# Final Recovery Plan for the Southern Oregon/ Northern California Coast Evolutionarily Significant Unit of Coho Salmon *(Oncorhynchus kisutch)*

2014

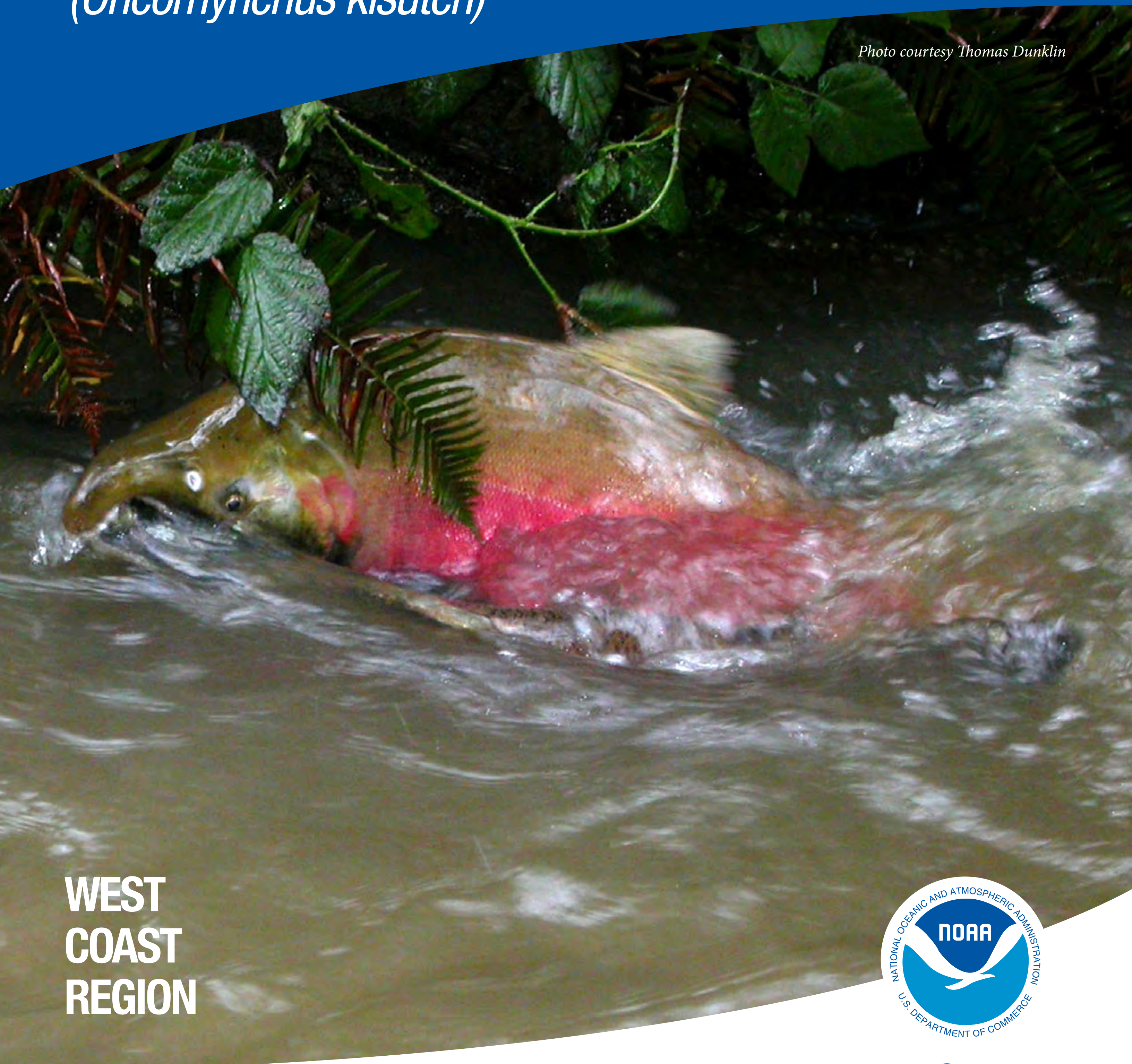


Photo courtesy Thomas Dunklin

WEST COAST REGION

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

NOAA FISHERIES

# Disclaimer

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the National Marine Fisheries Service (NMFS), sometimes prepared with the assistance of recovery teams, contractors, State agencies and others. Recovery plans do not necessarily represent the views, official positions or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Assistant Administrator. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any General agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

### Suggested citation:

National Marine Fisheries Service. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, CA.

### Electronic copies available at:

http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/southern_oregon_northern_california_coast/southern_oregon_northern_california_coast_salmon_recovery_domain.html

# Table of Contents

## APPENDICES

## POPULATION PROFILES (CHAPTERS 7 to 46)

# List of Figures

# List of Tables

# Executive Summary

## Need for Recovery

Thousands of coho salmon once returned to spawn in the rivers and streams of Northern California and Southern Oregon. Not long ago, these watersheds provided conditions that supported robust and resilient populations of coho salmon that could persist under dynamic environmental conditions. The combined effects of fish harvest, hatcheries, hydropower operations, and habitat alterations caused by land management led to declines in these populations. The National Marine Fisheries Service's (NMFS) evaluation of declining coho salmon abundance and productivity, as well as range reductions and diminished life-history diversity, supported the decision to list the Southern Oregon/Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) of coho salmon as a threatened species under the Endangered Species Act (ESA) in 1997, a decision that was reaffirmed in 2005.

