tributaries), flow requirements for fish in individual watersheds are rarely specified. However, since these species evolved under unimpaired flow regimes, it is reasonable to assume that approximating these conditions will likely foster favorable conditions. Hydrology was assessed using six different indicators.

Condition Indicator: Passage Flows for Adult and Smolt Targets

This indicator considered the effect of flow impairments on smolt and adult passage. Considerations included; (1) impairment precluding passage over critical riffles, and (2) the degree flow impairments reduce pulse-flows necessary for adult and smolt migration (including considerations on the magnitude, duration, and timing of freshets).

Ratings: Four life stages (egg, summer rearing, smolt and adult) are rated on four instream flow criteria: 1) summer rearing baseflows, 2) instantaneous flow reductions affecting eggs and summer rearing, 3) adult and smolt passage flows, and 4) redd scour affecting eggs. For most populations, there is generally little information about the suitability of flows to support these habitat attributes, although there may be sufficient data for some individual sub-populations, and for others there may be data for only one or two of the five indicators.

Assessment of the suitability of instream flows for CCC coho salmon relied in part on information developed via input from 15 fisheries researchers and aquatic resource managers familiar with stream flow issues in north-central coastal California. To further evaluate instream flow habitat attributes, a qualitative decision structure was created (a.k.a., the instream flow protocol) to develop ratings for each flow indicators.

The distribution and differences in seasonality of each target life stage were considered so as to accurately assess flow-related impacts. Watershed flow conditions were rated by reviewing relevant published information and seeking unbiased input from resource managers and researchers familiar with instream flows on a watershed by watershed basis. Each of the four flow related habitat attributes were scored using a instream flow protocol. The protocol analyzed three risk factors: setting, exposure and intensity, as defined below.

Setting rated the degree of aridity of a watershed given the natural setting of climate, precipitation, *etc*. in an undisturbed state. Four classes of setting were identified: xeric, mixed, mesic, and coastal (Table 5). Xeric watersheds are dominated by arid environments such as oak savannah, grassland, or chaparral. Mixed watersheds have a combination of xeric, mesic, and/or coastal habitats within them. Mixed watersheds are typically larger watersheds with inland regions. Mesic settings have moderate amounts of precipitation; examples include mixed coniferous/hardwood forest and hardwood-dominated forest (*e.g*., oak woodland, tanoak, *etc*.). Coastal settings are watersheds dominated by the coastal climate regime with cool moist areas. Coastal watersheds typically have high levels of precipitation, are heavily forested, and are predominantly within the redwood forest zone. Maps of vegetation types and average precipitation were provided to resource manager during the review.

Exposure rated the extent of stream likely impaired relative to each flow attribute. Specifically, exposure is the estimated proportion of historical IP-km habitat (by length) appreciably affected by reduced flows (Table 5). A stream reach may be appreciably affected, for example, if the value of summer rearing habitat is degraded by water diversions that reduce space, degrade water quality, reduce food availability, or restrict movement. NMFS reviewed maps of each watershed showing the spatial relationship between relevant habitat areas and high-risk land uses, such as agriculture. Exposure war rated (percent IP-km habitat by length) as > 15%, 5% to 15%, < 5%, or none, based on existing information and best professional judgment.

Intensity rated the likelihood that the land uses within the area of exposure divert substantial amounts of water during critical time periods. High intensity (Table 5) land use activities regularly require substantial water diversions from the stream at levels that impair the habitat attribute. Moderate intensity activities typically require irrigation, or have regular demand, but satisfy that demand often by means other than direct pumping of surface or subterranean stream flows. Low land use activities require diversions in small amounts. The intensity of water diversion impacts in the population was rated as high, moderate, low, or none, using existing information and knowledge of local land uses.

Table 5. Rating matrix for assessing flow conditions for four hydrology indicators.

	Poor	Fair	Good	Very Good
Setting	Xeric	Mixed	Mesic	Coastal
Exposure	> 15%	5-15%	< 5%	None
Intensity	High	Moderate	Low	None

Overall scores for each of the flow habitat attributes for each applicable life stage was determined by two steps. For a given habitat attribute, each risk-factor rating was assigned a value (Table 6). Then, the three risk factor rating scores were averaged to determine the overall rating. For example, to determine the rating for baseflow on summer rearing: the setting in the watershed is mixed (75), the exposure (of historical potential rearing habitat) to impacts of impaired summer base flows was > 15% (100), and the intensity was high (100), the average score of these three risk factors is 92, which results in an attribute rating of poor for summer rearing base flows in that watershed.

Table 6. Risk factor scores and the criteria defining poor, fair, good or very good ratings for a combined average risk score for each life stage and flow indicator.

	Poor	Fair	Good	Very Good
Setting	Xeric	Mixed	Mesic	Coastal
Score	100	75	50	25
Exposure	> 15%	5-15%	<5%	None
Score	100	75	50	25
Intensity	High	Moderate	Low	None
Score	100	75	50	25
Attribute Rating	**Poor**	**Fair**	**Good**	**Very Good**
Score Class	>75	51-75	35-50	<35

Recognizing that, for some populations, data may be very limited or non-existent for exposure and intensity ratings for individual flow related habitat attributes. Every reasonable effort was made to provide reliable sources for these ratings. Ratings were not solely based on professional judgment and/or personal communications. At least one quality reference (published document, agency report, *etc.*) was used and supplemented with one or two "personal communications" if possible. In cases where flow conditions (exposure and/or intensity) related to a particular habitat attribute could not be determined, the indicator was scored as unknown. Such ratings resulted in recovery plan recommendations for further investigation of the suitability of flow conditions for that attribute.

Condition Indicator: Flow Conditions (Instantaneous Condition) for Eggs and Summer Rearing Targets

This indicator provided an indication of the degree short-term artificial streamflow reductions impact juveniles or the survival-to-emergence of incubating embryos. This condition is often associated with instream diversions (*e.g.*, diversions for frost protection irrigation) and can be exacerbated in more arid conditions or smaller tributaries.

Ratings: As described above, all flow related indicators were assessed using the instream flow protocol conducted by a team of experts.

Condition Indicator: Redd Scour for Eggs Target

Redd scour refers to mobilization of streambed gravels at spawning sites that result in dislodging of embryos from their redds and subsequent mortality. This process is not strictly a function of stream flow but is a combination that is influenced by channel configuration, sediment dynamics, and channel roughness and stability largely control the stability of spawning substrates.

Ratings: As described above, all flow related indicators were assessed using the instream flow protocol conducted by a team of experts.

Condition Indicator: Flow Conditions (Baseflow) for Summer Rearing Target

This indicator measures the degree a watershed currently supports surface flows within historical rearing areas. Surface flows provide rearing space, allow for movement between habitats, maintain water quality, and facilitate delivery of food for juvenile salmonids. Inadequate surface flow may result from cumulative water diversions and/or significant physical changes in the watershed. Water diversions are withdrawals from stream surface waters and/or from subterranean stream flows that are likely hydrologically connected to the stream (*e.g*., pumping from wells in alluvial aquifers that are in close proximity to the stream).

Ratings: As described above, all flow related indicators were assessed using the instream flow protocol conducted by a team of experts.

Condition Indicator: Number, Conditions, and/or Magnitude of Diversions for Summer Rearing and Smolts

Diversions are structures or sites having potential to entrain or impinge of smolts. The indicator is the frequency of diversions along the IP-km smolt outmigration route. The diversion structure or sites analyzed were unscreened diversions located along the stream channel. Diversions without an actual structure in the stream were not included in the analysis.

Ratings: Frequency of diversions across IP-km

SEC assessed the density of diversions in each population across all IP-km, regardless if those areas are currently accessible by salmonids. This allowed assessment of conditions throughout all areas of potential importance to recovery, not just within the species' current distribution. Due to data limitations this rating only applied to the number of diversions and did not identify whether existing diversions are fish passage compliant (screened).

Once the data were analyzed, the following rating criteria were established to define good, fair, poor, based on the observed distributions (*i.e*., *a posteriori*):

Poor = > 5 diversions/10 IP-km;
Fair = 1.1 to 5 diversions/10 IP-km;
Good = 0.01 to 1 diversions/10 IP-km; and
Very Good = 0 diversions/10 IP-km.

Methods:

SEC queried the CDFG 2006 Passage Assessment Database to identify diversions and estimate the number of diversions in a watershed. SEC also reviewed the California State Water Resources Control Board (SWRCB) Division of Water Rights Point of Diversion (POD) database but found it of limited use at the time of analysis because it could not be downloaded for geographic analysis to associate it with appropriate IP-km. Although this database was complete, SEC was unable to determine the quantity of water diverted from each diversion. We therefore based the diversion indicator on the density of diversions, regardless of volume. The diversion density was calculated as the number of diversions per 10 IP-km.

Landscape Indicator: Impervious Surfaces for Watershed Processes Target

Modifications of the land surface (usually from urbanization) produce changes in both magnitude and type of runoff processes (Booth *et al*. 2002). Manifestation of these changes include increased frequency of flooding and peak flow volumes, decreased base flow, increased sediment loadings, changes in stream morphology, increased organic and inorganic loadings, increased stream temperature, and loss of aquatic/riparian habitat (May *et al*. 1996). The magnitude of peak flow and pollution increases with total impervious area (TIA) (*e.g.*, rooftops, streets, parking lots, sidewalks, *etc*.).

Spence *et al*. (1996) recognized channel damage from urbanization is clearly recognizable when TIA exceeds 10 percent. Reduced fish abundance, fish habitat quality and macroinvertebrate diversity was observed with TIA levels from 7.01-12 percent (Klein 1979; Shaver *et al.* 1995). May *et al*. (1996) showed almost a complete simplification of stream channels as TIA approached 30 percent and measured substantially increased levels of toxic storm water runoff in watersheds with greater than 40 percent TIA.

Ratings: Percentage of impervious surfaces in a watershed as:

Poor = > 10% of the total watershed;
Fair = 7% to 10% of the total watershed;
Good = 3% to 6% of the total watershed; and
Very Good = < 3% of the total watershed,

Methods:

The primary assessment tool used was the National Land Cover Database (Edition 1.0) which was produced by the Multi-Resolution Land Characteristics Consortium[4]. The rating thresholds apply to the TIA across all 28 focus populations. Statistics for percent coverage of each land cover type with an associated imperviousness rating were calculated using GIS thresholds for TIA from Booth (2000), May *et al*. (1996) and Spence *et al.* (1996).

Attribute: Landscape Patterns

We defined landscape patterns as disturbance resulting from land uses that cause perturbations resulting in direct or indirect effects to watershed processes. These are typically the result of land uses such as agriculture, timber harvest, and urbanization. These landuses were used as indicators to describe the degree of disturbance in a population.

Landscape Context Indicator: Agriculture for Watershed Processes Target

Agriculture is defined as the planting, growing, and harvesting of annual and perennial non-timber crops for food, fuel, or fiber.

Ratings: Percent of population area used for agricultural activities

[4] http://www.mrlc.gov/nlcd2006.php

Irrigated agriculture can negatively impact salmonid habitat (Nehlsen *et al*. 1991) due to insufficient riparian buffers, high rates of sedimentation, water diversions, and chemical application and pest control practices (Spence *et al*. 1996). On level ground, agricultural activities near streams are typically assumed to have more negative effects on streams than agriculture further away from streams due to the potential for stream channelization, clearing of riparian vegetation, and increased erosion. However, vineyards are often planted on steep terrain and may contribute to instream sedimentation even when located a substantial distance from stream channels.

Specific methods for conserving salmonid habitats on agricultural lands are not well developed but the principles for protecting streams on agricultural lands are similar to those for forest and grazing practices (Spence *et al*. 1996).

We defined ratings *a posteriori* based on the observed distribution of results. The following rating classes were thus formed:

Poor = >30% of population area used for agricultural activities;
Fair = 20% to 30% of population area used for agricultural activities;
Good = 10% to 19% of population area used for agricultural activities; and
Very Good = < 10% of population area used for agricultural activities.

Methods:
Assessments of agriculture were conducted via GIS interpretation of digital data layers. The California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program (FMMP) was the primary method used to measure the extent of agriculture in a population. Where these data were not available, USGS National Land Cover Database Zone 06 Land Cover Layer (Edition 1.0) was used. The FMMP data are presented by county, therefore where a population extended into more than one county the layers were merged to create a single dataset. The area represented by farmland polygons for each population was calculated using GIS.

Landscape Context Indicator: Timber Harvest for Watershed Processes Target
Rate of timber harvest was used to define the percent of a population exposed to timber harvest activities within the most recent 10 year period.

Ratings: Average rate of timber harvesting in population over last 10 years
Adverse changes to salmonid habitat resulting from timber harvest are well documented in the scientific literature (Hall and Lantz 1969; Burns 1972; Holtby 1988; Hartman and Scrivener 1990; Chamberlin *et al*. 1991; Hicks *et al.* 1991a). The cumulative effects of these practices include changes to hydrology (including water temperature, water quality, water balance, and soil structure, rates of erosion and sedimentation, channel forms and geomorphic processes (Chamberlin *et al*. 1991) which adversely affect salmonid habitats. These processes operate over varying time scales, ranging from a few hours for coastal streamflow response, to decades or centuries for geomorphic channel change and hill-slope evolution (Chamberlin *et al*. 1991).

Reeves *et al.* (1993) found that pools diminished in frequency in intensively managed watersheds. Streams in Oregon coastal basins with low timber harvest rates (< 25 percent) had 10 to 47 percent more pools per 100 meters than did streams in high harvest basins. Additionally, Reeves *et al.* (1993) correlated reduced salmonid assemblage diversity to rate of timber harvest.

Ligon *et al*. (1999) recommend a harvest limitation of 30-50 percent of the watershed area harvested per decade as a "red flag" for a higher level of review. Recent work in the Mattole River suggests a harvest threshold of 10 to 20 percent (Welsh, Redwood Sciences Laboratory, personal communication). Harvest areas of 15 percent of watersheds are considered excessive for some timberlands (Reid 1999). Based on these findings we defined these ratings for rate of timber harvesting per population:

Poor = >35% of population area harvested in the past 10 years;
Fair = 26% to 35% of population area harvested in the past 10 years;
Good = 15% to 25% of population area harvested in the past 10 years; and
Very Good = <15% of population area harvested in the past 10 years.

Methods:
Cal Fire's timber harvest history information was used to determine the aerial extent of approved timber harvest plans, by population. However, we only included the aerial footprint once in this analysis regardless of the number of times an area was harvested in the 10 year period.

The 25 categories of harvest associated with timber harvest in California were initially condensed in the following general categories; even aged harvest, uneven aged harvest, conversion, no harvest, and transition. However, due to the relatively short ten year period, it was determined that the only areas excluded from the rate-of-harvest analysis would be those where "no harvest" was included in the timber harvest plan. We acknowledge the different effects of the various silvicultural techniques (*i.e.*, even aged versus uneven aged harvest) but decided to combine all these harvest methods in order to capture all the potential cumulative effects of timber harvest within a population.

Landscape Context Indicator: Urbanization for Watershed Processes Target
Urbanization was defined as the growth and expansion of the human landscape (characterized by cities, towns, suburbs, and outlying areas which are typically commercial, residential, and industrial) such that the land is no longer in a relatively natural state.

Urbanization has affected only two percent of the land area of the Pacific Northwest, but the consequences of urbanization to aquatic ecosystems are severe and long-lasting. The land surface, soil, vegetation, and hydrology are all significantly altered in urban areas (Spence *et al*. 1996). Urban land use is commonly a low percentage of total catchment area, yet it exerts a disproportionately large influence, both proximately and over distance (Paul and Meyer 2001). Despite the many factors potentially limiting Pacific salmon populations, the percentage of urban land alone explained more than 60% of the variation in Chinook salmon recruitment in the interior Columbia River Basin (Regetz 2003; Allan 2004).

Major changes associated with increased urban land area include increases in the amounts and variety of pollutants in runoff, more erratic hydrology due to increased impervious surface area and runoff conveyance, increased water temperatures due to loss of riparian vegetation and warming of surface runoff on exposed surfaces, and reduction in channel and habitat structure due to sediment inputs, bank destabilization, channelization, and restricted interactions between the river and its land margin (Paul and Meyer 2001; Allan 2004). Enhanced runoff from impervious surfaces and stormwater conveyance systems can degrade streams and displace organisms simply because of greater frequency and intensity of floods, erosion of streambeds, and displacement of sediments (Lenat and Crawford 1994).

The degree of impervious surfaces, as discussed earlier (see hydrology attribute above), influences storm flow quantity and timing, and results in a concomitant decrease in baseflow. However, other impacts related to urban development such as runoff which contains a variety of pollutants that degrade water quality (Wang *et al*. 2001), and reductions in overall biological diversity and integrity have been shown to be negatively correlated with the percentage of urban land cover (Klein 1979; Steedman 1988; Limburg and Schmidt 1990; Lenat and Crawford 1994; Weaver and Garman 1994; Wang *et al*. 1997; Klauda *et al*. 1998), human population density (Jones and Clark 1987; Schueler 1997), and house density (Benke *et al.* 1981). These more general impacts, independent of the degree of impervious surfaces, require additional attention. For example, Yates and Bailey (2010) reported declining numbers of benthic macroinvertebrate taxa, and replacement of intolerant taxa with more tolerant (often warm water) taxa, due to increasing density of human development.

While agricultural and timber land uses have best management land-use practices that, if properly implemented, can minimize adverse impacts to watershed process, the impacts of urbanization are generally permanent. Wang *et al.* (1997; 2000; 2001) found that relatively low levels of population urbanization inevitably lead to serious degradation of the fish community. Additionally, while conservation measures exist for reversing or mitigating the degree of impervious surfaces (expanding riparian corridors, developing settling basins, storm water treatment, *etc.*), the other effects of urbanization can permanently alter natural watershed processes, and in some cases, little may be done to mitigate these effects.

Uncertainty exists as to the most appropriate predictor of disturbance to watershed process and subsequent biological response. Two assessment methods were considered; the total extent of urban land and impervious surface. Biological response measures have been predicted by impervious area in several landscape studies of stream urbanization (Walsh *et al*. 2001; Wang *et al*. 2001; Ourso and Frenzel 2003) and by urban land area in others (Morley and Karr 2002), suggesting hydrologic influences are primary in some studies, but the broader range of influences represented by urban area may be more important in others (Allan 2004); (Boyer et al. 2002).

Anadromous fish have been shown to be adversely affected by urbanization. Wang *et al*. (2001) found the impacts of urbanization occur to stream habitat and fish, across multiple spatial scales, and that relatively small amounts of urban land use in a watershed can lead to major changes in biota. There also appears to be threshold values of urbanization beyond which degradation of biotic communities is rapid and dramatic (May *et al*. 1997; Wang *et al*. 2000).

Limburg and Schmidt (1990) demonstrated a measurable decrease in spawning success of anadromous species (primarily alewives) for Hudson River tributaries from streams with 15 percent or more of the watershed area in urban land use. Stream condition almost invariably responds nonlinearly to a gradient of increasing urban land or impervious area (IA). A marked decline in species diversity and in the index of biological integrity scores with increasing urbanization has been reported from streams in Wisconsin around 8–12 percent IA *(Wang et al*. 2000; Stepenuck *et al.* 2002), Delaware, 8–15 percent IA, (Paul and Meyer 2001), Maryland, greater than 12 percent IA, (Klein 1979), and Georgia, 15 percent urban land (Roy *et al*. 2003). Additional studies reviewed in Paul and Meyer (2001) and Stepenuck *et al.* (2002) provide evidence of marked changes in discharge, bank and channel erosion, and biotic condition at greater than 10 percent imperviousness. Also, the supply of contaminants in urban storm runoff may vary independent of impervious area Allan (2004). Although considerable evidence supports a threshold in stream health in the range of 10 to 20 percent IA or urban land, others disagree (Karr and Chu 2000; Bledsoe and Watson 2001), and the relationship is likely too complex for a single threshold to apply.