Recovery can only be achieved through coordinated efforts to build strong conservation partnerships. Conservation partners may be individuals, groups, and government or non-government organizations including NMFS, industry, or tribes who have an interest in the recovery of SONCC coho salmon. The ESA envisions recovery plans as the central organizing tool for guiding each species' recovery process. The recovery plan is a road map to recovery – it lays out where we need to go and how best to get there. The SONCC Coho Salmon ESU recovery plan (Plan) was developed to provide a roadmap to recovery of this species which conservation partners can follow together. Specifically, the Plan is designed to guide implementation of prioritized actions needed to conserve and recover the species by providing an informed, strategic, and voluntary approach to recovery that is based on the best available science. Use of a recovery plan ensures that recovery efforts target limited resources effectively and efficiently. The Plan also provides recovery targets to work toward, as well as criteria by which progress toward recovery will be tracked.

## Current Species Status (Chapter 2)

The SONCC Coho Salmon ESU includes all naturally spawned populations of coho salmon in coastal streams between Cape Blanco, Oregon and Punta Gorda, California, as well as coho salmon produced by three artificial propagation programs: Cole Rivers Hatchery, Trinity River Hatchery, and Iron Gate Hatchery. An ESU is comprised of groups of populations with geographic and evolutionary similarities that are considered a "species" under the ESA. NMFS originally listed the SONCC coho salmon ESU as threatened under the ESA in 1997 (62 FR 24588, May 6, 1997). In 2005, following a reassessment of its status and after applying NMFS' hatchery listing policy, NMFS reaffirmed its status as threatened and also added several hatchery programs to the listed ESU (70 FR 37160, June 28, 2005).

NMFS issued guidelines in 1990 (55 FR 24296, June 15, 1990) for assigning listing and recovery priorities. Three criteria are assessed to determine NMFS' species' priority for recovery plan development, implementation, and resource allocation: 1) magnitude of threat; 2) recovery potential; and 3) existing conflict with activities such as construction and development. The recovery priority number for the SONCC coho salmon ESU is 1, as reported in the 2011-2012

Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species (NMFS 2013).

In 2006, NMFS modeled the historic population structure of the SONCC coho salmon ESU (Williams et al. 2006; Chapter 2, this volume). Each population is described in terms of its modeled capacity to support rearing juvenile coho salmon, based on the intrinsic ability of the habitat to support this life stage. This capacity is described as Intrinsic Potential or IP. Williams et al. (2006) calculated the number of kilometers of IP for each population. The role each population played in the historic function of the ESU is primarily based on how much IP it contains. Populations with more than 34 IP-km are described as independent because, due to their size, they are not dependent on strays from nearby populations to persist over time. Populations with from 5 to 34 IP-km are described as dependent because they are too small to persist without immigration from independent populations. NMFS grouped populations with similar geologic and genetic features into seven diversity strata (Williams et al. 2006). Williams et al. (2006) originally described 45 populations in the SONCC coho salmon ESU (Williams et al. 2006), but this recovery plan describes 40 populations, due to the recalculation of the amount of IP in some populations and exclusion of populations with less than 5 IP-km. Figure ES-1 shows the SONCC coho salmon ESU, including all 40 populations and seven diversity strata.

Populations with extremely low numbers of spawning adults can suffer from depensatory effects, which are problems with successful reproduction such as spawners being too scarce to find each other. The number of spawners needed to avoid depensatory effects is called the depensation threshold. Based on the amount of IP-km in each population, this recovery plan describes the extinction risk of each independent population. An independent population with spawner numbers below the depensation threshold is at high risk of extinction. Currently, over three quarters of SONCC coho salmon independent populations are at high risk of extinction (Figure ES-2). In a recovered ESU, these populations would be at moderate or low risk of extinction.

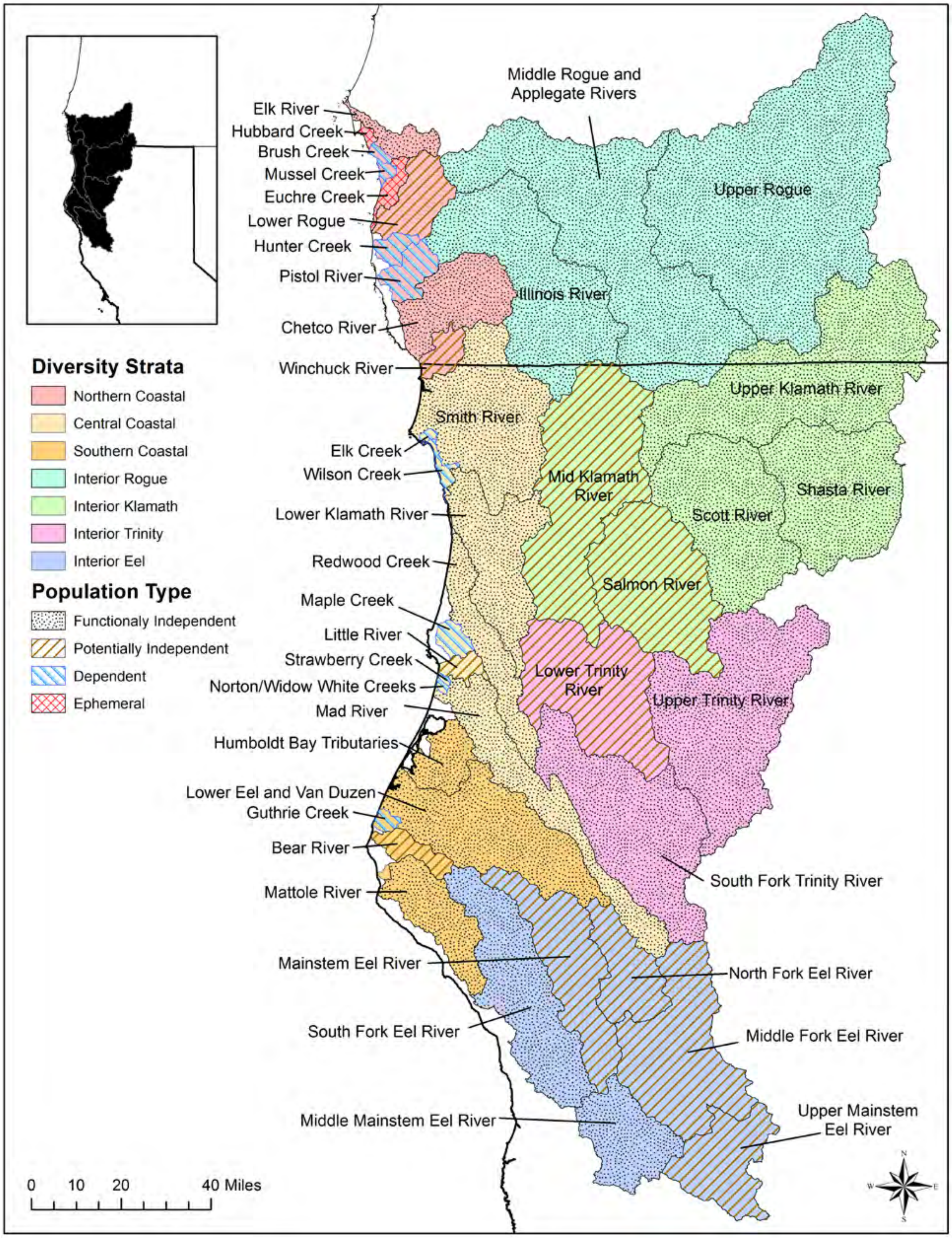



Figure ES-1. Populations and diversity strata of the SONCC coho salmon ESU.

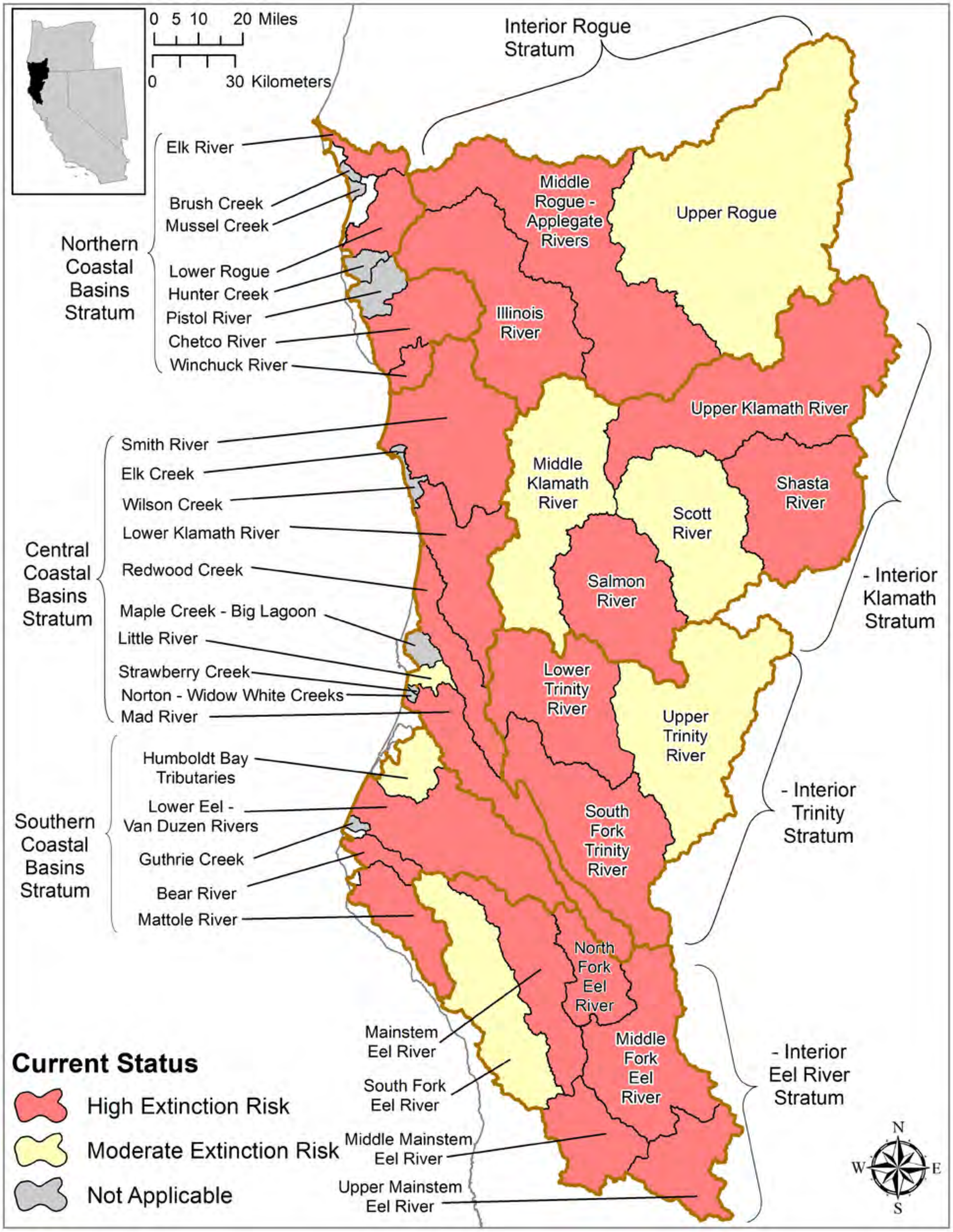



Figure ES-2. Current extinction risk of independent populations in the SONCC coho salmon ESU.