Ratings: Percent of population area developed for urban activities

Criteria were developed for five density classes of urbanization and condensed into for rating criteria:

> Poor = > 20% of watershed area in urban > 1 unit/20 acres;
> Fair = 12% to 20% of watershed area in urban > 1 unit/20 acres;
> Good = 8% to 11% of watershed area in urban > 1 unit/20 acres; and
> Very Good = < 8% of watershed area in urban > 1 unit/20 acres.

Methods:
Efforts to estimate impacts from urbanization in managed watersheds, require quantitative and predictive models describing the relationship between urbanization and the biological integrity of the community (Wang *et al.* 1997; Wang *et al.* 2000). One challenge in constructing such models is the identification of appropriate indicators reading the amount and extent of urbanization in statistical analysis and modeling. Urban land use encompasses a wide range of interrelated human activities that can be difficult to summarize numerically. Moreover, not only the type, but also the intensity and the location of the land use within the watershed are likely to determine its impact on the biological community of the stream (Booth and Jackson 1997; May *et al*. 1997). Proximity to the stream and width of riparian corridors also appear to be an important consideration in estimating the impact of urban land uses on stream biological communities, though accounting for this variability across the large scale of the NCCC Domain is problematic. In addition, adverse impacts of urban land use are clearly experienced at considerably lower percentages of catchment area than is true for agricultural land use, and most studies report a nonlinear response of stream condition to increasing urbanization.

The primary method used to measure the extent of urban development in a watershed (population) was to query data from the California Department of Forestry and Fire Protection, Fire and Resource Assessment Program (FRAP), and from the GIS layer of DENCLASS10. This GIS layer provided year 2000 census block data merged, with county Topologically Integrated Geographic Encoding and Referencing (TIGER) files, into a single statewide data layer. These data sources provided a detailed depiction of spatial demographics, primarily in sparsely populated rural areas. The data were collapsed from ten classification of housing density into five classes represented by urban polygons to summarize and describe the intensity of urban development for each population area.

Total areas of the populations were then calculated in GIS from population boundary polygons, and these areas used to describe the percentage of urban development over five classes of housing density within each population (density classes range from lowest to highest):

> 0 to less than 1 housing unit /160 acres;
> 1 unit/160 acres to 1 unit/20 acres;
> 1 unit/20 acres to 1 unit/5 acres;
> 1 unit/5 acres to 2 units/acre; and
> 2 units/acre to greater than or equal to 5 units/acre.

Attribute: Passage/Migration

Passage was defined as the absence of physical barriers that prevent or impede the up- or downstream passage of migrating adult, smolts, and juvenile salmonids. Excluding spawning salmonids from portions of their IP-km can increase the likelihood of extirpation by reducing the amount of available spawning and rearing habitat and thereby lower the carrying capacity of the watershed (Boughton *et al*.

2005). Assessment of the percentage of IP affected by barriers should include all IP-km (including upstream of impassable dams if they are proposed for remediation). Passage requirements were evaluated individually for each target, according to the time period specific to each life stage. Passage was assessed using two indicators.

Condition Indicator: Physical Barriers for Adult, Summer and Winter Rearing Targets

Physical barriers are structures or sites preventing or impeding up- or downstream passage of migrating adult and juvenile salmonids.

The indicator was defined as the proportion of IP-km free of known barriers and thereby accessible to migrating salmonids. The physical barriers attribute included only total barriers which are complete barriers to fish passage for all anadromous species at all life stages at all times of year. Passage was evaluated individually for each target, according to the time period specific to the life stage.

Ratings: Accessible proportion of IP-km

Rating thresholds were defined according to the following criteria:

Poor = < 50% or < 32 IP-km of historical IP-km accessible;
Fair = 50% to 74% historical IP-km habitat accessible;
Good = 75% to 90% of historical IP-km accessible; and
Very Good = > 90% of historical IP-km accessible.

Ratings for poor conditions addressed accessible proportions of the watershed, and the minimum threshold of potential habitat (expressed as IP-km) required for the population to be considered viable -in-isolation (32 IP-km for coho salmon, 20 IP-km for Chinook salmon, and 16 IP-km for steelhead). These thresholds assume populations historically operated close to the natural carrying capacity of the watershed.

Methods:

SEC queried the CDFG Passage Assessment Database (PAD)[5] to calculate the proportion of IP-km blocked to anadromy by impassable barriers. The PAD contains data and point file coverage for all known fish passage barriers. Each barrier in the database was identified as a full, partial or natural barrier. SEC evaluated only total or complete barriers to avoid overestimating actual impediments to migration.

In each population, the furthest downstream barrier was identified and listed in a Microsoft Excel spreadsheet. SEC calculated the total IP-km lost per barrier. All lost IP-km were summed, and divided by the watershed IP-km for each population to yield the percent inaccessible IP-km.

Other passage impediments were also considered; such as estuary mouths and flow-related barriers (*e.g.*, at critical riffles). These passage impediments were separated into their own attributes due to substantial differences in assessment methods. Natural barriers were not included in this attribute because they are already taken into consideration in the development of the IP networks. IP-km inadvertently indicated above natural barriers was removed from the IP-km network..

[5] http://nrm.dfg.ca.gov/PAD/Default.aspx

Large dams were evaluated as barriers because any IP reaches upstream of these barriers may have value to recovery. Spence *et al*. (2008) presented viable population targets both with and without IP km above large dams. For some watersheds it may be possible in to attain recovery goals without passage over these dams.

Condition Indicator: Passage at Mouth or Confluence for Adult, Summer Rearing, and Smolt Targets

Passage into and out of tributaries from the mainstem migratory reaches or estuaries is critical for spawning adults and emigrating smolts. Juvenile salmonids also move between stream reaches during the summer rearing phase.

Flow variability and channel conditions may limit salmonid migration into and out of tributaries and mainstem channels. Depending upon rainfall year, low flows may disconnected tributary confluences due to aggradation, or channel incision. Inaccessible tributaries may preclude the adult spawning population from accessing historical habitats, limiting overall carrying capacity and diversity in the population. Spawners waiting for flows to rise in order to access natal streams are susceptible to predation and other forms of mortality such as recreational fishing. Impacts to smolt outmigration and summer movement could also limit carrying capacity.

Ratings: Accessible proportion of IP-km

Thresholds are defined as follows:

Poor = <50% or <32 IP-Km of historical IP-Km accessible;
Fair = 50% to 74% of historical IP-Km habitat accessible;
Good = 75% to 90% of historical IP-Km accessible; and
Very Good = >90% of historical IP-Km accessible.

Methods:

Ratings were determined based on reviews of watershed reports, co-manager feedback, literature reviews, and best professional judgment. Conditions considered include:

- Annual variability in passage;
- Seasonality of passage conditions;
- Severity of condition; and
- Geographic scope of problem.

Attribute: Riparian Vegetation

Riparian vegetation is all vegetation in proximity to perennial and intermittent watercourses potentially influencing salmonid habitat conditions. Riparian vegetation mediates a variety of biotic and abiotic factors interacting and influence the stream environment. An adequately sized riparian zone with healthy riparian vegetation filters nutrients and pollutants, create a cool microclimate over a stream, provide food for aquatic organisms, maintain bank stability and provide hard points around which pools are scoured (Spence *et al.* 1996). NMFS (1996a) noted that “studies indicate that in Western states, about 80 to 90 percent of the historic(al) riparian habitat has been eliminated.” Four indicators were developed to evaluate this attribute.

Condition Indicator: Canopy Cover for Summer Rearing Target

Canopy cover is the percentage of stream area shaded by overhead foliage. Riparian vegetation forms a protective canopy, particularly over small streams by: (1) maintaining cool stream temperature in summer and insulating the stream from heat loss in the winter, (2) contributing leaf detritus, and (3) facilitating insect fall into the stream which supplements salmonid diets (Murphy and Meehan 1991). Reduction in canopy cover can change the stream environment and adversely affect salmonids by; (1) elevating temperature beyond the range preferred for rearing, (2) inhibiting upstream migration of adults, (3) increasing susceptibility to disease, (4) reducing metabolic efficiency, and (5) shifting of the competitive advantage of salmonids to non salmonid species (Hicks *et al*. 1991b).

Ratings: Average canopy closure at the reach, stream and population scale
CDFG (2004) recognized 80 percent canopy as optimal for salmonid habitat at a reach scale. Given canopy closure varies inversely with stream order (as a function of channel width), an average canopy closure of 70 percent was used to describe good conditions. This accounts for the natural range of variability, and acknowledged bias in riparian shading estimates. Average stream canopy closure below 70 percent was rated progressively lower; average stream canopy above 80 percent was rated to identify refugia areas.

Stream level rating criteria
Poor = < 50% average stream canopy;
Fair = 50% to 69% average stream canopy;
Good = 70% to 80% average stream canopy; and
Very Good = > 80% average stream canopy.

Each population rating according to the following criteria:

Population level rating
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75% to 90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Methods:
CDFG (2004) habitat typing survey methods use a spherical densitometer to estimate relative vegetative canopy closure or canopy density to provides an index of stream shading. Four measurements are taken from the middle of the stream, in four quadrants from the middle of a habitat unit (downstream, right bank, upstream, left bank). Typically, canopy is recorded in approximately every third habitat unit in addition to every fully-described unit. This provides an approximate 30 percent sub-sample for all habitat units. The sub-sample is expressed as an average for each stream reach. SEC queried the stream summary database for mean percent canopy cover for each stream reach and extrapolated these data to characterize each stream, for all streams within each population (where survey data existed). Canopy closure at the stream scale was calculated from reach scale data, and aggregated by determining the percentage of streams/IP-km meeting optimal criterion at the population scale.

<u>Condition Indicator: Diameter at Breast Height (DBH) for Adult, Summer and Winter Rearing Targets</u>
Intact riparian zones, often characterized by an adequate buffer of mature hardwood and/or coniferous forests, are an important component of a properly functioning habitat conditions for salmonids. Buffers mediate upslope processes such as sediment delivery.

Spence *et al*. (1996) recognized the distance equal to the potential height of riparian trees (one site potential tree height[6]) as a minimum buffer to allow for recruitment of large wood to Pacific salmon streams. The Forest Ecosystem Management Assessment Team (1993) extended the zone of influence to two site potential tree heights or to the top of any inner gorge areas. The 100 meter buffer used for this indicator is approximately equivalent to two site potential tree heights in old growth Douglas-fir or forests or 1½ site potential tree heights in mature redwoods. Spence *et al.* (1996) suggested 200-240 feet as an appropriate site potential tree height for redwoods. Beardsley *et al*. (1999) used a diameter of 40 inches as indicative of old growth forests in the Sierra Nevada. The diameter of coastal riparian redwoods before disturbance may often have been several feet in diameter (Noss 2000). Due to data limitations south of San Francisco, two ratings for this indicator were developed.

Rating 1: Tree Diameter (North of the Golden Gate), percent of riparian zones (100 meters from centerline of the active channel) in CWHR class 5 and 6

Tree diameter was used as an indicator of riparian function based on the average DBH of a stand of trees within a buffer that extends 100 meters back from the edge of the active channel.

The California Wildlife Habitat Relationships (CWHR) model[7] was used to determine predominant vegetation patterns and corresponding size class categories to estimate average tree size diameters within 100 meters of all IP-km. CWHR is an information system and predictive model for terrestrial species in California. The information in CWHR is based on current published and unpublished biological information and professional judgment by recognized experts on California's wildlife communities. Using CWHR information obtained from CalFire, GIS was used to evaluate riparian conditions across all IP-km in independent populations and all anadromous blue-line streams in dependent populations. Data on tree size classifications were available only for the populations north of the Golden Gate. Classes 5 and 6 are typically older, larger trees expected to contribute to good conditions and were rated as follows:

> Poor = ≤ 39% CWHR size class 5 and 6 across IP-km;
> Fair = 40% to 54% CHWR size class 5 and 6 across IP-km;
> Good = 55% to 69% CWHR size class 5 and 6 across IP-km; and
> Very Good = > 69% CWHR size class 5 and 6 across IP-km.

Rating 2: Tree Diameter (South of the Golden Gate), WHR density classes across blue line streams in population

For the Santa Cruz diversity stratum (stream south of the Golden Gate), no comprehensive CWHR classification of the various size classes was available. WHR data were compiled into CWHR density classes of conifer, conifer-hardwood, and hardwood woodland categories. Because these data lack a structural element, it was necessary to default to the WHR density criteria as a proxy of riparian structure while acknowledging these data are not as robust as the diversity stratum north of the Golden Gate[8]. We

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[6] Site potential tree height is the expected height a tree would attain under properly functioning conditions and varies by tree species, local climate, soils, *etc*.

[7] For more information on the CWHR model, go to: http://ceic.resources.ca.gov/catalog/FishAndGame/WildlifeHabitatRelationshipsWHRSystem.html

[8] Recovery staff were familiar with riparian stand conditions in the Santa Cruz diversity stratum and those north of San Francisco Bay and overall tree species structure and composition in these areas. Staff determined Santa Cruz

compared the high density categories (conifer, conifer-hardwood, hardwood woodland) of the Santa Cruz diversity stratum to the equivalent high density categories from the northern diversity strata and determined conditions were good if ≥ 80 percent of the population had high density categories of conifer, conifer-hardwood, and/or hardwood woodland, on average in the riparian buffer for the watershed (population). This condition was described as 60 to 100 percent canopy closure; CWHR class D. For the Santa Cruz Diversity Stratum, this indicator was rated using the percentages of size classes under density rating D to obtain the following total percentage for the size classes:

Poor = ≤ 69% CWHR density rating D across IP-km;
Fair = 70% to 79% CHWR density rating D across IP-km;
Good = ≥ 80% CWHR density rating D across IP-km; and
Very Good = no rating.

Methods:
CWHR vegetation characterization exists for three of the four coho salmon diversity strata targeted for recovery actions. Unlike data available for the northern diversity strata, to date no wide scale CWHR categorization data was available for the Santa Cruz diversity stratum. Typically, the most current and detailed data were collected for various regions of the state or for unique mapping efforts (farmland, wetlands, riparian vegetation). Various sources were compiled into the CWHR system classification. The dates for the source data vary from 1970's (urban areas) to 2000. The bulk of the forest and rangeland data were collected by CalFire/USFS 1994-1997.

Alternative tree size criteria were initially considered when evaluating riparian stand condition. This alternative considered 100 meter wide riparian stands, where more than 80 percent of the stand was comprised of trees with average DBH of 20 inches or greater, was indicative of very good conditions. However, the 20-inch DBH criteria could not be used because the corresponding CWHR size class (size class 4), encompasses a wide range of tree diameters (11-23.9 QMD (quadratic mean diameter)) (Table 7). The large range rendered size class 4 an unsuitable proxy for the 20 inch indicator. The difference in size and ecological function in a tree with an 11 inch DBH versus a 24-inch DBH is substantial, where an 11 inch tree (depending on site conditions) is almost always younger (unless it is suppressed and/or located on poor soil types) and smaller (in height as well as diameter than a 24 inch tree). Therefore, we applied size class 5 and 6 when evaluating riparian condition. Overall, we believe CWHR is the best available GIS tool to characterize riparian condition across large landscapes due to it wide-spread application, ease of use via GIS, and its standardization as an assessment tool.

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structure and composition generally comports to that in the northern diversity strata and was not comprised of inordinate proportions of dense stands of CWHR size class 1-3 trees.

Table 7. CWHR Size Class Criteria.

CWHR Code	CWHR Size Classes	DBH
1	Seedling tree	< 1.0″
2	Sapling tree	1.0″ – 5.9″
3	Pole tree	6.0 – 10.9″
4	Small tree	11.0″ – 23.9″
5	Medium/large tree	≥ 24.0″
6	Multi-layered stand	A distinct layer of size class 5 trees over a distinct layer of size class 4 and/or 3 trees, and total tree canopy of the layers > 60% (layers must have > 10.0% canopy cover and distinctive height separation).

CWHR size classes were reviewed for watersheds considered to maintain properly functioning riparian condition in four locations: Smith River at Jedidiah Smith State Park, Redwood Creek in Redwood National Park, Prairie Creek, and the South Fork Eel at Humboldt Redwoods State Park. In total, we reviewed CWHR size classes in the riparian zones of 95 miles of blue line streams and used this information to establish criteria for reference conditions. These data indicated at least 70 percent of the 100 meter wide riparian zones were comprised on CWHR size class 5 and 6 forest. From these results we determined a 100 meter wide riparian buffer consisting, on average, of ≥69 percent CWHR size class 5 and 6 tree represented very good conditions in the three northern diversity strata.

Landscape Context Indicator: Riparian Species Composition for Watershed Processes Target

Changes to the historical riparian vegetative community due to introduction of non-native plants or domination of early seral communities can adversely affect salmonid habitat. Invasive non-native plants such as *Arundo donax* can out-compete native plants and even form barriers to migration. Early seral species such as alder can suppress long lived conifers and significantly delay future large woody debris recruitment of these conifers. Hardwoods like alder do not form long lived woody debris elements as do conifers such as redwood and Douglas-fir.

Ratings: Current departure of riparian vegetation (within 100 meters of streams across IP-km) from historical conditions

Ecological status relates the degree of similarity between current vegetation and potential vegetation for a site or population. It can be measured on the basis of species composition within a particular community type or on the basis of community type composition within a riparian complex. Ratings were derived from Winward (1989) who developed criteria for potential natural communities.

Species composition is the presence and persistence (composition and structure) of the historical vegetative community within 100 meters of a watercourse within all IP-km of a population. Rating criteria were defined as follows:

Poor = < 25% historical riparian vegetation species composition;
Fair = 25% to 50% historical riparian vegetation species composition;
Good = 51% to 74% historical riparian vegetation species composition; and
Very Good = ≥ 75% historical riparian species composition.

Methods:
Historical vegetation status per population was difficult to obtain. We reviewed CalFire's database on major vegetation communities and determined major differences in historical vegetation species composition based on the percent of population in urban, agriculture, and herbaceous categories. Some inaccuracy likely exists with this approach because some urban areas and agricultural areas may have some riparian areas within the range of historical vegetation species composition. However, based on the widths of the riparian buffers used in this assessment we believe the majority of the areas in these categories do not maintain the historical vegetation patterns.

Attribute: Sediment

Sediment provides several important habitat functions for salmonids, including supporting spawning redds, delivering intergravel flows capable of delivering oxygen to incubating eggs, and supporting food production for rearing juveniles.

Condition Indicator: Gravel Quality Bulk samples and Embeddedness for Eggs Target
Sediment, relative to its function as a key habitat attribute for the egg life stage, was defined as streambed gravels with particle size distribution of sufficient quality to allow successful spawning and incubation of eggs. These substrates must be located within spawning habitat defined by the IP-km model.
Gravel quality was defined using two evaluation methods: bulk sampling (Valentine 1995) and embeddedness (Flosi *et al*. 2004). When bulk sampling data is available, the indicator is the portion of the sampled substrate consisting of > 0.85 millimeters and/or < 6.4 millimeters (NCRWQCB 2006). For HAB 8 data, gravel quality was defined as the distribution of embeddedness values.

Rating 1: Percent pool-tail outs sampled with embeddedness values of 1 and 2
SEC calculated the percentage of pool tail-outs within all IP km with embeddedness values of 1, 2, 3, 4, or 5 and presented them as frequency distributions at the stream scale. A bias analysis was used to determine our degree of confidence in the data and to extrapolate the data to characterize each stream. Ratings were based on frequency distributions because embeddedness scores (1-5) are ordinal numbers; and cannot be averaged and used in the simple rating of poor = > 2, fair = 1 -2, and good = < 1. Also, embeddedness estimates are visual and involve some subjectivity. Embeddedness estimates are not as rigorous as bulk gravel samples in describing spawning and incubation habitat conditions (KRIS Gualala[9]).