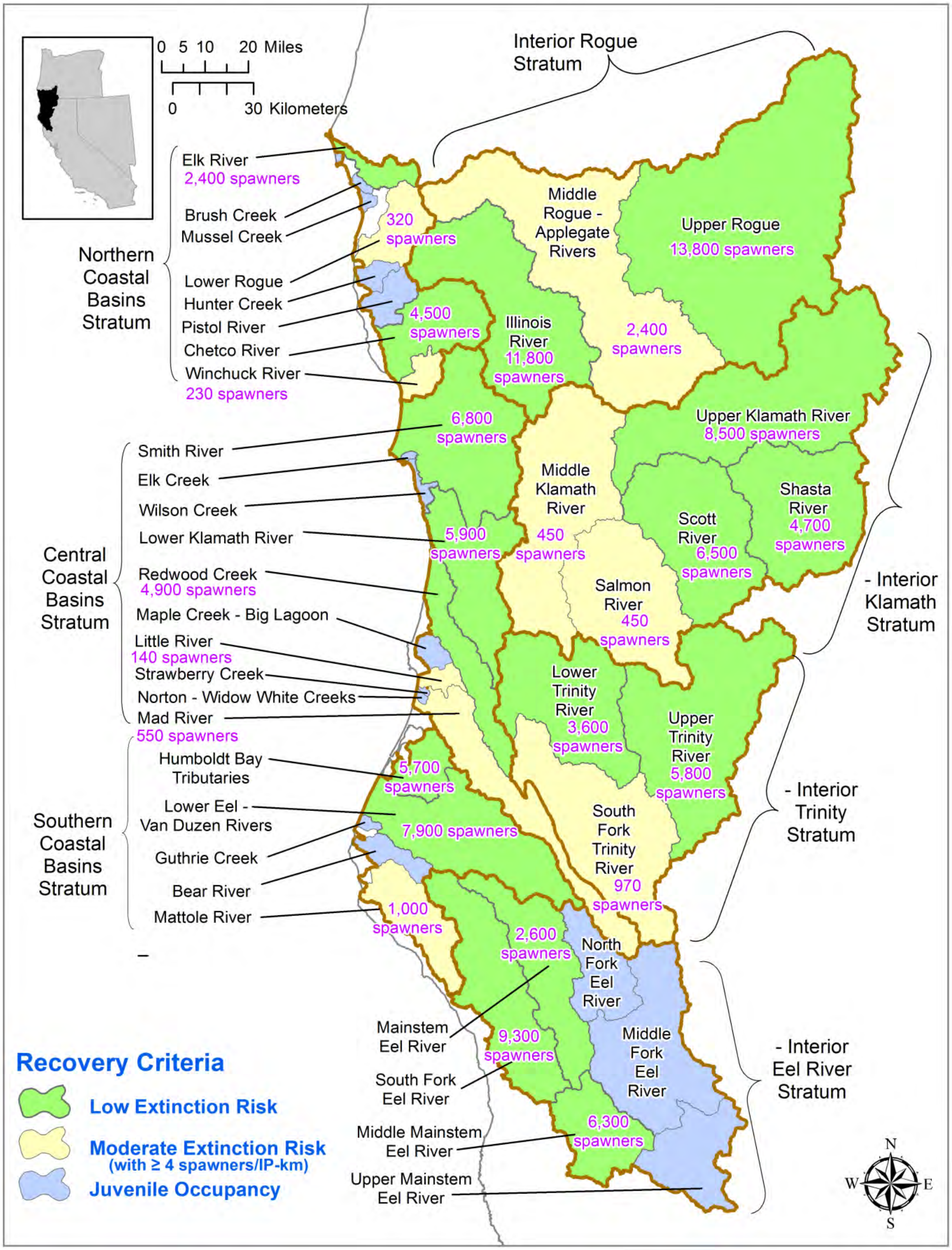



Figure ES-3. Minimum target extinction risk and recovery criteria for each population.

## Stresses and Threats (Chapters 3 and 7 to 46)

Stresses are the physical, biological, or chemical conditions and associated ecological processes that that may impede SONCC coho salmon recovery. These are the factors that the fish feel, such as disease, limited habitat access, insufficient instream flows, impaired water quality, and insufficient amount and quality of habitat. Threats are those activities or impacts that cause or contribute to stresses such as hydropower, diversions, land management, invasive species, fish harvest, timber harvest, and hatcheries. The Plan includes recovery actions to restore various aspects of coho salmon habitat, and SONCC coho salmon recovery also depends on ongoing efforts to change past and current practices that diminish salmon habitat.

Chapter 3 describes the stresses and threats that NMFS believes are currently limiting populations from producing enough adults to avoid a high risk of extinction. Chapters 7 to 46 rank these stresses and threats for each population, and contain tables that describe the actions needed to reduce these stresses and threats. Chapters 7 to 46 also describe the key limiting stresses and threats for each population. Key limiting stresses and threats are those stresses and threats that are the most pressing factors limiting recovery of populations. Recovery actions to address key limiting stresses and threats often have a higher priority than those to address other stresses and threats. The key limiting stresses and threats for each population are shown in Table ES-1.

The lack of floodplain and channel structure is a key limiting stress in nearly all coastal populations and about half of interior populations. Good floodplain structure is present when the river retains areas off the main channel such as ponds and old oxbows. These areas are particularly important for coho salmon as they provide refuge from high winter flows. Good channel structure is present when there are sufficient pools and instream structure, such as complex wood jams. In coastal populations, the most common key limiting threat (52% of populations) is channelization, which results in straightening and simplification of the stream channel and reduction of off-channel habitat. In a third of all populations and 63% of interior populations, the amount of water in streams and rivers is insufficient for coho salmon needs, making altered hydrologic function another prevalent key limiting stress. In 35% of all populations and 71% of interior populations, dams and diversions are a key limiting threat, as they lead to a reduction in the amount of water in streams and rivers.

Table ES-1. SONCC coho salmon ESU populations and their key limiting stresses and threats.

| Stratum | Populations | Key Limiting Stresses | | Key Limiting Threats | |
|---|---|---|---|---|---|
| Northern Coastal Basin | Elk River | Structure | Water Quality | Agriculture | Channelization |
| | Brush Creek | Structure | Riparian | Roads | Timber Harvest |
| | Mussel Creek | Structure | Riparian | Timber Harvest | Channelization |
| | Lower Rogue River | Structure | Water Quality | Roads | Development |
| | Hunter Creek | Structure | Riparian | Roads | Timber Harvest |
| | Pistol Creek | Structure | Riparian | Roads | Timber Harvest |
| | Chetco River | Structure | Riparian | Channelization | Development |
| | Winchuck River | Structure | Water Quality | Channelization | Development |
| Central Coastal Basin | Smith River | Structure | Estuary | Channelization | Agriculture |
| | Elk Creek | Structure | Riparian | Channelization | Development |
| | Wilson Creek | Structure | Riparian | Roads | Timber Harvest |
| | Lower Klamath River | Structure | Sediment | Channelization | Agriculture |
| | Redwood Creek | Structure | Estuary | Channelization | Roads |
| | Maple Creek/Big Lagoon | Structure | Sediment | Roads | Timber Harvest |
| | Little River | Structure | Sediment | Roads | Agriculture |
| | Strawberry Creek | Estuary | Barriers | Barriers | Channelization |
| | Norton/Widow White Creek | Structure | Riparian | Channelization | Roads |
| | Mad River | Structure | Sediment | Roads | Mining |
| Southern Coastal Basin | Humboldt Bay tributaries | Structure | Estuary | Channelization | Roads |
| | Lower Eel/Van Duzen Rivers | Structure | Estuary | Channelization | Dam/Diversion |
| | Guthrie Creek | Structure | Sediment | Timber Harvest | Agriculture |
| | Bear River | Structure | Riparian | Roads | Timber Harvest |
| | Mattole River | Structure | Hydro Function | Dam/Diversion | Development |
| Interior Rogue River | Illinois River | Structure | Hydro Function | Dam/Diversion | Roads |
| | Middle Rogue/Applegate Rivers | Structure | Hydro Function | Dam/Diversion | Development |
| | Upper Rogue River | Structure | Hydro Function | Agriculture | Development |
| Interior Klamath | Middle Klamath River | Structure | Water Quality | Dams/Diversion | Fire |
| | Upper Klamath River | Hydro Function | Barriers | Dam/Diversion | Roads |
| | Shasta River | Hydro Function | Water Quality | Dam/Diversion | Agriculture |
| | Scott River | Hydro Function | Riparian | Dam/Diversion | Agriculture |
| | Salmon River | Structure | Riparian | Fire | Climate Change |
| Interior Trinity | Lower Trinity River | Structure | Hydro Function | Channelization | Hatcheries |
| | South Fork Trinity River | Hydro Function | Water Quality | Dam/Diversion | Roads |
| | Upper Trinity River | Hydro Function | Hatchery Effects | Dam/Diversion | Hatcheries |
| Interior Eel | Mainstem Eel River | Structure | Water Quality | Dam/Diversion | Invasive Species |
| | Middle Mainstem Eel River | Hydro Function | Sediment | Dam/Diversion | Roads |
| | Upper Mainstem Eel River | Hydro Function | Barriers | Dam/Diversion | Roads |
| | Middle Fork Eel River | Structure | Water Quality | Channelization | Roads |
| | South Fork Eel River | Structure | Hydro Function | Dam/Diversion | Roads |
| | North Fork Eel River | Water Quality | Sediment | Roads | Fire |

## Recovery Strategy (Chapters 4 and 6)

The goal of this Plan is to recover the SONCC coho salmon ESU to the point where the species no longer needs the protections afforded by the Federal ESA and can be removed from the ESA list of threatened and endangered species. A recovered SONCC coho salmon ESU will be naturally self-sustaining, and the factors that caused it to be listed will be sufficiently reduced to allow it to persist over time.

The strategy to recover SONCC coho salmon is to carry out recovery actions to restore habitat and reduce stresses and threats, so that populations will rebuild to the levels needed to play their respective roles in recovery, as described in Figure ES-3. These levels are associated with target minimum extinction risks, also shown in Figure ES-3.

Each population must play a role in rebuilding to a recovered ESU. These roles are described in Williams et al. (2008). A certain number of independent populations must be at low risk of extinction to achieve recovery. These populations are called “Core populations” in this plan. A subset of remaining independent populations must be at moderate risk of extinction (and recover to hundreds to low thousands of fish). These populations are called “Non-Core 1 populations”. The remaining populations don’t need a minimum number of fish, instead they must have sufficient habitat occupied by juvenile fish. These populations are called “Dependent” and “Non-Core 2” populations. Figure ES-4 shows the role of each population.

In 2008, NMFS developed an assessment framework to track the SONCC coho salmon ESU’s progress toward recovery (Williams et al. 2008 and Chapters 2 and 4 of this plan). The framework describes a needed configuration of populations with different numbers of spawning adults in various populations such that populations will play different roles in recovery (i.e., when describing core, non-core, dependent) but does not identify which independent populations will be core and which will be non-core. This recovery plan describes which populations will be core and non-core, and identifies the number of spawning adults needed and the needed spatial distribution of juvenile fish for each population. The number of spawning adults needed is based on the population’s role in recovery and on the amount of modeled IP-km in each population.