As described in Flosi *et al*.(2004), a score of 1 indicates substrate is less than 25 percent embedded; this is considered optimal salmonid spawning habitat. A score of 2 indicates 25-50 percent embedded and moderately impaired. A score of 3 indicates 50-75 percent embedded and highly impaired, 4 indicates 75-100 percent embedded and severely impaired, a 5 indicates the substrate is unsuitable for spawning. The embeddedness ratings used by Bleier *et al.* (2003) states the best spawning substrate is 0-50 percent embedded. CDFG's target value is 50 percent or greater of sampled pool tail-outs are within this range. Streams with less than 50 percent of their length in embeddedness values of 50 percent or less, are considered inadequate for spawning and incubation.

Typically, embeddedness ratings are recorded in every pool habitat unit, in addition to every fully-described unit which provides an approximate 30 percent sub-sample for all habitat units. This sub-

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[9] http://www.krisweb.com/krisgualala/krisdb/html/krisweb/index.htm

sample is expressed as an average for each stream reach. Embeddedness rating criteria is based on criteria developed in the North Coast Watershed Assessment Program (Bleier *et al*. 2003):

Stream level embeddedness
Poor = <25% of the scores were 1s and 2s;
Fair = 25% to 50% of the scores were 1s and 2s;
Good = >50% of the scores were 1s and 2s; and
Very Good = Not defined.

The representative nature of the datasets were extrapolated to the overall population, for all streams within each population (where data were available). Rating each population required two steps; calculation of the average at the stream scale from the reach scale data, and determining the percentage of streams/IP-Km meeting optimal criteria, at the population scale.

Each population was rated according to the following criteria:

Population level embeddedness
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75% to 90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Rating 2: Percent of fines in low flow bulk samples from potential spawning sites
Ratings criteria for bulk sampling data were developed from a variety of sources, including the regional sediment reduction plans by the USEPA (1998; 1999) and the North Coast Regional Water Quality Control Board (2000; 2006) who developed a threshold of 0.85 mm for fine sediment with a target of less than 14 percent. NMFS (1996b) Guidelines for Salmon Conservation also used fines less than 0.85 millimeters as a reference and recognized less than 12 percent as properly functioning condition, 12-17 percent as at risk, and greater than 17 percent as not properly functioning. Fine sediments less than 11 percent are fully suitable, 11-15.5 percent somewhat suitable, 15.5-17 percent somewhat unsuitable and over 17 percent fully unsuitable. McMahon (1983) found that egg and fry survival drops sharply when fines make up 15 percent or more of the substrate.

Rating criteria for bulk samples are:

Poor = > 17% 0.85mm and/ or > 30% 6.3mm;
Fair = 15% to 17% 0.85mm;
Good = 12% to 14% 0.85mm and/or <30% 6.3mm; and
Very Good = < 12% 0.85mm.

Methods:
SEC queried regional data sources for bulk sediment core sample (McNeil) surveys as the preferred method for evaluating spawning gravel quality. However, few watersheds had data sufficient for a comprehensive analysis. In these circumstances, SEC used HAB 8 data from CDFG.

<u>Condition Indicator: Quantity and Distribution of Spawning Gravels for Adult Target</u>

The quantity and distribution of spawning substrate is the amount of spawning habitat available to the spawning population. Distribution indicates the degree of dispersion of habitat across IP-km in a population.

Ratings: Amount of optimal spawning habitat available
Female salmonids usually spawn near the head of a riffle, just below a pool, where water changes from a laminar to a turbulent flow and where there is small to medium gravel substrate. The flow characteristics at the redd location usually ensures good aeration of eggs and embryos, and flushing of waste products. Water circulation in these areas facilitates fry emergence from the gravel. Optimal conditions for spawning have nearby overhead and submerged cover for holding adults and emerging juveniles; water depth of 10 to 54 centimeters (cm); water velocities of 20 to 80 cm per second; clean, loosely compacted gravel (1.3 to 12.7 cm in diameter) with less than 20 percent fine silt or sand content; cool water (4° to 10° C) with high DO (8 mg/l); and an intergravel flow sufficient to aerate the eggs. The lack of suitable gravel often limits successful spawning in many streams.

Ratings for were developed to spatially estimate the percentage of streams within each population meeting optimal conditions. Optimal conditions are based on scientific literature, and defined according to the following criteria:

Poor = < 50% IP-km meet optimal conditions;
Fair = 50% to 74% of IP-km meet optimal conditions;
Good = 75% to 90% of IP-km meet optimal conditions; and
Very Good = > 90% of IP-km meet optimal conditions.

Methods:
To assess population conditions relative to these criteria, watershed reports, co-manager documentation and knowledge, and literature reviews to obtain quantitative data or estimates were used. Where quantitative data were lacking, a qualitative approach was used based upon best available information, spatial data and IP-km habitat potential to inform best professional judgment ratings.

<u>Condition Indicator: Gravel Quality (Embeddedness) for Summer and Winter Rearing Targets</u>
We defined food productivity, relative to its function as a key habitat attribute for summer survival, as streambed gravels with particle size distribution of sufficient quality to facilitate productive macro-invertebrate communities. These substrates must be located within spawning habitat as defined by the IP-km model. Gravel quality was defined using the distribution of embeddedness values from HAB 8.

Suttle *et al*. (2004) examined degraded salmonid spawning habitat, and its effects on rearing juveniles due to fine bed sediment in a northern California river. Responses of juvenile salmonids, and the food webs supporting them, showed increasing concentrations of deposited fine sediment decreased growth and survival. Declines were associated with a shift favorable in invertebrates toward unfavorable invertebrates (burrowing taxa unavailable as prey). Fine sediment can transform the topography and porosity of the gravel riverbed and profoundly affect the emergent ecosystem, particularly during biologically active periods of seasonal low flow. Salmonid growth decreased steeply and roughly linearly with increasing fine sediment concentration. This result was consistent with the effects of sedimentation on the food supply available to salmonids.

Ratings: Embeddedness scores
Rating criteria for embeddedness are:

Stream level embeddedness
Poor = < 25% of the embeddedness scores were 1s and 2s;
Fair = 25% to 50% of the embededdness scores were 1s and 2s;
Good = > 50% of the embededdness scores were 1s and 2s; and
Very Good = Not defined.

The representative nature of the datasets were extrapolated to the overall population, for all streams within each population where the data existed to rate each population by determining the percentage of streams/IP-km met optimal criteria, at the population scale. Each population was rated according to the following criteria:

Population level rating criteria
Poor = < 50% of streams/IP-km rating good or better;
Fair = 50% to 74% of streams/IP-km rating good or better;
Good = 75% to 90% of streams/IP-km rating good or better; and
Very Good = > 90% of streams/IP-km rating good or better.

Methods:
SEC queried CDFG HAB 8 data to rate this indicator. As described in Flosi *et al*. (2004), a score of 1 indicates substrate is less than 25 percent embedded; this is considered optimal salmonid spawning habitat. A score of 2 indicates 25-50 percent embedded and moderately impaired. A score of 3 indicates 50-75 percent embedded and highly impaired, 4 indicates 75-100 percent embedded and severely impaired, a 5 indicates the substrate is unsuitable. The percentage of pool tail-outs within all IP-km was calculated for embeddedness values, as discussed above, as a surrogate indicator for productive food availability for rearing juveniles.

Attribute: Sediment Transport

Sediment transport is the rate, timing, and quantity of sediment delivered to a watercourse. Because of their significant contribution to increased sediment in streams, two road related indicators were developed for this attribute.

Landscape Context: Road Density for Watershed Processes Target
Road density is the number of miles of roads per square mile of population. A series of data layers were used to calculate road density within each dependent and independent population.

Construction of a road network can lead to greatly accelerated erosion rates in a watershed (Haupt 1959; Swanson and Dryness 1975; Swanson *et al*. 1976; Beschta 1978; Gardner 1979; Reid and Dunne 1984). Increased sedimentation in streams following road construction can be dramatic and long lasting. The sediment contribution per unit area from roads is often much greater than that from all other land management activities combined, including log skidding and yarding (Gibbons and Salo 1973). Sediment entering streams is delivered chiefly by mass soil movements and surface erosion processes (Swanston 1991). Failure of stream crossings, diversions of streams by roads, washout of road fills, and accelerated scour at culvert outlets are also important sources of sedimentation in streams within (Furniss *et al.* 1991). Sharma and Hilborn (2001) found lower road densities (as well as valley slopes and stream gradients) were correlated with higher coho smolt density.

According to Furniss *et al*. (1991) "…roads modify natural drainage networks and accelerate erosion processes. These changes can alter physical processes in streams, leading to changes in streamflow regimes, sediment transport and storage, channel bank and bed configuration, substrate composition, and stability of slopes adjacent to streams. These changes can have important biological consequences, and they can affect all stream ecosystem components. Salmonids require stream habitats for food, shelter, spawning substrate, suitable water quality, and access for migration upstream and downstream during their life cycles. Roads can cause direct and indirect changes to streams that affect each of these components."

Ratings: Number of road miles per square mile in population
Cederholm *et al.* (1980) found fine sediment in salmon spawning gravels increased by 2.6 - 4.3 times in watersheds with more than 4.1 miles of roads per square mile of land area. Graham Matthews and Associates (1999) linked increased road densities to increased sediment yield in the Noyo River in Mendocino County, California. King and Tennyson (1984) found the hydrologic behaviors of small forested watersheds were altered when as little as 3.9 percent of the watershed was occupied by roads. NMFS (1996b) guidelines for salmon habitat characterize watersheds with road densities greater than three miles of road per square mile of watershed area (mi/sq. mi) as "not properly functioning" while "properly functioning condition" was defined as less than or equal to two miles per square mile, with few or no streamside roads.

Armentrout *et al.* (1998) used a reference of 2.5 mi./sq. mi. of roads as a watershed management objective to maintain hydrologic integrity in Lassen National Forest watersheds harboring anadromous fish. Regional studies from the interior Columbia River basin (USFS 1996) show that bull trout do not occur in watersheds with more than 1.7 miles of road per square mile. The road density ranking system shown in Figure 2 was developed based on the Columbia basin findings (USFS 1996).

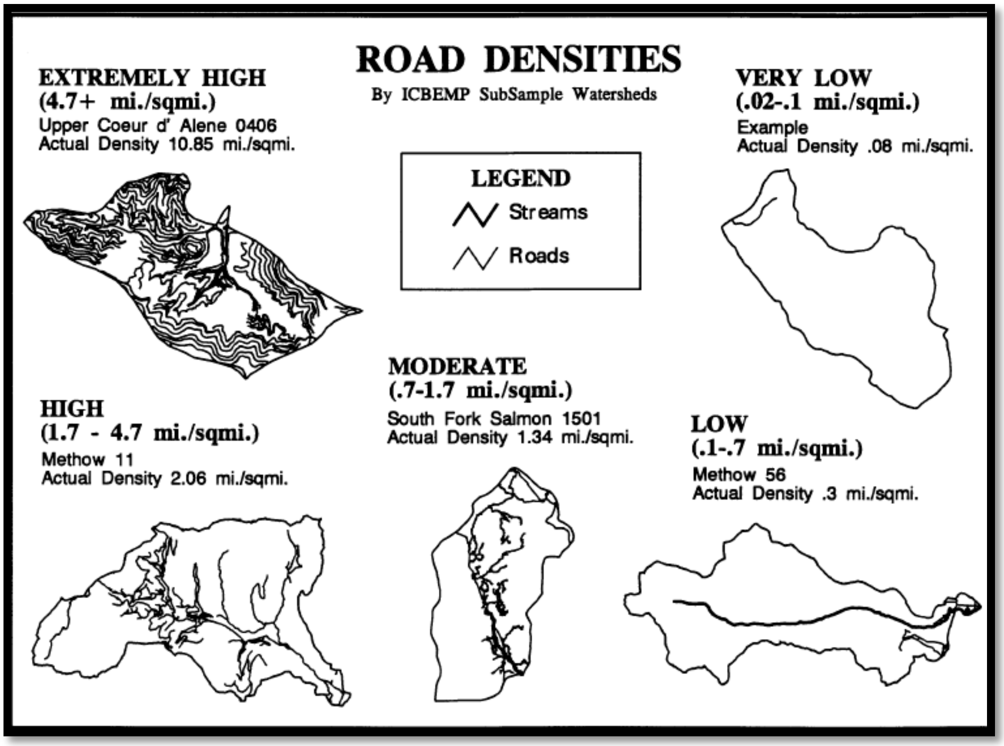

Figure 2. Graphic from the Interior Columbia Basin Management Plan, showing classes of road densities for sample watersheds (USFS, 1996).

The most inclusive datasets available for each population (see below) were used. The goal was to be as precise as possible for each population while acknowledging some inconsistency (due to the use of four datasets) may result from this approach.

Poor = > 3 miles/square mile of population
Fair = 2.5 to 3 miles/square mile of population
Good = 1.6 to 2.4 miles/square mile of population
Very Good = < 1.6 miles/square mile of population

Methods:
GIS analysis of the miles of road networks within a population made use of several data sources:

1. CalFire Timber Harvesting History. GIS vector dataset, 1:24,000. 2007. Watersheds between Cottaneva Creek (inclusive) and the Russian River (inclusive);
2. CalTrans, Tana_rds_d04. GIS vector dataset, 1:24,000. 2007. Marin County watersheds;
3. U.S. Census Bureau, Roads. GIS vector dataset., 1:24,000. 2000. San Mateo County watersheds; and
4. County of Santa Cruz – Roads; Streets. GIS vector dataset, 1:24,000. 1999. Santa Cruz County watersheds.

The resulting linear measurement (in miles) was compared against the total population area in square miles to derive watershed (population) road density.

Landscape Context Indicator: Streamside Road Density for Watershed Processes Target

Streamside road density is the density of roads, per square mile of a 200 meter riparian corridor (100 meters on either side of the stream centerline) within the population.

Roads frequently constitute the dominant source of sediments delivered to watercourses. Roads constructed within the riparian buffer zone pose many risks to salmonids habitat including the loss of shade, decreased large wood recruitment, and delivery of fine sediment and initiation of mass wasting (Spence *et al*. 1996). Rock revetments are often used to prevent streams from eroding road beds, resulting in channel confinement that can lead to incision of the stream bed. Roads in close proximity to watercourses may have a greater number of crossings which may act as: (1) impediments to migration, (2) flow restrictions which artificially change channel geometry, and (3) sources of substantial sediment input due to crossing failure.

Ratings: Number of road miles per square mile within 100 meters of the watercourse (centerline)
The USFS (2000) provides data for near stream roads in road miles per square mile and a frequency distribution was used to derive values showing very low relative risk as very good (<0.1 mi/sq. mi) and the opposite end of the frequency spectrum as posing high relative risk to adjacent coho habitat as poor (> 1 mi/sq. mi).

Poor = > 1 mile/square mile of riparian corridor;
Fair = 0.5 to 1 mile/square mile of riparian corridor;
Good = 0.1 to 0.4 mile/square mile of riparian corridor; and
Very Good = < 0.1 mile/square mile of riparian corridor.

Methods:
The most inclusive datasets available for each population were used. The goal was to be as precise as possible for each population while acknowledging some inconsistency (due to the use of four datasets) may result from this approach.

A series of GIS data layers were used to calculate the riparian buffer and road density within each dependent and independent population:

To create the riparian buffer these stream files were used:
1. Streams - CalFire, Hydrography watershed Assessment; Wahydro. GIS vector dataset, 1:24,000. 1998. Watersheds from Cottaneva Creek (inclusive) to the Russian River (inclusive); and
2. Streams - USGS National Hydrography Dataset; Flowline (1801, 1805), vector digital dataset, 1:24,000. 2004. Watersheds in Marin, San Mateo, and Santa Cruz counties.

To create the road layer these stream files were used:

1. CalFire Timber Harvesting History. GIS vector dataset, 1:24,000. 2007. Watersheds between Cottaneva (inclusive) and the Russian River (inclusive);
2. CalTrans, Tana_rds_d) 4. GIS vector dataset, 1:24,000. 2007. Marin County watersheds;
3. U.S. Census Bureau, Roads. GIS vector dataset., 1:24,000. 2000. San Mateo County watersheds; and
4. County of Santa Cruz – Roads; Streets. GIS vector dataset, 1:24,000. 1999. Santa Cruz County watersheds.

Attribute: Smoltification

This attribute focuses on temperature criteria required during the physiological changes young salmonids undergo in preparation to enter the ocean (smoltification) and potential anthropogenic sources which lead to alterations in stream water temperature. While the smoltification process can occur throughout the wet season, most salmonids smolt and emigrate to the ocean during the spring months (specific emigration periods vary between and among species and across the geographic range). Naturally occurring warmer water temperatures (such as those that may occur in streams within the southern extent of the NCCC Recovery Domain or where solar radiation occurs naturally) were distinguished from temperature impairments due to human induced alterations.

Condition Indicator: Smoltification Stream Temperature for Smolt Target

The extent and magnitude of spatial and temporal temperature variations within emigration routes was considered when evaluating potential impacts. For example, where access to cold water refugia is lost, the length of warm water exposure was considered with respect to behavior alteration and/or physiological impairment during smoltification.

Ratings:

In considering anthropogenically altered water temperature regimes and effects on smoltification and emigration, location, extent, magnitude (significance of temperature alteration), and duration of the effects were evaluated. The rating criteria considered the following factors:

- ❑ Magnitude of temperature alteration (*i.e.*, how much does the temperature deviate from natural stream water temperatures or from preferred criteria);
- ❑ Relative percent of rearing habitat, or relative percent of the emigrating population affected by anthropogenically altered temperature regimes;
- ❑ Relative location and extent of the affected reaches within the population (*i.e.*, the importance of the individual reach to the population); and
- ❑ The duration these effects persist (including effects on diel temperature fluctuations).

The basis for establishing the effect of temperature on smoltification and emigration was made where possible, it must ultimately be extrapolated to the population level. For example, a large anthropogenic temperature alteration low in the mainstem of a watershed could be considered fairly significant in affecting not only the reach in which the alteration occurs, but for the entire population, since emigrating smolts from the upstream reaches will have to pass through the downstream affected reach(s).

For rating the population, optimal conditions are described as > 6° C but < 16° C [Temperature expressed as maximum weekly maximum temperature (MWMT)], and/or anthropogenic thermal inputs/alterations do not affect smoltification or emigration.

Temperature ratings are:

Poor = < 50% IP-km (> 6° and < 16° C);
Fair = 50% to 74% IP-km (> 6° and < 16° C);
Good = 75% to 90% IP-km (> 6° and < 16° C); and
Very Good = > 90% IP-km (> 6° and < 16° C).

Methods:

A literature review was conducted to identify sources of temperature information, and evaluate temperature thresholds necessary to support and to avoid delays smoltification and emigration. Examples of anthropogenic sources of in-stream temperature alteration to be considered include, but are not limited to:

- Off channel pond discharges;
- On-channel pond complexes;
- Agricultural land discharges;
- Dams and reservoirs (USEPA 2003);
- Riparian clearing that reduces canopy cover and increases instream solar warming;
- Water withdrawals (USEPA 2003);
- Channeling, straightening or diking (USEPA 2003); and
- Removing upland vegetation or creating impervious surfaces (USEPA 2003).

Attribute: Velocity Refuge

Velocity refuge is habitat providing space and cover for adult and juvenile salmonids during high velocity flood flows. Refuge habitats may include main-channel pools with LWD (or other forms of complexity), or off-channel habitats such as alcoves, backwaters, or floodplains (Bustard and Narver 1975; Bell *et al*. 2001). Floodplains are geomorphic features frequently inundated by flood flows, and often appear as broad flat expanses of land adjacent to channel banks.

Condition Indicator: Floodplain Connectivity for Adult and Winter Rearing Targets

Floodplain connectivity is the frequency of floodplain inundation in unconfined reaches. Frequencies approximating those of an unaltered state retain the ability to support the emergent ecological properties associated with floodplain connectivity. Although this definition goes beyond an indication for velocity refuge, the broader concept was refined because it represents important habitat features for the target life stages.