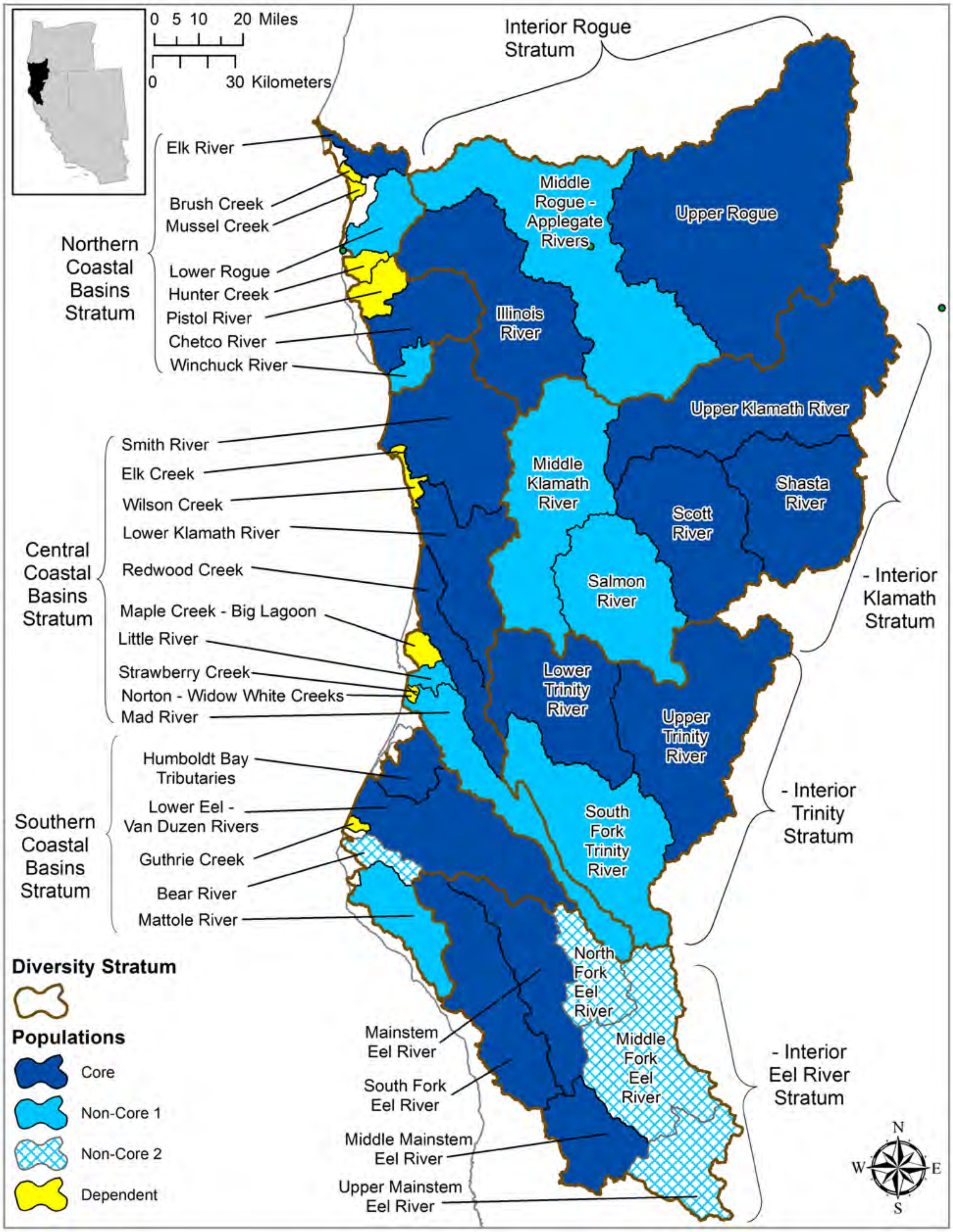



Figure ES-4. The role of each population in the recovery of the SONCC coho salmon ESU.

Table ES-2 shows the recovery objectives and criteria for each population type. There are recovery objectives for four biological parameters of each population: spawner abundance, productivity (growth rate), spatial structure, and diversity (Table ES-2). The Plan's recovery criteria, explained in Chapter 4 and shown in Table ES-2, describe how progress toward each recovery objective will be measured.

Table ES-2. Recovery objectives and criteria by Viable Salmonid Population parameter.

| VSP Parameter | Population Role | Biological Recovery Objective | Biological Recovery Criteria[1] |
|---|---|---|---|
| Abundance | Core | Achieve a low risk of extinction[2] | The geometric mean of wild adults over 12 years meets or exceeds the "low risk threshold" of spawners for each core population[2,3,4] |
| | Non-Core 1 | Achieve a moderate or low risk of extinction[2] | The annual number of wild adults is greater than or equal to four spawners per IP-km for each non-core population[2] |
| Productivity | Core and Non-Core 1 | Population growth rate is not negative | Slope of regression of the geometric mean of wild adults over the time series ≥ zero[4] |
| Spatial Structure | Core and Non-Core 1 | Ensure populations are widely distributed | Annual within-population juvenile distribution ≥ 80%[4] of habitat[5,6] (outside of a temperature mask[7]) |
| | Non-Core 2 and Dependent | Achieve inter- and intra-stratum connectivity | ≥ 80% of accessible habitat[4] is occupied in years[8] following spawning of cohorts that experienced high marine survival[9] |
| Diversity | Core and Non-Core 1 | Achieve low or moderate hatchery impacts on wild fish | Proportion of hatchery-origin adults (pHOS) < 0.05 |
| | Core and Non-Core 1 | Achieve life-history diversity | Variation is present in migration timing, age structure, size and behavior. The variation in these parameters[10] is retained. |

[1] All applicable criteria must be met for each population in order for the ESU to be viable.
[2] See Table 4-2 for specific spawner abundance requirements needed to meet this objective.
[3] In the Shasta River, Upper Trinity River, and Upper Rogue River populations, IP above some anthropogenic dams was excluded from the spawner target, so the low-risk threshold for these populations is based on the IP downstream of those dams.
[4] Assess for at least 12 years, striving for a coefficient of variation (CV) of 15% or less at the population level (Crawford and Rumsey 2011).
[5] Based on available rearing habitat within the watershed (Wainwright et al. 2008). For purposes of these biological recovery criteria, "available" means accessible. 80% of habitat occupied relates to a truth value of +1.0,(true: juveniles occupy a high proportion of the available rearing habitat within the watershed (p. 56, Wainwright et al. 2008).
[6] The average for each of the three year classes over the 12 year period used for delisting evaluation must each meet this criterion. Strive to detect a 15% change in distribution with 80% certainty (Crawford and Rumsey 2011).
[7] Williams et al. (2008) identified a threshold air temperature, above which juvenile coho salmon generally do not occur, and identified areas with air temperatures over this threshold. These areas are considered to be within the temperature mask.
[8] If young-of-year are sampled, sampling would occur the spring following spawning of the cohorts experiencing high marine survival. If 1+ juveniles are sampled, sampling would occur approximately 1.5 years after spawning of the cohorts experiencing high marine survival, but before outmigration to the estuary and ocean.
[9] High marine survival is defined as 10.2% for wild fish and 8% for hatchery fish; Sharr et al. 2000. If marine survival is not high, then this criterion does not apply.
[10] This variation is documented in the population profiles in Chapters 7 to 46 of this plan.

## Recovery Actions

Chapters 5 and 7 to 46 include over 4,000 recovery action steps and their respective priorities. Recovery actions are designed to address acute issues by reducing threats, and to restore processes which create and maintain good coho salmon habitat by reducing stresses. Recovery actions include removal of or establishment of passage at dams; reducing unpermitted diversions; ensuring sufficient water quantity and quality; restoring in-channel habitat and upslope ecological function; and creating suitable estuarine nurseries. In addition, managing fisheries, reducing detrimental effects of land use activities; decreasing disease and non-native predator species, and operating hatcheries consistent with recovery goals are essential. Each recovery action is assigned a priority. The priority of each action is based on whether it will prevent a significant decline in the population or habitat, whether it addresses a key limiting stress or threat, whether it would help a population at high risk of extinction, and whether it would benefit coho salmon immediately.

## Monitoring & Adaptive Management (Chapter 5)

Monitoring is necessary to assess the recovery of SONCC coho salmon by determining if specific recovery criteria are met, and to evaluate whether changes in the recovery strategy are necessary. The Plan identifies acceptable sampling standards and the necessary data to be collected over time, including measuring the abundance and distribution of coho salmon in each population. The adaptive management element offers a feedback loop for continuous scientific evaluation of the foundational scientific framework, monitoring, and recovery action aspects of the Plan so that new information can suggest whether to add or discontinue actions or strategies. Web-based recovery action implementation tracking tools are under development.

## Benefits of Recovery

Achieving delisting of SONCC coho salmon by implementation of the recovery actions identified in the Plan is estimated to cost approximately $5 billion over the amount of time needed to recover the species (just over 100 years). Approximately $1.6 billion of that total cost is associated with monitoring actions required to meet delisting criteria. While a significant investment, the recovery of SONCC coho salmon will concurrently result in a wide array of economic, societal and ecosystem benefits. The largest economic returns resulting from recovered coho salmon populations are associated with sport and commercial fishing. For example, the California commercial and recreational salmon fisheries are estimated to generate a total of $118-279 million[1] in income annually, and provide roughly two to three thousand jobs. These figures will increase as salmon runs increase, providing both economic gains and more commercial and recreational fishing opportunities. With a revived sport and commercial fishery, these substantial economic gains and the creation of jobs would be realized across the SONCC coho salmon range, most notably for river communities and coastal counties.

[1] Employment impacts of CA salmon fishery closures in 2008 and 2009. University of the Pacific. Available at: http://forecast.pacific.edu/BFC%20salmon%20jobs.pdf

The economy will also be stimulated through the employment of workers needed to implement recovery projects. Habitat restoration projects stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects[2]. Every dollar invested in watershed restoration projects travels through the state's economy. Design, implementation, and maintenance of habitat restoration projects require hiring consultants, contractors, employees, and field crews, and purchasing equipment, goods and services. People hired to carry out such projects spend their wages on goods and services in their local communities. In Oregon, 90% of investments in habitat restoration have been shown to stay in the state[2].

Many of the actions identified in this plan are designed to improve watershed-wide processes which benefit many native species of plants and animals (including other state and federally protected species) by restoring ecosystem functions. In addition, restoration of habitat provides substantial benefits for human communities such as: improving and protecting the quality of important surface and ground water supplies; reducing damage from flooding resulting from floodplain development; and controlling invasive exotic animal and plant species which can threaten water supplies and increase flooding risk. Restoring and maintaining healthy watersheds also enhances important human uses of aquatic habitats, including outdoor recreation, ecological education, field based research, aesthetic benefits, and the preservation of tribal and cultural heritage.

## Summary

The Plan provides a comprehensive roadmap for the recovery of SONCC coho salmon to be followed by conservation partners. Recovery will require implementation of actions that conserve and restore the key biological, ecological, and landscape processes that support the ecosystems upon which coho salmon populations depend. The Plan identifies specific recovery actions that protect or restore coho salmon or their habitat and outlines a monitoring and evaluation program to guide its adaptive management elements so that the most effective means of achieving recovery will be utilized. Biological recovery goals, objectives and measurable criteria, and web-based management tools, will provide for a mechanism to track recovery progress. Salmon recovery is best viewed as an opportunity to diversify and strengthen the economy while enhancing the quality of life for present and future generations.

[2] The Economic Impacts of Forest and Watershed Restoration in Oregon, Available at: http://www.oregon.gov/OWEB/MONITOR/job_creation_local_economies.shtml

# 1. Background

## 1.1 Introduction

Populations of coho salmon (*Oncorhynchus kisutch*) once ranged across the western part of North America from the coastal river basins of Alaska to interior areas of Washington and probably inhabited most coastal streams in Washington, Oregon, and northern and central California (62 FR 24588, May 6, 1997). These populations were sufficiently large that they were able to withstand changing environmental conditions. Fisheries for these and other salmonids supported vibrant communities across the Pacific Northwest. Salmon were a critical part of healthy ecosystems in rivers and the ocean.