Ratings: Percent of floodplain connectivity of flood-prone zones within IP-km

Periodic inundation of floodplains by storm flows provides several ecological functions beneficial to salmon, including: coarse sediment sorting, fine sediment storage, groundwater recharge, velocity refuge, formation and maintenance of off-channel habitats, and enhanced forage production (Stanford *et al*. 2004). Floodplain connectivity is associated with more diverse and productive food webs (Power *et al*. 1996). Channel incision can result in the reduction or elimination of access for biota to lateral floodplain habitats (Power *et al*. 1996).

Stream complexity that creates low velocity areas during high flow events, whether from LWD, off-channel habitats, or wetland areas, is an important component of winter rearing habitat. Bell (2001) documented increased fidelity and survival of winter rearing juvenile coho salmon in alcoves and backwaters in a Northern California stream. Others have documented increased densities of coho salmon in side-channel pools (Bjornn and Reiser 1991). In British Columbia, juveniles preferred stream flows < 15 cm/sec (Bustard and Narver 1975). Bisson *et al.* (1988) indicated a preferred velocity of < 20 cm/sec, and < 30 cm/sec was cited in a third study (Tschaplinski and Hartman 1983). Salmonids use off-channel habitats during winter for refuge during high flow events and floodplains for feeding during early spring and summer.

The United States Forest Service (USFS) (2000) Region 5 watershed condition rating system is aimed at maintaining "…the long-term integrity of watersheds and aquatic systems on lands the agency manages." Scores were based on best professional judgment, by staff familiar with instream conditions necessary of salmonid rearing using criteria are similar to regional standards (USDA 1995; Spence *et al.* 1996).

The USFS considers channel condition to be properly functioning when more than 80 percent of the low gradient response reaches have floodplain connectivity, while 50-80 percent was considered partially functional and less than 50 percent non-functional. Ratings are as follows:

Poor = < 50% response reach connectivity;
Fair = 50% to 80% response reach connectivity;
Good = > 80% response reach connectivity; and
Very Good = Not defined.

Methods:
This indicator was assessed by quantifying the degree of urbanization, channelization, incision and other factors affecting flood-prone areas for each population. Federal Emergency Management Agency's (FEMA) delineation of Zone A Flood Zone Designation maps assisted this interpretation in the definition of flood-prone areas. NMFS watershed characterization maps and statistics also assisted to describe the degree of urbanization and other land uses such as agriculture.

The ratings for this indicator were determined based on NMFS analysis of watershed reports, co-manager documentation, literature reviews, and best professional judgment. Where quantitative data was lacking, a qualitative approach was utilized using the best available literature, spatial data and IP-km habitat potential to inform best professional judgment ratings

Attribute: Viability

This attribute addresses a suite of demographic indicators defining population status and provides an indication of their extinction risk. The viability attribute is a population metric and, in conjunction with habitat attributes, provides a means to validate assumptions and conclusions. For example, if habitat quality was rated as good, and fish density or abundance was poor, it provided a basis to re-evaluate conclusions and examine assumptions about causative relationships between populations and habitat. In the specific context of a key attribute, viability is the suite of demographic indicators defining the population status (which relate directly to their extinction risk).

Size Indicator: Density for Adult Target
Density was used as an indicator for the spawner life-stage because it is one of the principle metrics used to define population viability in the biological viability report (Spence *et al*. 2008) developed by the Technical Recovery Team (TRT).

Ratings: Average spawner density per IP-km

The TRT established criteria of one spawning adult per IP-km as a reasonable threshold to indicate a population at high risk of depensation[10] (Spence *et al*. 2008). This threshold was used as an indicator for a poor spawner density.

The TRT also developed density criteria for population viability. For the smallest of independent populations (*i.e*., those with 32 IP-km), adult spawning densities should exceed 40 fish per IP-km. Densities may decrease to 20 fish per IP-km as the size of an independent population approaches ten times the minimum size (*i.e*., 32 IP-km). This formula represents the spawner density threshold for a low risk of extinction, and was used as our criteria for a good rating (Table 8). A fair rating was any density between poor and good. A criterion rating for very good was not established.

Table 8. Population specific density (# of adults/IP-km) criteria for spawning adult coho based on TRT density criteria (Spence *et al*. 2008).

Population	Poor	Fair	Good	Very Good
Usal Creek	≤1	Between	≥34.0	None
Cottaneva Creek	≤1	Between	≥34.0	None
Ten Mile River	≤1	Between	≥34.9	None
Wages Creek	≤1	Between	≥34.0	None
Pudding Creek	≤1	Between	≥34.0	None
Noyo River	≤1	Between	≥34.0	None
Caspar Creek	≤1	Between	≥34.0	None
Big River	≤1	Between	≥28.9	None
Albion River	≤1	Between	≥38.1	None
Big Salmon Creek	≤1	Between	≥34.0	None
Navarro River	≤1	Between	≥28.3	None
Garcia River	≤1	Between	≥34.9	None
Gualala River	≤1	Between	≥24.8	None
Russian River	≤1	Between	≥20.0	None
Salmon Creek	≤1	Between	≥34.0	None
Pine Gulch	≤1	Between	≥34.0	None
Walker Creek	≤1	Between	≥37.5	None
Lagunitas Creek	≤1	Between	≥37.3	None
Redwood Creek	≤1	Between	≥34.0	None
San Gregorio Creek	≤1	Between	≥34.0	None
Pescadero Creek	≤1	Between	≥38.0	None
Gazos Creek	≤1	Between	≥34.0	None
Waddell Creek	≤1	Between	≥34.0	None
Scott Creek	≤1	Between	≥34.0	None

[10] At very low densities, spawners may find it difficult to find mates, small populations may be unable to saturate predator populations, and group dynamics may be impaired, *etc*. Small populations may experience a reduction in per-capita growth rate with declining abundance, a phenomenon known as depensation (Spence *et al*. 2008).

San Vicente Creek	≤1	Between	≥34.0	None
San Lorenzo River	≤1	Between	≥34.6	None
Soquel Creek	≤1	Between	≥34.0	None
Aptos Creek	≤1	Between	≥34.0	None

Methods:
To assess the indicator by population, the estimated annual spawning population (N_a) divided by the amount of IP-Km available for spawning (N_a/IP-Km). N_a was measured as the geometric mean of annual spawner abundance for the most recent three to four generations (Spence *et al.,* 2008). The TRT evaluated current abundance for all independent populations in the ESU and found data availability was insufficient in most cases. We were therefore forced to make reasonable inferences based on what information was available. Data sources we used for this assessment included the NMFS Fisheries Science Center database, literature review, and previous status assessments (Good *et al.* 2005; Spence and Williams 2011).

<u>**Size Indicator: Abundance for Smolt Target**</u>
We use abundance as an indicator not only because it is a direct measure of population size, but because smolt populations can be estimated with various out-migrant trapping and mark and recapture methods.

Ratings
We used the following equation was used to calculate the number of smolts (at time *t*) needed to satisfy abundance criteria (S_t):

$$S_t = \frac{A_{t+i}}{0.01_i}$$

Where A_{t+1} is the adult abundance after time interval (*i*) divided by the assumed marine survival of 1 percent during time interval *i*. Therefore, to calculate smolt abundance criteria for each population: good criteria would be the low risk abundance (the low risk adult target in Spence *et al*. (2008) divided by 0.01); and poor criteria would be the "high risk abundance" (the high risk adult target in Spence *et al*. (1996) divided by 0.01). Fair criteria would be abundance levels between low risk and high risk. For example, for the Noyo River this calculation yields the following rating (Table 9).

Table 9. Example of smolt indicator criteria for smolt abundance Noyo River coho calculated from TRT adult abundance criteria.

Smolt Abundance	Poor	Fair	Good
	<High Risk	Moderate Risk	> Low Risk
Noyo River	<11,800	11,800- 400,000	>400,000

Methods:
To assess the status of smolt production for a given population we need to rely on available monitoring data, most of which is contained in data sources such as the NMFS Fisheries Science center database, NMFS recovery library, and previous status assessments (Good *et al.* 2005). When no population estimates are currently available for the smolt life stage (or any other), we reviewed the data sources and made reasonable inferences as to the probable status of smolts.

<u>Size Indicator: Density for Summer Rearing Target</u>
Assessing juvenile density provides an indication of species presence and relative carrying capacity. Consistently low density estimates within a population may suggest the population or habitat is not functioning properly. High density estimates suggest a population is properly functioning and can be used by fishery managers to prioritize threat abatement efforts.

Ratings: Average juvenile density in population
Although methods for estimating the population abundance of juvenile coho salmon have been developed (Hankin and Reeves 1988), there are few estimates for populations within the CCC coho salmon ESU using these techniques. Estimates of juvenile density however, are more common and provide some indication of life-stage-specific status. Density estimates may also be useful in indicating habitat quality if streams are adequately seeded.

Rating criteria for juvenile density were based on the assumption that approximately 1.0 fish per square meter is a reasonable benchmark for fully occupied, good habitat (Nickelson *et al.* 1992; Solazzi *et al.* 2000). Ratings are as follows:

Poor = < 0.2 fish/meter^2;
Fair = 0.2 to 0.5 fish/meter^2;
Good = 0.5 to1.0 fish/meter^2; and
Very Good = > 1.0 fish/meter^2

Methods:
The juvenile density indicator was informed through a review of the literature including CDFG reports, NMFS technical memorandums, watershed analyses, section 10 research reports, and fisheries management and assessment reports. Co-managers were also interviewed. The information was compiled and synthesized by NMFS biologists (with extensive field experience) who used best professional judgment to rate the density.

<u>Size Indicator: Spatial Structure for Summer Rearing Target</u>
Current distribution of the population occupying available habitat is one of the four key factors in determining salmonid population persistence (McElhany *et al*. 2000). Species occupying a larger proportion of their historical range have an increased likelihood of persistence (Williams *et al.* 2007). To evaluate current distribution the historical range (IP-km) was compared to the percentage of habitat currently occupied by the juvenile life stage in the population.

Ratings: Current versus historical juvenile distribution across IP-Km
The following indicator ratings developed by Williams *et al.* (2006) for a similar conservation assessment described in Williams *et al.* (2007)

Poor = < 50% of historical range;
Fair = 50% to 74% of historical range;
Good = 75% to 90% of historical range; and
Very Good = > 90% of historical range.

Methods
California Department of Fish and Game, NMFS, and other agency and organization surveys, data sources and reports were used in evaluating the percentage of historical habitat currently occupied by the

species. Population characterization maps were compared with IP-km maps to provide a spatial representation to estimate the percentage of the historical range currently occupied.

Attribute: Water Quality

Water quality was assessment as an attribute to classify three indicators: water temperature, toxicity, turbidity.

Condition Indicator: Temperature (Mean Weekly Maximum Temperature (MWMT)) for Summer Rearing Target

Water temperature is an important indicator of water quality, particularly with respect to juvenile coho salmon, due to a close association with temperature conditions. Juvenile salmonids respond to stream temperatures through physiological and behavioral adjustments that depend on the magnitude and duration of temperature exposure. Acute temperature effects result in death after exposures ranging from minutes to days. Chronic temperature effects are associated with exposures ranging from weeks to months. Chronic effects are generally sub-lethal and may include reduced growth, disadvantageous competitive interactions, behavioral changes, and increased susceptibility to disease (Sullivan *et al*. 2000). A measure of chronic temperature was used because it is more typical of the type of stress experienced by summer rearing juveniles in the CCC coho ESU rather than acute temperature stress.

Ratings: Proportion of IP-km in each temperature threshold class

Juvenile salmonids prefer water temperatures of 12° C to 15° C (Brett 1952; Reiser and Bjornn 1979), but not exceeding 22° C to 25° C (Brungs and Jones 1977) for extended time periods. Chronic temperatures, expressed as the maximum weekly average temperature, in excess of 15° C to 18° C, are negatively correlated with coho salmon presence (Hines and Ambrose 2000; Welsh *et al*. 2001). Sullivan *et al.* (2000) recommended a chronic temperature threshold of 16.5° C for this species. Water temperatures for good survival and growth of juvenile coho salmon range from 10° to 15° C (Bell 1973; McMahon 1983). Growth slows considerably at 18° C and ceases at 20° C (Stein *et al*. 1972; Bell 1973). The likelihood of juvenile coho salmon occupying habitats with maximum weekly average temperatures exceeding 16.3° C declined significantly (Welsh *et al.* 2001) in the Mattole River watershed in southern Humboldt County, California.

Temperature thresholds for chronic exposure are typically based on the maximum weekly average temperature (MWAT) metric. Due to some confusion in the literature regarding the appropriate definition and application of MWAT, the seven day moving average of the daily maximum (7DMADM or MWMT) indicator was used, rather than the seven day moving average of daily average (7DMADA or MWAT), because it correlated more closely correlated with observed juvenile distribution (Hines and Ambrose 2000). However, where MWMT data was not available, MWAT was used. We established two sets of rating criteria where the calculation of for MWMT was two degrees Celsius higher than the MWAT.

Work by Hines and Ambrose (2000) and Welsh *et al*. (2001) in northwestern California found that coho salmon juveniles were absent in streams where the MWAT exceeded 16.8° C. Welsh *et al*. (2001) noted transitory water temperature peaks can be harmful to salmonids and are better reflected by the maximum floating weekly maximum water temperature (MWMT). The Oregon Department of Fish and Wildlife uses an MWMT value of 64° F as a criterion protective of water quality, which is similar to the finding of Welsh *et al*. (2001).

Population level temperature ratings are:

Poor = < 50% IP-km (< 16° C MWMT);
Fair = 50% to 74% IP-km(< 16° C MWMT);
Good = 75% to 90% IP-km(< 16° C MWMT); and
Very Good = > 90% IP-km (< 16° C MWMT).

Methods:
To assess conditions throughout each population, it was necessary to evaluate temperature conditions throughout all potential rearing areas (*i.e*. across all IP-km). A method for spatializing site-specific temperature data was established by plotting these data on a map of the IP-km network. Each data point was color coded to indicate the temperature threshold the site exceeded (*i.e.,* sites with MWMT > 16° C were colored red, *etc*.). For locations with multiple years of data, we averaged the MWMT or MWAT values and indicated the number of years of data and standard deviations. The temperatures were extrapolated to IP-km reaches based upon an understanding of typical spatial temperature patterns and staff knowledge of specific watershed conditions. Finally, where temperature data was limited or absent, best professional judgment was used and assigned a low confidence rating in the results.

Condition Indicator: Toxicity for Adult, Summer and Winter Rearing, and Smolt Targets
Optimal conditions for salmonids, their habitat and prey, include clean water free of toxins, contaminants, excessive suspended sediments, or deleterious temperatures. Toxins are substances (typically anthropogenic in origin) which may cause acute, sub-lethal, or chronic effects to salmonids or their habitat. These include (but are not limited to) toxins known to impair watersheds, such as copper, diazinon, nutrients, mercury, polyaromatic hydrocarbons (PAHs), pathogens, pesticides, and polychlorinated biphenyls (PCBs), herbicides and algae.

All target life stages of salmonids depend on good water quality, and the water quality attribute is impaired when toxins or other contaminants are present at levels adversely affecting one or more salmonid life stages, their habitat or prey. Salmonids are sensitive to toxic impairments, even at very low levels (Sandahl *et al.* 2004; Baldwin and Scholz 2005). For example, adult salmonids use olfactory cues to return to their natal streams to spawn, and low levels of copper has been show to impair this ability (Baldwin and Scholz 2005).

Adult salmon typically begin the freshwater migration from the ocean to their natal streams after heavy late-fall or winter rains breach the sand bars at the mouths of coastal streams (Sandercock 1991). These same flows may carry toxins from a variety of point and non-point sources to the stream. The exposure of returning adults to toxins in portions of their IP-km can reduce the viability of the population by impairing migratory cues, or reducing the amount of available spawning and rearing habitat, thereby lowering the carrying capacity of the population. Each life stage was assessed according to the seasonality of effects produced by the toxin for each life stage across all IP- km.

Ratings: Risk of adverse effects to salmonids due to toxins
Ratings for toxicity are:

Poor = Acute effects to fish and their habitat (*e.g.,* mortality, injury, exclusion, mortality of prey items);

Fair = Sub lethal or chronic effects to fish and their habitat (*e.g.,* limited growth, periodic exclusion, contaminants elevated to levels where they may have chronic effects). Chronic effects could include suppression of olfactory abilities (affecting predator avoidance, homing, synchronization of mating sues, *etc*.), tumor development (*e.g*., PAHs). This could include populations without data but where land use is known to contribute pollutants (*e.g*., significantly urbanized or supporting intensive agriculture, particularly row crops, orchards, or confined animal production facilities);

Good = No acute or chronic effects from toxins are noted and/or population has little suspect land uses, and insufficient monitoring data are available to make a clear determination. Many Northern California populations (particularly those held in private timber lands) are likely to meet these criteria; and

Very Good = No evidence of toxins or contaminants. Sufficient monitoring conducted to make this determination, or areas without contributing suspect land uses (*e.g*., many wild and scenic rivers, wilderness areas, *etc*.). Available data should support very good ratings.

Methods:
For this analysis, some constituents were excluded from consideration because they were assessed by other indicators (*i.e.,* Water Quality/Temperature). We reviewed a variety of materials to derive appropriate ratings, including data from the California Regional Water Quality Control Boards, the U.S. Environmental Protection Agency, and other local and regional sources to inform our ratings of water quality limited segments for any toxins known or suspected of causing impairment to fish. We also reviewed scientific literature, and available population specific water quality reports. Working with SEC and NMFS staff water quality specialists, a qualitative decision structure was developed (Figure 3) to rate each population where more specific data were lacking.

Decision Matrix for Each Life Stages/Water Quality/Toxicity for Key Independent/Dependent Populations
Each life stage must be assessed according to the seasonality of affects produced by the toxin for each life stage across all IP-km.

1. Are toxins/chemicals present in the watershed which could potentially (through direct discharge, incidental spills, chronic input, etc.) entering the water column?

   a. Yes: > 2
   b. No: Toxicity not a threat (assumed to be good)

2. Is the chemical/substance a known toxin to salmonids?

   a. Yes: >3
   b. No: Toxicity not a threat (assumed to be good)

3. Are salmonids spatially/temporally exposed to the toxin during any life stage or are the toxin present in a key subwatershed (where salmonids no longer occur) important for species viability.

   a. Yes: > 4
   b. No: Toxicity not a threat (assumed to be Good/Fair)

4. Potential salmonid presence to toxin established. Use best professional judgment to assign Fair/Poor rating. Consider toxicity of chemical compound, persistence of the compound, spatial extent/temporal exposure, future reintroduction efforts, and potential overlap of land use activities (*e.g.*, pesticide/herbicide intensive farming practices) to species viability/presence when assigning rating.

Figure 3. Qualitative decision structure for evaluating water quality/toxicity. The matrix was used to determine the likelihood of toxins being present and adversely affecting freshwater salmonid life history stages.

Condition Indicator: Turbidity for Adult, Summer and Winter Rearing, and Smolt Targets
Research has demonstrated highly turbid water can adversely affect salmonids, with harmful effects as a direct result of suspended sediment within the water column. The mechanisms by which turbidity impacts stream-dwelling salmonids are varied and numerous. Turbidity of excessive magnitude or duration reduces feeding efficiency, decrease food availability, impair respiratory function, lower disease tolerance, and can also directly cause fish mortality (Cordone and Kelley 1961; Berg and Northcote 1985; Gregory and Northcote 1993; Velagic 1995; Waters 1995; Harvey and White 2008). Mortality of very young salmonids due to increased turbidity has been reported by Sigler *et al.* (1984). Even small pulses of turbid water will cause salmonids to disperse from established territories (1995), which can displace fish into less suitable habitat and/or increase competition and predation, decreasing chances of survival.

Ratings:

Risks to each life stage were assessed according to the seasonality of affects produced by the turbidity for each life stage across all IP-km.

The ratings were based upon the percentage of IP-km habitat within a population maintaining a moderate or lower sub lethal effect in regard to turbidity dose (*i.e.*, based upon both concentration and exposure duration). Using Figure 4, turbid conditions that score a 4 SEV or higher during any time scale along the x-axis represent conditions likely limiting juvenile salmonid survival. Conversely, a score of 3 SEV or lower represent conditions favoring survival to the next life stage. The extent that favorable turbidity conditions exist across the spatial population scale determines the overall score for a given population.

Data regarding turbidity was unavailable for many populations. In the absence of turbidity data, information and data from reports regarding sediment input from roads, sediment contributions from landslides and other anthropogenic sources, and best professional judgment was used to assess turbidity risk at the population scale.

Each target life stage was assessed independently according to the seasonality of affects produced by the turbidity for adults, summer and winter juvenile rearing, and smolts across IP-km:

Poor = < 50% of IP-km maintains score of 3 SEV or lower;
Fair = 50% to 74% of IP-km maintains score of 3 SEV or lower;
Good = 75% to 90% of IP-km maintains score of 3 SEV or lower; and
Very Good = > 90% of IP-km maintains score of 3 SEV or lower.

Methods:
Turbidity indicators focused on suspended sediment concentration and duration of exposure. To document the relationship between dose (the product of turbidity and exposure time) and the resultant biological response of fish, Newcombe (2003) reviewed existing data to develop empirical equations to estimate behavioral effects from a given turbidity dose. For juvenile and adult salmonids, the expected behavioral response and severity of ill effects (SEV) is illustrated in Figure 4 (from Newcombe 2003).

Visual clarity of water (yBD) and related variables — alternate: NTU, zSD; preferred: BA, yBD

Duration of exposure to conditions of reduced VISUAL CLARITY ($\log_e$ hours)

Severity-of-ill-effect Scores (SEV) -- Potential

$$SEV = -4.49 + 0.92 (\log_e h) - 2.59 (\log_e yBD)$$

Fish reactive distance: *calibrated for trout*

NTU	zSD (m)	BA (m^{-1})	yBD (m)		a	b	c	d	e	f	g	h	i	j	k	ψ_{BD} (cm)	xRD (cm)	
				$\log_e$ hours	0	1	2	3	4	5	6	7	8	9	10			
				Δ_{15}	Δ_{16}	Δ_{17}	Δ_{18}	Δ_{19}	Δ_{20}	Δ_{21}	Δ_{22}	Δ_{23}	Δ_{24}	Δ_{25}				
1100	0.01	500	0.010	Δ_{14}	7	8	9	10	11	12	13	14				1	-	O
			0.014	Δ_{13}	7	7	8	9	10	11	12	13	14			1	-	N
400	0.03	225	0.02	Δ_{12}	$_P6^{\pi}$	7	7	8	9	10	11	12	13	14		2	-	M
			0.03	Δ_{11}	4	5	6	7	8	9	10	11	12	13	14	3	-	L
150	0.07	100	0.05	Δ_{10}	3	$_P4^{\pi}$	$_P5^{\pi}$	6	7	8	9	10	11	12	13	5	-	K
			0.07	Δ_9	2	3	4	5	6	7	8	9	10	11	11	7	-	J
55	0.15	45	0.11	Δ_8	$_P\underline{1}^{\pi}$	2	3	4	5	6	7	8	9	10	10	11	6	I
			0.16	Δ_7	$\underline{0}$	$\underline{1}$	2	3	4	$\underline{5}$	6	7	8	9	9	16	17	H
20	0.34	20	0.24	Δ_6	$\underline{0}$	$_P\underline{0}^{\pi}$	$_P\underline{1}^{\pi}$	2	3	4	5	6	7	$\underline{8}$	8	24	30	G
			0.36	Δ_5	$\underline{0}$	$\underline{0}$	$\underline{0}$	$\underline{1}$	2	3	4	5	6	6	7	36	42	F
7	0.77	9	0.55	Δ_4	$\underline{0}$	$_P\underline{0}^{\pi}$	$\underline{0}$	$\underline{0}$	$\underline{1}$	2	3	4	4	5	6	55	55	E
			0.77	Δ_3	$\underline{0}$	$_P\underline{0}^{\pi}$	$^P\underline{0}_{\pi}$	$\underline{0}$	$\underline{0}$	$\underline{1}$	2	3	4	4	5	77	66	D
3	1.53	4	1.09	Δ_2	$\underline{0}$	$_P\underline{0}^{\pi}$	$\underline{0}$	$\underline{0}$	$\underline{0}$	$\underline{0}$	1	2	3	4	5	109	77	C
			1.69	Δ_1	$\underline{0}$	$\underline{0}$	$\underline{0}$	$\underline{0}$	0	0	0	1	2	2	3	169	90	B
1	3.68	2	2.63		$^P\underline{0}_{\pi}$	$^P\underline{0}_{\pi}$	$^P\underline{0}_{\pi}$	0	0	0	0	0	0	1	2	263	104	A
						Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7	Δ_8	Δ_9	Δ_{10}			
				Duration	1	3	7	1	2	6	2	7	4	11	30			
					Hours			Days			Weeks		Months					

Figure 1. Impact Assessment Model for Clear Water Fishes Exposed to Conditions of Reduced Water Clarity. A model to estimate severity of impact on rearing success of clear water fish as a function of reduced visual clarity of water (m) and duration of exposure (h), for juvenile and adult life history phases; includes calibration for reactive distance of trout.

KEY:

*y*BD Black disk sighting range (m): horizontal measurement in water of any depth (reciprocal of beam attenuation).

*ψ*BD Black disk sighting range (cm): a convenient calibration for measurements made in very cloudy water.

BA Beam attenuation (m^{-1}): measures absorption and scattering of light by "water constituents" – clay and color; reciprocal of black disk sighting range.

*z*SD Secchi disk sighting range (m): a vertical measurement, usually in deep water.

*x*RD Reactive distance of adult trout (pooled data for rainbow, lake and brook) to fish prey as a function of visual clarity. Alternate, proportional, calibrations can be inferred for largemouth bass and bluegill based on their maximum reaction distances (200 cm, and 30 cm, respectively).

NTU Nephelometric turbidity units: a measure of light scattering by suspended clay particles (0.2 to 5 µm diameter).

SEV Severity of Ill Effect Scale

a. Semi-Quantitative

$0 \le$ nil < 0.5; $0.5 \le$ minor < 3.5; $3.5 \le$ moderate < 8.5; $8.5 \le$ severe < 14.5. Impact assessment is based on net duration (less clear water intervals) and weighted average visual clarity data. Recurrent events sum when integrated over relevant intervals: for a year class (a life history phase, or a life cycle); a population ("year over year" events); habitat damage (hours < duration ≤ years); and restoration (year < time ≤ years). For events involving suspended sediment (may include clay as one of the particle sizes in a range of sizes) (see Newcombe and Jensen, 1996).

b. Qualitative

- 0: *Ideal.* Best for adult fishes that must live in a clear water environment most of the time.
- 1-3: *Slightly Impaired.* Feeding and other behaviors begin to change.
- 4-8: *Significantly Impaired.* Marked increase in water cloudiness could reduce fish growth rate, habitat size, or both.
- 9-14: *Severely Impaired.* Profound increases in water cloudiness could cause poor "condition" or habitat alienation.

c. Stipple – Areas with least available data (1 day to 30 months).

Predator Prey Dynamics

(a) $^P\underline{0}_{\pi}$: Some predatory fish (P) catch more prey fish (π) in clear water ($^P\pi$) than they do in cloudy water.

(b) $_p\underline{1}^{\pi}$, $_p\underline{5}^{\pi}$: Survival of some fishes is enhanced ($_p{}^{\pi}$) by natural, seasonal, cloudiness (two examples shown).

(c) *SEV*: Severity of ill effect data, underscored, are from published sources (see Literature Cited), or have the support of consensus within the discussion group, or both.

aA, kO Row labels (upper case) and column labels (lower case); paired, these serve as cell coordinates (two examples shown).

Figure 4. Impact Assessment Model for Clear Water Fishes Exposed to Conditions of Reduced Water Clarity (from Newcombe 2003).

Assessing Future Conditions: Stresses

Stresses and threats are the drivers and mechanisms leading to population decline. Stresses are defined as "the direct or indirect impairment of salmonid habitat from human or natural sources" (TNC 2007). Stresses represent altered or impaired key attributes for each population, such as impaired watershed hydrology or reduced habitat complexity. They are the inverse of the key attributes. For example, the attribute for passage would become the stress of impaired passage. These altered conditions, irrespective of their sources, are expected to reduce population viability. Stresses are initially evaluated as the inverse of the key attribute ranking (*e.g*., key attributes rated as poor may result in a stress ranking as very high or high). Ultimately the resulting stress ranking is determined using two metrics, the severity of damage and scope of damage. For each population and life stage, stresses were ranked using these metrics, which were combined using algorithms contained in CAP to generate a single rank for each stress identified. Stresses ranked very high or high are likely sources of significant future threats and may impair recovery.

Severity of damage is defined as the level of damage to the conservation target that can reasonably be expected within ten years under current circumstances (*i.e*., given the continuation of the existing situation). Severity is ranked from low to very high according to the following criteria:

Very High	The stress is likely to destroy or eliminate the conservation target over some portion of the target's occurrence at the site.
High	The stress is likely to seriously degrade the conservation target over some portion of the target's occurrence at the site.
Medium	The stress is likely to moderately degrade the conservation target over some portion of the target's occurrence at the site.
Low	The stress is likely to only slightly impair the conservation target over some portion of the target's occurrence at the site.

Scope of damage is defined as the geographic scope of impact on the conservation target at the site that can reasonably be expected within 10 years under current circumstances (*i.e*., given the continuation of the existing situation). Scope is ranked from low to very high according to the following criteria:

Very High	The stress is likely to be very widespread or pervasive in its scope, and affect the conservation target throughout the target's occurrences the site.
High	The stress is likely to be widespread in its scope, and affect the conservation target at many of its locations at the site.
Medium	The stress is likely to be localized in its scope, and affect the conservation target at some of the target's locations at the site.

Low	The stress is likely to be very localized in its scope, and affect the conservation target at a limited portion of the target's location at the site.

Fifteen stresses were identified and evaluated for specific conservation targets (life stages):

1. Altered Riparian Species Composition & Structure;
2. Altered Sediment Transport: Road Condition & Density;
3. Estuary: Impaired Quality & Extent;
4. Floodplain Connectivity: Impaired Quality & Extent;
5. Hydrology: Gravel Scouring Events;
6. Hydrology: Impaired Water Flow;
7. Impaired Passage & Migration;
8. Impaired Watershed Hydrology;
9. Instream Habitat Complexity: Altered Pool Complexity and/or Pool/Riffle Ratios;
10. Instream Habitat Complexity: Reduced Large Wood and/or Shelter;
11. Instream Substrate/Food Productivity: Impaired Gravel Quality & Quantity;
12. Landscape Disturbance;
13. Reduced Density, Abundance & Diversity;
14. Water Quality: Impaired Instream Temperatures; and
15. Water Quality: Increased Turbidity or Toxicity.

Stresses with a high level of severity and/or broad geographic scope are ranked as high or very high. For example, in Table 10, the stress of hydrology – impaired water flow was ranked as very high for impacts to the summer rearing life stage. This stress also ranked as high for smolts, because in low water years, flows are inadequate for out-migration. This stress was ranked medium for adults and eggs, indicating it was not as severe and/or more limited in scope and, therefore, not as detrimental to those life stages, because flows during adult migratory and egg development periods are typically adequate. Stresses to the population are compiled in a summary table to describe major stresses for each population by target life stage (Table 10).

Table 10. CAP stress summary table for Soquel Creek population.

Stress Matrix

Central California Coast Coho Salmon ~ Soquel Creek

	Stresses (Altered Key Ecological Attributes) Across Targets	Adults	Eggs	Summer Rearing Juveniles	Winter Rearing Juveniles	Smolts	Watershed Processes
		1	2	3	4	5	6
1	Reduced Density, Abundance & Diversity	Very High		Very High		Very High	
2	Instream Habitat Complexity: Reduced Large Wood and/or Shelter	High		Very High	High	Very High	
3	Hydrology: Impaired Water Flow	Medium	Medium	Very High		High	
4	Instream Substrate/Food Productivity: Impaired Gravel Quality & Quantity	Low	High	Medium	High		
5	Instream Habitat Complexity: Altered Pool Complexity and/or Pool/Riffle Ratios	High		Medium	High		
6	Floodplain Connectivity: Impaired Quality & Extent	Medium			High		
7	Water Quality: Impaired Instream Temperatures			High		Low	
8	Altered Sediment Transport: Road Condition & Density						High
9	Hydrology: Gravel Scouring Events		High				
10	Impaired Watershed Hydrology						High
11	Water Quality: Increased Turbidity or Toxicity	Medium		Medium	Medium	Medium	
12	Impaired Passage & Migration	Medium		Medium	Low	Low	
13	Estuary: Impaired Quality & Extent			Medium		Medium	
14	Landscape Disturbance						Medium
15	Altered Riparian Species Composition & Structure			Low			Low

Assessing Future Conditions: Sources of Stress (Threats)

Threats are termed the "sources of stress," and are defined as the "proximate activities or processes that have caused, are causing or may cause the stress" (TNC 2007). NMFS used the CAP common threat taxonomy as a basis to define the principal factors most relevant to the recovery of CCC coho salmon. CAP defines direct threats to the species as the sources of stress likely to limit viability into the future. Threats may result from currently active actions s such as ongoing land uses, or from actions likely to occur in the future (usually within ten years), such as increased water diversion or development. Threats contribute to stresses in ways likely to impair salmonid habitat into the future. Many threats are driven by human activities, however, naturally occurring events such as severe weather events may also threaten the species. For each population and life stage, threats were ranked using two metrics, contribution and irreversibility, which are combined by CAP algorithms to generate a single rank for each threat identified.

Contribution is defined as the expected contribution of the source of stress, acting alone, to the full expression of a stress under current circumstances (*i.e.*, given the continuation of the existing management/conservation situation). Threats ranked as very high for contribution are very large contributors to the particular stress and low ranks are applied to threats that contribute little to the particular stress. Contribution is ranked from low to very high according to the following criteria:

Very High	The source is a very large contributor of the particular stress.
High	The source is a large contributor of the particular stress.
Medium	The source is a moderate contributor of the particular stress.
Low	The source is a low contributor of the particular stress.

Irreversibility is defined as the degree to which the effects of a threat can be reversed. Irreversibility is ranked from low to very high according to the following criteria:

Very High	The source produces a stress that is not reversible, for all intents and purposes (*e.g.*, wetland converted to shopping center).
High	The source produces a stress that is reversible, but not practically affordable (*e.g.*, wetland converted to a agriculture).
Medium	The source produces a stress that is reversible with a reasonable commitment of additional resources (*e.g.*, ditching and draining of wetland).
Low	The source produces a stress that is easily reversible at relatively low cost (*e.g.*, ORVs trespassing in wetland).

Threats with a high level of contribution to a stress and/or high irreversibility are ranked as high or very high. For example, in Table 11 the threat of residential and commercial development was ranked as very high for its effects to two life stages, and high for three others, because residential development is a very high contributor to poor water quality and impaired riparian conditions in Soquel Creek (as an example).

The threat of development is also essentially irreversible. Summary tables of threats ranked for each population describe major threats for each target life stage (Table 11). The overall threat rank (last column) summarizes the aggregate threat rating and thereby identifies the most limiting threats to a population.

The threat status for each target (last row) summarizes the aggregate ranks applied across all life stages and illustrates the targets that are most vulnerable. Threats ranked as high or very high are more likely to contribute to a stress that in turn, reduces the viability of a target life stage. When multiple life stages of a population had high or very high threats, the viability of the population was diminished.

Table 11. CAP threat summary table for Soquel Creek population.

Summary of Threats
Central California Coast Coho Salmon ~ Soquel Creek

	Threats Across Targets	Adults	Eggs	Summer Rearing Juveniles	Winter Rearing Juveniles	Smolts	Watershed Processes	Overall Threat Rank
	Project-specific threats	1	2	3	4	5	6	
1	Residential and Commercial Development	High	Medium	Very High	High	Very High	High	Very High
2	Water Diversion and Impoundments	Medium	Medium	Very High	Medium	Very High	High	Very High
3	Severe Weather Patterns	Medium	High	Very High	High	High	High	Very High
4	Roads and Railroads	High	High	High	High	High	High	Very High
5	Fire, Fuel Management and Fire Suppression	Medium	Medium	High	Medium	High	Medium	High
6	Logging and Wood Harvesting	Medium	Medium	High	Medium	High	Medium	High
7	Channel Modification	Medium	Medium	High	High	Medium	Low	High
8	Fishing and Collecting	High	-	Medium	-	High	-	High
9	Mining	Medium	Medium	Medium	Medium	Medium	Medium	Medium
10	Agriculture	Medium	Medium	Medium	Medium	Medium	Low	Medium
11	Disease, Predation and Competition	Medium	-	Medium	Low	Medium	Low	Medium
12	Recreational Areas and Activities	Low	Low	Medium	Low	Medium	Low	Medium
13	Livestock Farming and Ranching	Low	Low	Low	Low	Medium	Low	Low
14	Hatcheries and Aquaculture	-	-	-	-	-	-	-
	Threat Status for Targets and Project	High	High	Very High	High	Very High	High	Very High

Threats evaluate future impediments likely to adversely affect recovery for each targeted salmonid population. The list of threats is based on their known impact to salmonid habitat, species viability, and the likelihood that the threat would continue into the future. Using the CAP common threat taxonomy as a basis, the following fourteen threats were evaluated in relation to each stress for a specific life stage:

1. Agriculture;
2. Channel Modification;
3. Disease/Predation/Competition;
4. Fire, Fuel Management and Fire Suppression;
5. Fishing/Collecting;
6. Hatcheries;
7. Livestock Farming and Ranching;
8. Logging and Wood Harvesting;
9. Mining;
10. Recreational Areas and Activities;
11. Residential and Commercial Development;
12. Roads and Railroads;
13. Severe Weather Patterns; and
14. Water Diversion and Impoundments.

Some threats occurred in all or most populations (*e.g.*, roads), while others were more limited in distribution (*e.g.*, mining). Where a threat did not occur in a given population, it was not evaluated and did not receive a rating. A matrix was developed illustrating which threats contribute to a particular stress (Table 12). This ensured a direct linkage between the threat and a particular stress. For example, the threat of fishing and collecting was only ranked against the population stress of reduced abundance, diversity, and competition. This approach reduced the potential for over estimating the effect of a stress across multiple threats. In this example, the threats of agriculture, livestock and recreation were not ranked against the stress of hydrology - impaired water flow. While these threats may contribute to impaired water flow, all impairments to water flow were evaluated only under the threat of water diversion and impoundments. Finally, the matrix facilitated the development of recovery actions with direct relationships to stresses or threats.

Very high or high threats are driven by social, economic, or political causes that then become the focus of conservation strategies. Conservation strategies are developed into recovery actions intended to reduce or abate the high or very high threats. In some cases recovery actions were developed for medium ranked threats based on knowledge or information that the threat could increase in the near future due to anticipated changes. The following section describes each threat and the information considered for ranking each major threat to CCC coho salmon recovery.

Table 12. Matrix showing which threats were evaluated against which stresses.

Stresses	Habitat Condition											Watershed Processes			Population
Threats	Estuary: Impaired Quality & Extent	Floodplain Connectivity: Impaired Quality & Exent	Hydrology: Gravel Scouring Events	Hydrology: Impaired Water Flow	Instream Habitat Complexity: Altered Pool	Instream Habitat Complexity: Reduced Large Wood	Instream Substrate/ Food Productivity: Impaired	Impaired Passage & Migration	Water Quality: Increased Turbidity or Toxicity	Water Quality: Impaired Instream Temperatures	Altered Riparian Species Composition & Structure	Impaired Watershed Hydrology	Landscape Distrubance	Altered Sediment Transport: Road Construction	Reduced Density, Abudance & Diversity
Agriculture				N/A											N/A
Channel Modification															N/A
Disease/Predation/ Competition(Invasive Animals and Plants)			N/A	N/A			N/A								
Fire				N/A											N/A
Fishing/Collecting	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Hatcheries	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	
Livestock				N/A											N/A
Logging				N/A											N/A
Mining				N/A											N/A
Recreation				N/A											N/A
Residential Development				N/A											N/A
Roads				N/A											N/A
Severe Weather Patterns															N/A
Water Diversion and Impoundments															

Threat: Agriculture

Agriculture was defined as annual and perennial crop farming and associated operations and, for recovery planning analysis purposes, excludes grazing, ranching or timber harvest.

Impacts to Salmonids: Agricultural practices can adversely affect salmonid habitat by altering riparian vegetation and natural drainage patterns, introducing water-borne pollutants, and increasing the likelihood of channel simplification, and chronic input of fine sediment.

Application to the ESU: The major agricultural practices within the CCC coho salmon ESU are vineyards and orchards (apples and pears), generally located north of San Francisco Bay. Brussel sprouts, lettuce, and flower crops (greenhouse and row crops) are grown in the southern areas of the ESU.

Threat Context: Some agricultural activities and programs have made strides in improving riparian protections, implementing pollution and sediment discharge controls, and promoting instream habitat restoration (*e.g.*, Fish Friendly Farming, Code of Sustainable Winegrowing Practices, TMDL's and others). However, the overall impact to coho salmon and their habitat is generally vary substantial where these activities occur, and particular aspects of agriculture can have major direct and indirect impacts (*e.g.*, use of plethoris to control gypsy moth and removal of riparian vegetation from farming areas due to perceived threats regarding *e-coli* from wild animals).

Threats Evaluated and Ranked: The analysis included all practices and operations associated with agriculture, including land conversions, continuous or seasonal ground disturbances, maintenance, planting, harvesting, and fertilizing of row crops, orchards, vineyards, commercial greenhouses, nurseries, gardens, *etc.*

Threats were evaluated for their potential to:

1. Introduce water-borne pollutants, such as sediment and pesticides, into the aquatic environment, or adversely alter nutrient levels;
2. Alter riparian vegetation integrity, diversity, function, and composition;
3. Alter natural drainage channels and hydrology patterns; and
4. Simplify channel complexity and destabilize stream banks.

The final threat rankings were determined by the following:

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered. High or very high threats could include practices requiring large areas in cultivation and large quantities of pesticides and herbicides over significant proportions of the watershed.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered, but the effects could be reversed or ameliorated.

Low threat ranking results when ecosystem function and process are (or are expected to be) largely intact, slightly altered, and easily reversible. A low threat could include practices that have a low impact and use little or no herbicides and pesticides in the watershed and do not impact riparian vegetation.

Resources Utilized: GIS analysis of the total acres, and percentage of a watershed under cultivation, watershed specific assessments, NMFS staff knowledge of watersheds, and ongoing practices, *etc*.

Threat: Channel Modification

Channel modification was defined as directly and/or indirectly modifying and/or degrading natural channel forming processes and morphology of perennial, intermittent and ephemeral streams and estuarine habitats.

Impacts to Salmonids: Channel modifying structures such as rip rap and gabions reduce the occurrence and creation of undercut banks and side channels, limit or eliminate large woody debris (LWD) recruitment, and often result in the removal of riparian vegetation. These techniques are used extensively to line channel banks and beds. Bank stabilization structures eliminate or severely reduce streambed gravel recruitment necessary for salmonid spawning and macroinvertebrate habitat. Bank stabilization, levee construction for flood control, and filling in floodplains for land reclamation also disconnect rivers and streams from their floodplains. These activities prevent the creation of, or block access to, off-channel habitat used by salmonids as refuge from high stream flows, and impede stream geomorphic processes.

Application to the ESU: In the process of protecting public and private infrastructure and property, channel modification has reduced salmonid habitat suitability by permanently altering natural channel forming processes, particularly in the many urbanized watersheds within the CCC coho salmon ESU.

Threat Context: Permits from the U.S. Army Corps of Engineers (Corps) are required for most channel modifications. Issuance of a permit to alter streams (including channelization, removal of LWD, and placement of rock slope protection, *etc*.) utilized by listed salmonids requires an Endangered Species Act (ESA) Section 7 consultation with NMFS. Once channel modifying infrastructure is in place it is usually followed by increased development, which in turns leads to additional channel modification. For example, bank armoring at one site can cause erosion downstream, resulting in sequential armoring of a stream reach. Once infrastructure is in place it is often impractical, difficult, and expensive to remove. With a growing human population the pressure to modify natural stream channels is expected to continue.

Threats Evaluated and Ranked: The analysis included evaluation of estuarine management (*e.g*., lagoon breeching, dredging), flood control activities, large woody debris removal, levee construction, vegetation removal, herbicide application, stream channelization, bank stabilization (hardening that limits channel movement or meander), dredging and other forms of sediment removal. These actions typically occur within the two-year bankfull stage and adversely affect channel forming processes.

Threats were evaluated for their potential to:

1. Damage instream and near stream habitat and lower habitat complexity;

2. Precipitate riparian habitat loss, decrease channel roughness (decrease in Manning's N roughness coefficient);
3. Alter drainage channels and hydrologic patterns;
4. Alter riparian zone diversity, function, and composition;
5. Alter channel and stream bank stability;
6. Alter or destroy floodplain, estuarine, and wetland habitats;
7. Introduce water-borne pollutants, such as sediment and chemicals, into the aquatic environment, or adversely alter nutrient levels; and
8. Simplify channel morphology (*e.g.*, by increasing incision rate and decreasing floodplain connectivity).

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered. High or very high threats could include large levee projects within salmonid habitat that adversely modify sediment transport, impair salmonid migration, accelerate stream velocities, and alter riparian vegetation structure from historical conditions.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered but could be reversed or ameliorated.

Low threat ranking results when ecosystem function and process are (or are expected to be) largely intact, slightly altered, and easily reversible. A lower threat could include bank stabilization projects that use bioengineering techniques.

Resources Utilized: No central repository of channel modifying activities exists for watercourses in the CCC coho salmon ESU, and the quality and quantity of information varies significantly between watersheds. Information sources included watershed assessments, CDFG habitat typing information, personal communications with local experts, and staff knowledge of individual watersheds.

Threat: Disease, Predation and Competition

Disease, predation and competition includes diseases having, or predicted to have, significant harmful effects on salmonids and/or their habitat, as well as native (*e.g.*, sea lions, mergansers, *etc*.) and non-native predator species (*e.g.*, large mouth or striped bass). It also includes invasive non-native plants (*e.g.*, *Arundo donax*) that degrade riparian or aquatic habitats.

Impacts to Salmonids: Infectious disease can influence adult and juvenile coho salmon survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Specific diseases such as bacterial kidney disease, *ceratomyxosis*, *columnaris*, *furunculosis*, infectious hematopoietic necrosis virus, redmouth and black spot disease, erythrocytic inclusion body syndrome, and whirling disease, among others, are present and are known to affect coho salmon (Rucker *et al.* 1953; Wood 1979; Leek 1987; Foott *et al.* 1994). Diseases such as bacterial kidney disease have been identified as a limiting factor in some populations (*e.g.*, Noyo River), particularly those subject to artificial propagation.

Piscivorous predators may also affect the abundance and survival of salmonids. Cooper and Johnson (1992) and Botkin *et al*., (1995) reported marine mammal and avian predation may occur on some local salmonid populations, but it was a minor factor in the decline of coast wide salmonid populations. However, Moyle (2002), found that when fish populations are low, predation by seals and sea lions on returning spawners may prevent recovery. Predation by marine mammals (primarily harbor seals and California sea lions) is of concern in some areas experiencing dwindling run sizes of salmon. Predation by non-native striped bass (*Morone saxatilis*) may also impact some coho salmon populations. Although predation does occur from a number of sources, it is believed to be a minor factor in the overall decline of coastwide salmonid populations but may play a significant role in keeping small populations from increasing.

Principal competitors for the food and space of juvenile coho salmon are other salmonids, especially Chinook salmon and steelhead (Moyle 2002), both of which are listed species within the range of CCC coho salmon. Other sources of competition include invasive non-native riparian plant species (*e.g., Arundo donax*) which can completely disrupt riparian communities.

Application to the ESU: Disease, predation and competition may significantly influence salmonid abundance in some local populations when other prey species are absent and physical conditions lead to the concentration of salmonid adults and juveniles (Cooper and Johnson 1992). Also, altered stream flows can create unnatural riverine conditions that favor non-native species life histories over the native cold water species (Brown et al. 1994; California Department of Fish and Game 1994; McEwan and Jackson 1996; National Marine Fisheries Service 1996a).

Threat Context: Relative to other threats, disease and predation are not major factors contributing to the overall decline of coho salmon in the CCC ESU. However, they may compromise the ability of depressed populations to rebound. Competition in the context of habitat alteration leading to reduced survival is a serious limiting factor in some streams in the ESU.

Threats Evaluated and Ranked: The following threats were evaluated and ranked: introduction of non-native animal species that prey upon and/or (directly or indirectly) compete with native salmonids; introduction of non-native vegetation that competes with and/or replaces native vegetation; and creation of conditions favorable to increased populations and/or concentration of native predators.

Threats were evaluated for their potential to:

1. Simplify or modify instream or riparian habitat condition;
2. Reduce feeding opportunities;
3. Shift the natural balance between native/non-native biotic communities and salmonid abundance, resulting in disproportional predation and competition;
4. Increase opportunities for infectious disease;
5. Change water chemistry (*e.g*., inputs of acidic detritus from *Eucalyptus*, or low dissolved oxygen (DO) resulting from increased foreign biomass) and,
6. Impede instream movement and migration, or reduce riparian function (*e.g., Arundo donax*).

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered, or impacts to the population are severe. High or very high threats occur when amelioration of the consequences of this threat are largely irreversible.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered, but the effects could be reversed or ameliorated, or impacts to the population are moderate. Medium threats occur when the consequences of this threat are largely irreversible but could be ameliorated.

Low threat ranking results when ecosystem function and process are (or are expected to be) largely intact, slightly altered, and easily reversible

Resources Utilized: NMFS used a variety of resources to evaluate this threat, from region wide assessments of the impacts of predation to site specific watershed assessments and individual reports. In general, there was little site specific information to evaluate this threat, and in many cases NMFS staff solicited the opinions of local experts as well as utilizing best professional judgment after considering information on pinniped and bird predation and competition and predation by non-native species.

Threat: Fire and Fuel Management

Threats include fires (wildfires and prescriptive burns) and fire suppression actions (firefighting and fire prevention).

Impacts to Salmonids: Fire, particularly catastrophic wildfires, can impair salmonid habitat by reducing or eliminating riparian canopy, resulting in increased soil erosion that can render instream rearing habitat unsuitable for many decades. Hotter fires consume organic matter that binds soils, leading to an increase in erosion potential, and high intensity fires can volatilize minerals in the soil causing it to become hydrophobic. Fire retardants used in suppression may contain chemicals potentially harmful to the environment. Many retardants contain ammonia, which is toxic to fish, and its conversion products, including nitrates, increase oxygen demand in streams and stimulate algal growth. Use of water pumped directly from streams to suppress fires may degrade salmonid habitat.

Application to the ESU: The interior and southern areas of the ESU may have significant fire risk with potential for watershed disturbance and increased sediment yield. Coastal ecosystems have higher rainfall, more resilient vegetation (*e.g.*, redwood forest), less extreme summer air temperatures and, therefore, less risk of catastrophic fire. Spence *et al*. (1996) recognized the extent of watershed damage and risk to salmonid habitat is directly related to burn intensity.

Threat Context: Fire management techniques such as prescriptive burns or timber thinning would not normally take place in riparian vegetation, so impacts to coho salmon are expected to be inadvertent, or resulting from severe fire conditions. Few areas within the range of CCC coho salmon are on Federal lands, so most firefighting activities are conducted by local fire districts and CalFire. Unlike federal lands, where NMFS has extensive interaction with the Forest Service to minimize adverse consequences from firefighting actions, NMFS has little interaction with local firefighting agencies in the CCC ESU. Consequently, impacts from firefighting (*e.g.*, road building and construction of fire breaks, water diversion, aerial retardants) likely have considerable adverse impacts to CCC coho salmon and their habitats.

Threats Evaluated and Ranked: Construction of fire breaks, roads, application of fire retardants, water use planning, fuels management, and fire suppression.

Threats were evaluated for their potential to:

1. Increase erosion, sedimentation and landslide potential;
2. Elevate fuel loading leading to a higher potential of catastrophic burns;
3. Impair future large woody debris recruitment; and
4. Alter vegetative/riparian communities through invasive species/post-fire management.

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered. High threats may include high fuel loading over a large area, or extensive burns upstream of, or adjacent to, critical spawning and rearing areas.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered, but the effects could be reversed or ameliorated.

Low threat ranking results when ecosystem function and process are (or are expected to be) largely intact, slightly altered, and easily reversible. A mature redwood forest upstream or adjacent to salmonid habitat generally will rank as a low threat due to the fire resistant qualities of redwood.

Resources Used: The current prediction for regional effects from fire intensity, frequency and duration as well as fire and fuel management practices (fire suppression, prescribed burning and limited use of mechanical treatments to reduce fire fuel loads) were examined.

Threat: Fishing and Collecting

This threat includes harvesting salmonids for recreation, subsistence, in-situ research, or cultural purposes, and includes illegal and legal activities such as accidental mortality/bycatch.

Impacts to Salmonids: Commercial and sport-fishing for coho salmon is closed in California due to recognition of the dramatic species declines. However, coho salmon are incidentally caught as bycatch by both commercial and sport-fishers. These activities are most likely to impact the adult lifestage. The amount of bycatch is unknown, but it may have a significant adverse effect due to the extremely low population levels, where every individual is of greater significance to the population's persistence than when the population was large. Fish deaths caused by activities such as fishing could be more damaging to the population when populations are depleted due to natural conditions (such as changes in ocean productivity) (National Research Council 1996). Handling hooked fish before releasing them also contributes to mortality (Clark and Gibbons 1991).

Application to the ESU: Moyle (2002) states that the present populations are so low that moderate fishing pressure on wild coho may prevent recovery, even in places were stream habitats are adequate. In California, coho salmon caught incidentally must be immediately released, but the act of capture comes at a cost to the individual through energetic expenditure, injury, increased susceptibility to disease, or eventual predation (*i.e.* marine mammals eating the fish before it is landed).

Threat Context: The opening of freshwater the sport-fishing season (Table 13) as early as November 1 north of San Francisco Bay[11] and December 1 south of San Francisco Bay[12], likely preferentially targets coho salmon during the early portion of fishing season as this species migrates into freshwater earlier than steelhead (Shapovalov and Taft 1954). This early start likely places adult coho salmon at greater risk of capture than if the season were setback to a later date.

Table 13. Independent (I) and dependent (D) watersheds where winter freshwater fishing for hatchery steelhead is permitted by California 2012-2013 sport-fishing regulations. Note: sport-fishing regulations include additional possession limits and additional regulations may apply.

Watershed	Season	Daily Bag Limit
Albion (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Aptos (D)	Dec 1 – Mar 7	0
Big River (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Cottaneva (D)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Garcia (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Gualala (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Navarro (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Noyo (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Pescadero (I)	Dec 1 – Mar 7	0
Russian (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Salmon (D)	Nov 1 – Mar 31	0
San Gregorio (D)	Dec 1 – Mar 7	0
San Lorenzo (I)	Dec 1 – Mar 7	0
Scott (D)	Dec 1 – Mar 7	0
Soquel (D)	Dec 1 – Mar 7	0
Ten Mile (I)	Nov 1 – Mar 31	2 hatchery trout or hatchery steelhead
Waddell (D)	Dec 1 – Mar 7	0
Walker (~I)	Nov 1 – Mar 31	0

The bag limits set forth in the 2012-2013 California Freshwater Sport Fishing Regulations are likely a source of confusion for some fishers and should be amended to reflect actual fishery conditions. Eight independent watersheds and one dependent watershed have a bag limit for both hatchery trout or hatchery steelhead, when in reality only the Russian River has hatchery trout or steelhead plantings. The current stated bag limits may encourage fishers to unknowingly target specific streams where no stocking occurs and in turn, incidentally hook coho salmon.

Commercial and ocean sport-fishing near the mouths of a watershed when sandbars remain closed may inadvertently result in increased rates of adult coho salmon capture. Adult coho

[11] Minimum flow requirements (based on a minimum of 500 cfs at the gauging station on the mainstem Russian River near Guerneville (Sonoma County) and 15 cfs at the gauging station at the Oak Knoll Bridge on the mainstem Napa River (Napa County))

[12] Minimum flow requirements are determined (based on an undefined flow at the Big Sur and Carmel rivers in Monterey County) by DFG.

salmon congregating offshore while awaiting entry into the estuaries are likely at more risk of capture than those returning to watersheds without sandbars, or where sandbars have breached.

Most streams in the ESU do not have minimum flow requirements, which has resulted in some sport-fishing in streams at extremely low flows early in the season when coho are likely present. This may also result in increased risk to adults.

Threats Evaluated and Ranked: Incidental harvest for recreation and subsistence, authorized relocation, research and collection, incidental capture (*e.g*., hooking), and illegal activities such as poaching and unpermitted collection.

Threats were evaluated for their potential to:

1. Increase mortality/harm and displacement;
2. Increase competition when fish are relocated; and
3. Precipitate dispensatory effects at the population level.

High or very high threat rankings results when impacts to the population are (or are expected to be) severe. High or very high threats may occur in critical adult staging areas with extensive legal and illegal fishing pressure.

Medium threat ranking results when impacts to the population are (or are expected to be) moderate but could be reversed or ameliorated.

Low threat ranking results when impacts to the population are (or are expected to be) low and easily reversible. Low threat may occur in watersheds under large private (*i.e.,* commercial timberlands) ownership where public access is restricted or in areas with significant enforcement presence.

Resources Used: Recreational steelhead angling was the main activity considered for this indicator rating because it is the type of fishing most likely to impact adult salmonids. We ranked the impact of fishing and collecting by tallying the number of fishing trips reported in the CDFG Steelhead Fishing Report and Restoration Card during each species' adult migration period for the most recent year of record when available.

Threat: Hatcheries

Hatcheries are artificial propagation facilities designed to produce fish for harvest, or for escaping harvest to spawn. A conservation hatchery differs from a production hatchery since it specifically tries to supplement or restore naturally spawning salmon populations. Artificial propagation, especially the use of production hatcheries, has been a prominent feature of Pacific salmon fisheries enhancement efforts for several decades.

Impacts to Salmonids: Hatchery operations can affect salmonids in a number of ways, including adverse effects to the species through changes in their genetics, ecological and behavioral patterns, harvest rates (overfishing) and disease.

<u>Genetic Risks</u>

Genes determine the characteristics of living things. Human intervention in the rearing of wild animals has the potential to cause genetic change. These genetic changes impact salmon diversity and the health of salmon populations. Hatchery programs vary and therefore the risks identified below vary by hatchery. Genetic risks of artificial propagation to wild populations include:

1. *Inbreeding* - Inbreeding can occur when the population for a hatchery comes from a small percentage of the total wild and/or hatchery fish stock (*e.g*., 100 adults are used as broodstock out of a population of 1 million). If only a small number of individuals are used to create the new hatchery stock, genetic diversity within a population can be reduced. Inbreeding can affect the survival, growth and reproduction of salmon;
2. *Intentional or artificial selection for a desired trait (such as growth rate or adult body size)* - Although not common practice today, some hatchery programs intentionally select for larger fish (or other specific traits). This selection changes the genetic makeup of the hatchery stock, moving it further away from naturally reproducing salmon stocks;
3. *Selection resulting from nonrandom sampling of broodstock* - The makeup of a hatchery population comes from a selection of wild salmon and/or returning hatchery salmon that are taken into captivity (*i.e*., broodstock). If, for example, only early-returning adults are used as broodstock, instead of adults that are representative of the population as a whole (*i.e*., early, normal, and late-returning adults), there will be genetic selection for salmon that return early;
4. *Unintentional or natural selection that occurs in the hatchery environment* - Conditions in hatchery facilities differ greatly from those in natural environments. Hatcheries typically rear fish in vessels (*i.e*., circular tanks and production raceways) that are open and have lower and more constant water flow than occurs in natural streams and rivers. They also tend to hold fish at much higher densities than occurs in nature. This type of environment has the potential to alter selection pressures in favor of fish that best survive in hatchery rather than natural environments; and
5. *Temporary relaxation during the culture phase of selection that otherwise would occur in the wild* - Artificial mating disrupts natural patterns of sexual selection. In hatcheries, humans select the adult males and females to mate, not the salmon. Humans have no way of knowing which fish would make the best natural breeders. In addition, selection pressures that would normally be encountered in the wild, such as predation and foraging challenges, are relaxed until the time when juveniles are released from the hatchery. Fish raised in hatchery environments face very different pressures than those raised in the wild.

<u>Ecological and Behavioral Risks</u>
Hatchery-produced fish often differ from wild fish in their behavior, appearance, and/or physiology. Ecological risks of artificial propagation on wild populations include:

1. *Competition for food and territory* - Competition between wild and hatchery fish can occur. It is most likely to occur if the fish are of the same species (*e.g.,* between wild Chinook salmon and hatchery reared Chinook salmon), and if they share the same habitat (quiet, shallow water or deep fast water) and diet;
2. *Predation by larger hatchery fish* **-** If hatchery released salmon are larger than wild salmon, evidence suggests that, for certain species, hatchery released salmon can feed on wild salmon;

3. *Negative Social Interactions* - Juvenile salmon establish and defend foraging territories through aggressive contests. When large numbers of hatchery fish are released in streams where there are small numbers of wild fish, hatchery fish are more likely to be more aggressive, and disrupt natural social interactions;
4. *Carrying Capacity Issues* **-** Carrying capacity is a measure of the maximum population (*e.g.,* numbers of salmon) supported by a particular ecosystem. Carrying capacity changes over time with varying predator abundance and resources such as food and habitat. When hatchery fish are released into streams where there are wild fish, competition for food and space can arise. Many streams and watersheds are degraded due to contamination, development, *etc*., and have a reduced carrying capacity; and
5. *Behavioral* - Hatchery environments are different than stream environments. Hatcheries typically rear fish in vessels (*i.e*., circular tanks and production raceways) that produce sterile environments where there are no complex habitat features (*i.e*., sticks and wood), little or no overhead cover (such as cover from nearby trees and undercut stream banks), and a predictable food supply. Consequently, hatchery fish tend to have different foraging, social, and predator-avoidance behavior.

<u>Overfishing</u>
Large-scale releases of hatchery fish have supported commercial, Tribal, and sport fishing practices for many years. However, large-scale releases of hatchery fish in a mixed population fishery creates a risk of overfishing for wild populations. Because hatchery populations are typically abundant and have high survival rates, they can generally support higher harvest rates. Wild stocks, on the other hand, are typically less abundant, and their populations could be harmed by high harvest rates. NMFS and CDFG fisheries managers are currently evaluating opportunities to support selective harvest of hatchery fish (*i.e*., harvest that doesn't impact wild stocks). Selective harvest opportunities could be supported through catch and release programs and/or in places where hatchery stocks are isolated from wild stocks (*i.e*., where hatchery stocks use a different stream or enter the stream at a different time than wild stocks).

<u>Fish Health</u>
The effect of disease on hatchery fish and their interaction with wild fish is not well understood. However, hatcheries can have disease outbreaks, and once diseased fish are released, they can transmit disease to wild fish.

Application to the ESU: Historically, out of basin and out-of-ESU hatchery coho salmon were released in many watersheds in the ESU. Some fish originated from Baker Lake in Washington State in the early part of the last century and, until recently, coho salmon from the Noyo River Egg Collecting Station (ECS) were outplanted in many watersheds in the ESU. Most of the hatcheries in the ESU were smaller than the production hatcheries in other parts of California but the long history of outplanting has likely adversely affected genetic diversity of coho salmon in the ESU to some degree. Disease, particularly bacterial kidney disease, has been a source of concern in regards to the Noyo ECS (now closed). In addition, excluding grilse from the Noyo ECS spawning program may have decreased genetic diversity of the Noyo population.

Threat Context: Two hatcheries are currently operating in the ESU: the Corps' Don Clauson Hatchery at Warm Springs Dam in the Russian River watershed, and the King Fisher Flat facility on Scott Creek operated by Monterey Bay Salmon and Trout Project. Both facilities are operated as conservation hatcheries, and receive considerable oversight from NMFS and CDFG. Conservation hatcheries are not operated for maximum production but are operated with the goal of ensuring genetic integrity of the target population. See Spence *et al*. (2008) for additional information.

Threats Evaluated and Ranked: High or very high threat rankings result when impacts to the population are (or are expected to be) severe. High or very high threats may include a facility operated for the purpose of maximum production with no consideration for genetic impacts to the population.

Medium threat ranking results when impacts to the population are (or are expected to be) moderate but could be reversed or ameliorated. Medium threats might include a facility operated with minimal regulatory oversight or that takes a significant proportion of a spawning run but attempts to minimize genetic impacts.

Low threat ranking results when impacts to the population are (or are expected to be) low and easily reversible. An example of low threat would include a conservation broodstock facility operated with significant oversight by regulatory agencies and with backup rearing facilities.

Resources Used: Sources of information included, personal communications with local experts, hatchery managers, and NMFS and CDFG staff knowledgeable with the operations of the two existing broodstock facilities.

Threat: Livestock Farming and Ranching

This treat is considered as domestic terrestrial animals raised in one location, or domestic or semi-domesticated animals allowed to roam in the wild and supported by natural habitats (*e.g*., cattle feed lots, chicken farms, dairy farms, and cattle ranching).

Impacts to Salmonids: Livestock grazing is the most widespread land-management practice in the western North America, occurring over 70 percent of the western United States (Noss and Cooperrider cited in Donahue 1999). The impacts of livestock grazing in riparian areas have been widely studied. Direct effects include elevated levels of fecal coliform bacteria and sediment in streams, degraded stream banks and bottoms, altered channel morphology from livestock trampling, lowered ground water tables and reduced streamside vegetation leading to a deterioration of fish habitat (Duff *et al*. 1980; Armour et al. 1991; Kovalchik and Elmore 1992; Overton *et al*. 1994; Belsky et al. 1999; Donahue 1999).

Animal waste carried by runoff can contaminate water sources through the addition of oxygen-depleting organic matter (Knutson and Naef 1997). Runoff from concentrated fecal sources can degrade water quality, causing lethal conditions for fish. As the biochemical oxygen demand increases, dissolved oxygen within the water column decreases and ammonia is released, creating water quality conditions stressful to fish.

Application to the ESU: Behnke and Zarn (1976) and Armour *et al*., (1991) indicated that overgrazing is one of the major contributing factors in the decline of Pacific Northwest salmon. George *et al*., (2002) found that cattle trails in California produced 40-times more sediment than adjacent vegetated soil surfaces. In the CCC ESU, the adverse impacts from cattle grazing are believed to be less problematic than other areas of California, because it is limited in extent. Point source impacts from livestock facilities have impacts in some watersheds in the ESU.

Threat Context: To address potential environmental impacts of livestock operations, several programs have been developed. These programs assist landowners in developing best management practices for their respective land use. These include the Rangeland Water Quality Short-course, and the Dairy Quality Assurance Program. Livestock grazing and ranching is generally concentrated in just a few of the watersheds targeted for coho recovery.

Threats Evaluated and Ranked: NMFS evaluated grazing intensity and seasonality, stockyard proximity to the stream channel, damage to riparian zones, water quality impacts resulting from animal waste, and increased erosion.

Threats were evaluated for their potential to:

1. Elevate the concentration of water-borne pollutants such as sediment, toxic chemicals/substances (*i.e*., hormones), and nutrient levels;
2. Alter riparian zone diversity, function, and composition;
3. Alter drainage channels and hydrology (soil compaction); and
4. Simplify channel structure and alter stream bank stability.

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered but could be reversed or ameliorated.

Low threat ranking results when ecosystem function and process are largely intact, (or are expected to be) slightly altered, and easily reversible.

Resources Utilized: The quality and quantity of information varied significantly between watersheds. Sources of information included watershed assessments, CDFG stream survey notes, personal communications with local experts, and NMFS staff knowledge of individual watersheds.

Threat: Logging and Wood Harvesting

This threat includes the harvesting of trees and ancillary post-harvest effects of these activities; including changes to hydrologic patterns and increased contribution of water-borne pollutants, such as sediment and elevated nutrient levels. Additionally, this threat includes conversion of timberland (to vineyards, rural residential development, or other uses).

Impacts to Salmonids: Many watersheds in the CCC coho salmon ESU are heavily forested, and timber harvest is a major threat to coho salmon habitat. Spence *et al*., (1996) summarized the major effects of timber harvest on salmonids as follows: "Riparian logging depletes LWD, changes nutrient cycling and disrupts the stream channel. Loss of LWD, combined with alteration of hydrology and sediment transport, reduces complexity of stream micro- and macrohabitats and causes loss of pools and channel sinuosity. These alterations may persist for decades or centuries. Changes in habitat conditions may affect fish assemblages and diversity."

Spence *et al*., (1996) cited studies by McCammon (1993) and Satterland and Adams (1992) showing increased peak flows resulting from alteration of 15-30% of a watershed's vegetation, and concluded "that no more than 15-20% of a watershed should be in a hydrologically immature state at any given time." In many streams, reduced LWD as a result of past forestry practices has resulted in decreased cover and reduced gravel and organic debris storage. Reduced LWD has also decreased pool habitat volume and reduced overall hydraulic complexity (CDFG 2004). LWD also provides cover from predators and shelter from turbulent high flows. Heavy rainfall occurring after timber harvest operations can increase stream bank erosion, landslides, and mass wasting, resulting in higher sedimentation rates than historical amounts. This can reduce food supply, increase fine sediment concentrations which can reduce the quality of spawning gravels, and increase the severity of peak flows during heavy precipitation. Removing vegetative canopy cover increases solar radiation on the aquatic surface, which can increased water temperatures (Spence *et al.* 1996).

Application to the ESU: Timber harvest on non-federal land in California is regulated by the Z'berg-Nejedly Forest Practice Act of 1973 (Section 4511 of the Public Resources Code). NMFS believes that the current regulations are a qualitative improvement over historical practices; unfortunately, their effectiveness in protecting watershed processes that support salmonids has never been established (Dunne *et al.* 2001). The specific inadequacies of the Rules have been well-described by State organized committees, State and federal agencies and scientists(LSA Associates Inc. 1990; Little Hoover Commission 1994; CDFG 1995; CDF 1995; NMFS 1998a; Ligon et al. 1999; Dunne et al. 2001). Additionally, some timber harvest practices authorized in the ESU by CalFire (conversion) have been proven by NMFS Office of Law Enforcement to result in take of listed salmonids.

Threat Context:
Substantial timber harvesting has occurred in this ESU. Privately held forestlands currently support many of the remaining populations of CCC coho salmon, and the species is provided greater protection on forestlands than landscape subject to most other land use practices. The regulatory infrastructure and oversight represents an opportunity to meet recovery goals. NMFS analysis of this treat assumed that forest practices are being implemented at the minimum standard of the California Forest Practice Rules (CFPR).

Threats Evaluated and Ranked:
All operations associated with timber removal within the harvest unit, including skid trails, new road construction, opening of old road systems, and construction of landings and yarding corridors (does not include mainline transportation systems). Maintenance of road networks and erosion control devices following completion of harvest activities are also included.
Threats were evaluated for their potential to:

1. Introduce water-borne pollutants, such as sediment and toxic chemicals, into the aquatic environment, and adversely alter nutrient levels;
2. Alter riparian zone integrity, diversity, function (*i.e.*, LWD recruitment), and composition;
3. Alter drainage channels and hydrology;

4. Simplify channel complexity and lower stream bank stability; and
5. Compromise hillslope stability.

High or very high threat rankings results when (1) ecosystem function and process are (or are expected to be) severely altered or (2) impacts to the population are severe. High or very high threats occur when amelioration of the consequences of this threat are largely irreversible; or include activities that result in a permanent change to the landscape (*e.g*., conversion to agriculture, urban, or other uses or results in long-lived changes to vegetative communities).

Medium threat ranking results when (1) ecosystem function and process are (or are expected to be) moderately altered or (2) impacts to the population are moderate. Medium threats occur when the consequences of this threat are largely irreversible but could be ameliorated. Includes harvest activities meeting minimum requirements of the CFPRs.

Low threat ranking results when (1) ecosystem function and process remain largely intact or (2) are slightly altered, and easily reversible. This ranking includes, activities such as timber harvest that conforms to (or has higher standards beyond) CFPR (*e.g*., Pacific Forest Trust certified).

Resources Utilized:
NMFS used CalFire's Timber Harvest Plans in digital GIS format, which focused on land use over the last ten years, to analyze the percentage of land managed as timberlands. NMFS staff also used knowledge of watersheds assessments and ongoing practices for land use analysis.

Threat: Mining

This threat includes all types of mining and quarrying, including instream gravel mining.

Impacts to Salmonids:
Extraction of minerals and aggregate has affected fishery resources tremendously, and it continues to degrade salmonid habitat in many areas (Nelson *et al.* 1991). According to CDFG (2004), gravel extraction (the removal of sediment from the active channel) has various impacts on salmonid habitat by interrupting sediment transport and often causing channel incision and degradation (Kondolf 1993). The impacts from gravel extraction include; direct mortality, loss of spawning habitat, disruption of adult and juvenile migration and holding patterns, stranding of adults and juveniles, increases in water temperature and turbidity, degradation of juvenile rearing habitat, destruction or sedimentation of redds, increased channel instability and loss of natural channel geometry, bed coarsening, lowering of local groundwater level, and loss of LWD and riparian vegetation (Humboldt County Public Works 1992; Kondolf 1993; Jager 1994; Halligan 1997). Terrace mining (the removal of aggregate from pits isolated from the active channel) may have similar impacts on salmonids if a flood causes the channel to move into the gravel pits.

Application to the ESU:
Mining occurs within many watersheds in the ESU, including instream gravel mining on the mainstem Russian River. Upslope mining operations include barrow pits and mining operations in Soquel Creek and until recently, San Vicente Creek.

Threat Context:

According to CDFG (2004) while instream gravel extraction has had direct, indirect, and cumulative impacts on salmonids in the recent past, no direct impacts to coho salmon have been documented under the current (post-1995) mining monitoring. Reporting standards developed by CDFG and the mining industry were incorporated into the following regulatory efforts; County Conditional Use Permits, reclamation plans required by the Surface Mining and Reclamation Act and, the Corps Letters of Permission. Many rivers continue to suffer the effects of years of channel degradation from the millions of tons of aggregate removed from the systems over time (Collins and Dunne 1990). Most gravel mining operations occur in habitat that is currently considered migration habitat rather than current spawning and rearing. However, some of these instream operations occur in important areas for recovery of coho spawning and rearing habitat.

Threats Evaluated and Ranked:
Exploring for, developing, processing, storing, and producing minerals and rocks.

Threats were evaluated for their potential to:

1. Reduce the quantity and quality of stream gravel;
2. Reduce channel complexity;
3. Modify upstream channel sections (*e.g.*, headcuts);
4. Alter riparian zone integrity, diversity, function, and composition;
5. Alter channel geometry and hydrology;
6. Alter stream bank stability;
7. Simplify channels or cause incision and disconnection from its floodplain;
8. Alter or cause the loss of floodplain/estuarine habitats; and
9. Alter water quality by increasing sedimentation or turbidity, elevating water temperatures, and input of toxic metals.

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered. Activities that rank as high or very high threats may include instream gravel mining and mining activities within the 20-year bankfull channel.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered could be reversed or ameliorated. Activities ranking as a medium threat may include activities outside of the 20-year bankfull channel.

Low threat ranking results when ecosystem function and process are largely intact, (or are expected to be) slightly altered, and easily reversible. Activities that rank as low threats generally occur outside of the 100-year floodplain.

Resources Used:
No numeric values or categories were used to develop rankings. Instead NMFS utilized, watershed documentation, professional judgment, as well as consultations with knowledgeable individuals when ranking this threat after considering information and analyses from biological opinions on gravel mining operations through the CCC coho salmon ESU.

Threat: Recreational Areas and Activities

This threat addressed recreational activities (legal and illegal) that alter, destroy, and/or disturb habitats and species outside of established transport corridors.

Impacts to Salmonids:

The threat covers many types of activities that may directly and indirectly impact salmonids including: increased sedimentation to streams due to off road vehicle (ORV) use in the upper portion of a watershed; concentrated animal waste discharge from an equestrian facility that is directed into rearing habitat; loss of riparian vegetation due to construction and operation of on-stream recreational summer dams which leads to increased water temperature.

Application to the ESU:

Recreational areas and activities are numerous and diverse in the ESU. This threat category is often more likely to occur in areas with high human populations and includes legal and illegal activities and activities with temporary and permanent impacts.

Threat Context:

Since listing a number of actions have been undertaken to address some of the impacts related to recreational areas and activities. These actions include development of a white paper by NMFS regarding the impacts of recreational summer dams and increased enforcement and oversight by NMFS and CDFG regarding installation of these facilities. However, many of actions and their impacts remain unaddressed and impacts to salmonids and their habitat continue.

Threats Evaluated and Ranked:

Use of ORVs, mountain bikes, trail maintenance, equestrian uses, summer dams, amusement parks, and golf courses.

Stresses considered included the following:

1. Excessive erosion and sedimentation;
2. Stream crossings and effects of ORV or equestrian use in the channels;
3. Introduction of pollutants, garbage, toxic chemicals, and changes in nutrient levels;
4. Alteration in riparian zone integrity, diversity, function, and composition;
5. Alteration in streambank stability;
6. Diversion and/or impoundment of streams; and
7. Channel simplification, incision and disconnection from its floodplain.

High or very high threat rankings results when ecosystem function and process are (or are expected to be) severely altered. High or very high threat rankings may include heavy ORV use in riparian channels that results in the destruction or modification of stream banks and riparian vegetation or permanent alteration of high quality habitat due to construction of recreational facilities.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered but could be reversed or ameliorated. Medium threat ranking may include extensive mountain biking trails on steep slopes with substandard maintenance oversight.

Low threat ranking results when ecosystem function and process are largely intact, (or are expected to be) slightly altered, and easily reversible. Low threat ranking may include low impact activities such as hiking on designated and properly located and maintain trails.

Resources Used:
The category of Recreational Areas and Activities encompasses a diverse array of land and water uses and types of recreation. A centralized database was not available to adequately assesses this threat category. Staff used available watershed assessments and relied heavily upon their professional experience from working within the various watersheds to assess the degree of impact posed by this threat.

Threat: Residential and Commercial Development

This threat includes urban, industrial, suburban, recreational, or rural residential developments resulting in permanent alteration of the natural environment and encroachment onto floodplains and into riparian areas. Development includes military bases, factories, shopping centers, resorts, *etc*. This includes the physical and social (*e.g*., homeless encampments) consequences of development such as increased impervious surfaces, increased runoff, changes to the natural hydrograph (*e.g.,* flashy flows), household sewage, urban wastewater, increased sedimentation, industrial effluents, and garbage and other solid waste.

Impacts to Salmonids:
Urbanization can degrade habitat in obvious ways including; direct loss of habitat, channelization of streams, degradation of water quality, and dewatering of streams. It can also affect habitat in less obvious ways by altering and disrupting ecosystem processes that can have unintended impacts to aquatic ecosystems through increased flooding, channel erosion, landslides, and aquatic habitat destruction (Booth 1991).

According to CDFG (2004) the structure of the biological community and abundance and diversity of aquatic organisms are greatly altered by urban impacts on channel characteristics and water quality. Wang *et al*., (1997) found that high urban land use was strongly associated with poor biotic integrity and was associated with poor habitat quality. Fish populations are also adversely affected by urbanization. Limburg and Schmidt (1990, as cited in Spence *et al.* 1996) found a measurable decrease in spawning success of anadromous species in Hudson River tributaries that had 15 percent or more of the watershed in urban development. Wang *et al*. (2003) found a strong negative relation between urban land cover in the watershed and the quality of fish assemblages in coldwater streams in Wisconsin and Minnesota. In a study of urbanized Puget Sound streams in Washington State, Lucchetti and Fuerstenberg (1993, as cited in Spence *et al.* 1996) found that coho salmon appeared to be more sensitive than cutthroat trout (*Onchorynchus clarki*) to habitat alteration, increased nutrient loading, and degradation of the inter-gravel environment. They found, as impervious surfaces increased, coho salmon abundance declined, and concluded coho salmon are of particular concern in urbanized areas because of their specific habitat needs (smaller streams, relatively low velocity microhabitats and large pools). Other studies documented pollution associated with urban areas is causing impacts to juvenile Chinook salmon, including suppressed immune response due to bioaccumulation of PCBs and PAHs, increased mortality associated with disease, and suppressed growth (Spence *et al*. 1996).

Application to the ESU:
Historical records suggest coho salmon occurred in the Sacramento River system, but it was considered the rarest of the five salmon species known to inhabit the Central Valley (Hallock and Fry 1967; Brown *et al.* 1994). Though now extirpated, coho salmon did occur in streams that drained into the San Francisco Bay estuary. In fact, the earliest scientific specimen of coho salmon in California was collected by Professor Alexander Agassiz from Harvard University in San Mateo Creek, San Mateo County, in 1860 (Leidy 2004). Coho salmon are now extirpated from the Central Valley and the San Francisco Bay due to a variety of human caused factors – including urbanization. Watersheds where CCC coho salmon continue to persist have ongoing land management practices frequently cited as reasons for decline (dams, logging, roads, *etc.*) but in general have low rates of commercial and urban development. The adverse impacts of residential and commercial development are numerous, and these impacts are often closely interrelated with other activities evaluated separately in this document (*i.e.*, roads and channel modification).

Threat Context:
Within the California range of coho salmon, urban and suburban development occupy many of the watersheds targeted for recovery actions. Cities and towns with large developed areas within the range of CCC coho salmon include, from north to south, Fort Bragg, Ukiah, Healdsburg, Windsor, Sebastopol, Santa Rosa, Cotati, and Santa Cruz. Cities and towns with watersheds draining into the San Francisco Bay were not included in the recovery strategy.

Threats Evaluated and Ranked:
Threats were evaluated for their potential to:

1. Introduce pollutants, garbage (*e.g*., tires and common household trash), urban/industrial wastewater, sedimentation, toxic chemicals into the aquatic environment, and adversely alter nutrient levels (often as "shock pollution" occurring with the first flush of rains);
2. Alter riparian zone integrity, diversity, function, and composition;
3. Alter stream bank stability;
4. Simplify channels, or cause incision and disconnection from the floodplain;
5. Alter drainage channels and hydrology;
6. Increase stormwater runoff; and
7. Facilitate increased development and associated adverse consequences.

High or very high threat rankings result when (1) ecosystem function and process are (or are expected to be) severely altered or (2) impacts to the population are severe. High or very high threats occur when amelioration of the consequences of this threat is largely irreversible. High or very high threat rankings may occur in watersheds with extensive urban development resulting in extensive modification of riparian zones from historical conditions.

Medium threat ranking results when (1) ecosystem function and process are (or are expected to be) moderately altered or (2) impacts to the population are moderate. Medium threats occur when the consequences of this threat are largely irreversible but could be ameliorated.

Low threat ranking results when (1) ecosystem function and process remain largely intact or (2) are slightly altered, and easily reversible.

Resources Used:
GIS analysis of the percentage of watershed with impervious surfaces, watershed specific assessments, NMFS staff knowledge of watersheds and ongoing practices, *etc*., were examined.

Threat: Roads and Railroads

This threat includes roadways (highways, secondary roads, primitive roads, logging roads, bridges & causeways) and dedicated railroad tracks. It includes all roads (including mainline logging roads) not associated with the site-specific footprint of timber harvest activities.

Impacts to Salmonids:
Studies have documented the degradation that occurs to salmonid habitats as a result of forest, rangeland and other road networks (Furniss *et al.* 1991). Roads alter natural drainage patterns and accelerate erosion processes causing changes in streamflow regimes, sediment transport and storage, channel bed and bank configuration, substrate composition, and stability of slopes adjacent to roads systems (Furniss *et al.* 1991).

Application to the ESU:
Graham Matthews and Associates (1999) linked increased road densities to increased sediment yield in the Noyo River. NMFS (1996b) guidelines for salmon habitat characterize watersheds with road densities greater than three miles of road per square mile of watershed area (mi/mi2) as "not properly functioning" while "properly functioning condition" was defined as less than or equal to two miles per square mile, with few or no streamside roads.

Threat Context:
Since listing, a number of actions have been undertaken to address roads and road related threats. Through the Fishery Network of the Central California Coastal Counties (FishNet 4C) program, an evaluation of road related issues, including fish passage and ongoing maintenance practices has been conducted. Maintenance manuals and ongoing training programs were developed for roads staff in most counties in the ESU. The key focus of the FishNet 4C program is on implementing best management practices related to protecting water quality, aquatic habitat and salmonid fisheries. The guidelines outlined in the manuals address most routine and emergency road related maintenance activities undertaken by County Departments of Public Works, parks, and Open Space Districts, and other parties with responsibility for road maintenance. They address common facilities such as appropriate spoils storage sites and maintenance yards. The guidelines apply to activities related to county facilities, not to private development.

Restoration of problematic private and public roads is a large part of the CDFG restoration program and occurs in many of the targeted watersheds in the ESU. The magnitude of road related problems in the ESU is significant and it is anticipated that it will take many years to adequately address the most problematic roads. Additionally, many roads, particularly private non-timber roads are not subject to routine maintenance and chronic sediment input from these roads is a major problem in some watersheds.

Threats Evaluated and Ranked:
Threats were evaluated for their potential to affect:

1. Chronic and acute introduction of sediment from surface erosion and drainage;
2. Delivery of large quantities of sediment from road crossing or mass wasting associated with roads;
3. Passage impairment or blockage due to culverts, bridges, *etc*.;
4. Risks of spills;
5. Alteration of drainage channels, hydrology, infiltration and runoff;
6. Alteration in riparian zone diversity, function, and composition;
7. Channel simplification, incision and disconnection from its floodplain;
8. Alteration of channel and streambank stability;
9. Alteration or loss of floodplain or estuarine habitats;
10. Introduce water-borne pollutants, such as sediment and chemicals, into the aquatic environment, and adversely alter nutrient levels; and,
11. Facilitate increased development and associated consequences.

High or very high threat rankings result when (1) ecosystem function and process are (or are expected to be) severely altered or (2) impacts to the population are severe. High or very high threats occur when amelioration of the consequences of this threat is largely irreversible. A high or very high threat may occur in watersheds with high road densities, poor road maintenance practices, numerous stream crossings, and road placement on unstable areas and adjacency to stream zones.

Medium threat ranking results when (1) ecosystem function and process are (or are expected to be) moderately altered or (2) impacts to the population are moderate. Medium threats occur when the consequences of this threat are largely irreversible but could be ameliorated.

Low threat ranking results when (1) ecosystem function and process remain largely intact or (2) are slightly altered, and easily reversible.

Resources Utilized:
For areas where timber harvest is conducted, road densities were calculated using CalFire timber harvest GIS data[13]. Topologically Integrated Geographic Encoding and Referencing (TIGER) data generated by the U.S. Census Bureau provided additional data (2000)[14].

Threat: Severe Weather

This threat includes short-term extreme variations such as severe droughts and major floods, and long-term climatic changes outside the range of natural variation that may be linked to global warming and other large scale climatic events. These natural events exacerbate already degraded conditions.

Impacts to Salmonids:
Droughts can have a variety of negative impacts on salmon and other fish populations at several points of their life cycles. Adult salmon can experience difficulties reaching upstream spawning

[13] http://www.fire.ca.gov/resource_mgt/resource_mgt_forestpractice_gis.php

[14] http://www.census.gov/geo/www/tiger/

grounds during certain low flow conditions. Low flows can also increase pre-spawn mortality rates in returning adult salmon when high adult escapement coincides with elevated water temperatures, low dissolved oxygen levels, and increased disease transmission between fish (CDFG 2003). Drying streams can severely reduce juvenile rearing habitat which in turn reduces carrying capacity. Some salmon species spawn in channel margins, side channels and smaller tributaries, and spawning for those species would have to occur in mainstem waters if off channel and tributary habitat is unavailable because of low flows. Where this occurs, salmon redds within the mainstem river channel may be more susceptible to bed scour during the fall and winter (Washington Dept. Fish and Wildlife)[15]. In other cases, instream flow can drop after the salmon spawn, dewatering the redds and desiccating the eggs.

High flows associated with major storms and floods can result in complete loss of eggs and alevins as they are scoured from the gravel or buried in sediment (Sandercock 1991; NMFS 1998b). Juveniles and smolts can be stranded on the floodplain, washed downstream to poor habitat such as isolated side channels and off-channel pools, or washed out to sea prematurely. Peak flows can induce adults to move into isolated channels and pools and prevent their migration because of excessive water velocities (CDFG 2004) .

Climate change may profoundly affect salmonid habitat on a regional scale by altering streamside canopy structure, increasing forest fire frequency and intensity, elevating instream water temperatures; and altering rainfall patterns that in turn affect water availability. These impacts are likely to negatively impact salmonid population numbers, distribution, and reproduction.

Application to the ESU:
Droughts are a natural phenomenon in the Mediterranean climate of the CCC coho salmon ESU. Nonetheless, droughts can result in depressed salmons runs three years later, when those salmonids would be returning as adults. The drought of 1976/1977 is believed to have significantly impacted coho populations south of San Francisco Bay (Hope 1993; Smith 2011). Flooding also has beneficial effects, including: cleaning and scouring of gravels; transporting sediment to the flood plain; recruiting, moving and rearranging LWD; recharging flood plain aquifers (Spence *et al.* 1996); allowing salmonids greater access to a wider range of food sources (Pert 1993); and maintaining the active channel.

Streams can be drastically modified by erosion and sedimentation in large flood flows almost to the extent of causing uniformity in the stream bed (Spence *et al*., 1996). After major floods, streams can take years to recover pre-flood equilibrium conditions. Flooding is generally not as devastating to salmon in morphologically complex streams, because protection is afforded to the fish by the natural in-stream structures such as LWD and boulders, stream channel features such as pools, riffles, and side channels and an established riparian area (Spence *et al*., 1996).

Salmonids in the CCC ESU are at the southern extent of the species range, and may be more vulnerable to changes in water availability and instream temperatures. Climate change is discussed in more detail in Appendix A: Marine and Climate. Significant alteration in the instream and near-stream environments due to climate change may result in further range

[15] http://wdfw.wa.gov/drought/index.htm

contraction for salmonids and a reduction in overall habitat availability in the more resilient watersheds.

Threat Context:
In the ESU there is increased pressure for limited water resources in many of the focus watersheds. This problem is most severe in the southern part of the ESU where rainfall is generally less than in the northern part of the ESU. Compounding this problem is a larger human population in the southern watersheds with a higher number of instream water diversions.

Streams can be drastically modified by erosion and sedimentation in large flood flows almost to the extent of causing uniformity in the stream bed (Spence *et al*., 1996). After major floods, streams can take years to recover pre-flood equilibrium conditions. Flooding is generally not as devastating to salmon in streams with complex habitat features, because protection is afforded to the fish by the natural in-stream structures such as LWD and boulders, stream channel features such as pools, riffles, and side channels and an established riparian area (Spence *et al*., 1996).

NMFS has reviewed extensive data and modeling sources, and assumes the future effects of climate change and the expected sea level rise in California could include: lost estuarine habitat; reduced groundwater recharge and base-flow discharge; and associated rises in stream temperature and demand for water supplies. Smaller (remnant) salmonid populations in such areas are likely at most risk from climate change.

Threats Evaluated and Ranked:
Threats related to droughts were evaluated for their potential to effect:

1. Insufficient flows to facilitate egg incubation, adult escapement, juvenile rearing, smolt emigration, and juvenile immigration;
2. Poor water quality leading to increased instream temperatures, low dissolved oxygen, decreased food availability, increased concentrations of pollutants, *etc*.;
3. Earlier than normal water diversion for anthropogenic purposes; and
4. Insufficient flows to breach sandbars at river mouths.

Threats related to flooding were evaluated for their potential to:

1. Increase the frequency, duration, and magnitude of flooding beyond natural conditions;
2. Require flood control or management actions;
3. Cause loss of riparian and instream habitat attributes;
4. Increase frequency of channel scour beyond natural conditions; and
5. Increase turbidity beyond natural conditions.

Threats related to climate change were evaluated for their potential effects to managing limited water storage to provide cool water refugia, additional demands on existing water supplies, and changes in vegetation patterns.

Threats were evaluated for their potential to:

1. Elevate instream water temperatures and alter historical hydrologic patterns; and
2. Alter the composition of native plant communities, which may adversely alter riparian process and function.

High or very high threat rankings result when ecosystem function and process are (or are expected to be) severely altered. High or very high threat rankings may occur in heavily urbanized watersheds subjected to extensive diversion, historical and ongoing instream modification conducted for flood control purposes, and where circumstances preclude future opportunities to protect critical refugia habitats.

Medium threat ranking results when ecosystem function and process are (or are expected to be) moderately altered but could be reversed or ameliorated.

Low threat ranking results when ecosystem function and process are (or are expected to be) largely intact, slightly altered, and easily reversible. Low threat ranking may occur in watersheds with little urban interface, few diversions, intact floodplains, and where instream habitat forming features (such as LWD) are present and are not routinely removed.

Resources Used:
Droughts were evaluated in the context of available information regarding ongoing water diversions coupled with the effects of drought. A variety of resources were used to evaluate this potential impact, including individual watershed assessments, briefings with NMFS, CDFG, and others familiar with individual watersheds and existing diversions, *etc*.

For the threat of flooding, staff knowledgeable on specific watersheds and ongoing practices, *etc*., ranked this threat. In addition, NMFS reviewed models related to climate change where they predicted increased storms or flooding.

NMFS has considered future habitat condition scenarios for salmonids based on projected climate change impacts as described in Appendix A: Marine and Climate. We used existing information on the current distribution of extant populations and areas targeted for recovery, and evaluated current stresses into the future.

Threat: Water Diversion and Impoundment

This threat includes appropriative and riparian surface water diversions and groundwater pumping resulting in changes to water flow patterns outside the natural range of variation. This threat includes use, construction, and maintenance of seasonal dams for water diversions, as well as the operations of larger dams affecting the natural hydrograph and watershed processes such as sediment transport.

Impacts to Salmonids:
According to CDFG (2004) losses of coho salmon result from a wide range of conditions related to unscreened water diversions and substandard fish screens. Primary concerns and considerations for fish at diversions that are unscreened or equipped with poorly functioning screens include; delay of downstream migration and a reduction in the overall survival of downstream migrants, entrainment of juvenile coho salmon into the diversion, impingement of juvenile coho salmon on

the screen surfaces because of high approach velocities or low sweeping velocities, predator holding areas created by localized hydraulic effects of the fish screen and related facilities, entrapment of juvenile coho salmon in eddies or other hydraulic anomalies where predation can occur, elevated predation levels due to concentrating juveniles at diversion structures, and disruption of normal fish schooling behavior caused by diversion operations, fish screen facilities, or channel modifications. Dam operations also affect salmonids by altering the natural hydrograph, typically by reducing winter flows that provide cues to migrate, and altering summer flows to levels that may reduce the survival of rearing juveniles.

Application to the ESU:
Water is often handled in the regulatory or legal arena due to its relative scarcity in California's Mediterranean climate. Summer baseflow is a critical attribute that is degraded in many streams across the ESU. A substantial amount of coho salmon habitat has been lost or degraded as a result of water diversions and groundwater extraction (KRBFTF 1991; CDFG 1997). The nature of diversions varies from major water developments which can alter the entire hydrologic regime in a river, to small domestic diversions which may only have a localized impact during the summer low flow period. In some streams the cumulative effect of multiple small legal diversions may be severe. Illegal diversions are also believed to be a problem in some streams within the range of coho salmon (CDFG 2004).

Threat Context:
Water is the most important of all habitat attributes necessary to maintain a viable fishery and, based on the last 150 years of water development in California, one of the most difficult threats to address effectively. Few restoration projects address water because; in large part it is a very divisive issue. Diversions are subject to regulation by the State Water Resources Control Board through the appropriative water rights process, and by CDFG under Fish and Game Code § 1600 *et seq*. (which requires an agreement with the Department for any substantial flow diversion), Fish and Game Code § 2080 *et seq*. (California Endangered Species Act take authorization), and Fish and Game Code § 5937 (which requires sufficient water below a dam to maintain fish in good condition). NMFS has authority under ESA to regulate the take of coho salmon at diversions.

In some watersheds, the demand for water has already exceeded the available supply and some water rights have been allocated though court adjudication. These adjudications usually did not consider coho salmon habitat needs at a level that could be considered protective under the California Endangered Species Act or the Federal ESA. The use of wells adjacent to streams is also a significant and growing issue in some parts of the coho salmon range. Extraction of flow from such wells may directly affect the adjacent stream, but is often not subject to the same level of regulatory control as diversion of surface flow. Site specific groundwater studies are required to determine a direct connection between surface flow and groundwater, and these are often very costly and take a significant amount of time to complete.

Threats Evaluated and Ranked:
Threats were evaluated for their potential to:

1. Increase water diversion and withdrawal, both legal and illegal;
2. Increase chronic and acute sediment inputs from surface erosion and drainage;

3. Impair passage or create blockages;
4. Alter drainage channels and hydrology;
5. Alter riparian zone diversity, function, and composition;
6. Alter channel and streambank stability;
7. Alter or eliminate floodplain and/or estuarine habitats due to reduced freshwater inflow;
8. Introduce water-borne pollutants, such as sediment and chemicals, into the aquatic environment, and adversely alter nutrient levels;
9. Facilitate increased development and associated consequences;
10. Cause changes in water flow, fish habitat, and temperature;
11. Reduce gravel recruitment to downstream areas;
12. Cause dewatering and/or flow reductions;
13. Cause secondary effects to salmonids (*e.g*., increasing disease such as bacterial kidney disease); and
14. Delay sandbar breaching (*e.g*., Scott Creek).

High or very high threat rankings result when (1) ecosystem function and process are (or are expected to be) severely altered or (2) impacts to the population are severe. High or very high threats occur when amelioration of the consequences of this threat are largely irreversible.

Medium threat ranking results when (1) ecosystem function and process are (or are expected to be) moderately altered or (2) impacts to the population are moderate. Medium threats occur when the consequences of this threat are largely irreversible but could be ameliorated.

Low threat ranking results when (1) ecosystem function and process remain largely intact or (2) are slightly altered, and easily reversible.

Resources Utilized:
Fisheries biologists from CDFG and Regional Water Quality Control Boards were invited to participate in a structured decision-making process to provide individual opinions regarding flow conditions for specific habitat attributes, and also considered diversion and impoundments for each watershed. Workshop participants were asked to individually rate the hydrologic setting, the degree of exposure to flow impairments, and the intensity of those impacts for each CCC coho salmon population. GIS analysis of known diversion points, and the CDFG Passage Assessment Database (PAD)[16] were reviewed. NMFS GIS watershed characterizations, NMFS staff knowledge of watersheds and ongoing practices, *etc*., were also examined.

[16] http://nrm.dfg.ca.gov/PAD/Default.aspx

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