Part of the range of coho salmon occurs in the Southern Oregon/Northern California Coast (SONCC) Recovery Domain, which encompasses the rivers from Punta Gorda, California to Cape Blanco, Oregon. The coho salmon which occupy this area make up the SONCC coho salmon Evolutionarily Significant Unit (ESU). An ESU is a salmon stock that is considered a distinct population and hence a "species" under the Endangered Species Act. An ESU must meet two criteria: it must be substantially reproductively isolated from other nonspecific population units, and it must represent an important component of the evolutionary legacy of the species (57 FR 58612, November 20, 1991).

In the late 1990s, the populations that make up the SONCC Coho Salmon ESU were small, poorly distributed, and subject to factors that threatened their continued existence. Consequently, the ESU was listed as threatened under the Endangered Species Act (ESA) in 1997 (62 FR 24588, May 6, 1997), a finding that was reaffirmed in 2005 (70 FR 37160, June 28, 2005). A "threatened" species is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (ESA Section 3(20)). An "endangered" species is one that is in danger of extinction throughout all or a significant portion of its range (ESA Section 3(6)). The status of the species has continued to worsen since listing (Good et al. 2005, Williams et al. 2011), despite fishing prohibitions and habitat improvements.

The ESU continues to face challenges, as shown in the Rogue River. The Rogue River has the longest time series of coho salmon adult abundance information in the ESU, and its populations are among those in the best condition. Nonetheless, coho salmon returns there are a small fraction of what they once were. The Rogue River is the only river in the ESU with data on coho abundance in the 1800s. Based on extrapolations from cannery pack data, up to 114,000 adult coho salmon returned to the Rogue River in the late 1800s even after heavy fishing pressure had occurred for years (Meengs and Lackey 2005). Figure 1-1 shows the estimated number of adult coho salmon spawners that returned to the Rogue River from 1980 to 2010, based on counts at Huntley Park (Oregon State University (OSU) 2010), as well as the recovery target for all populations in the Rogue River as presented in this recovery plan. The number of adults has been consistently below that needed for the Rogue River to play its role in recovery of the SONCC coho salmon ESU.

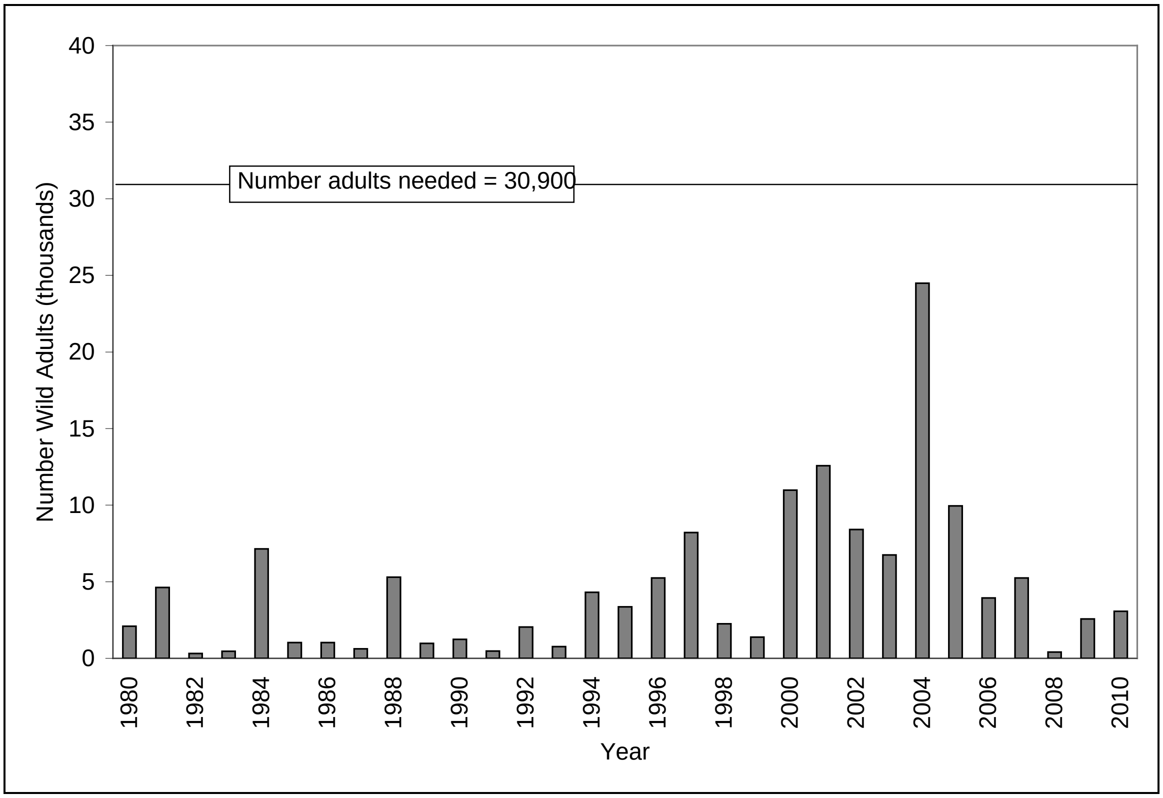



Figure 1-1. Estimates of the run size of wild Rogue basin coho salmon past Huntley Park, 1980-2010 (Oregon Department of Fish and Wildlife [ODFW] 2012), compared to number needed from Rogue River for ESU recovery.

## 1.2 What is a recovery plan?

"Recovery" is the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the ESA are no longer needed (NMFS 2010). When a species is listed under the ESA, a recovery plan generally must be prepared (ESA Section 4(f)(1)). The ESA envisions recovery plans as the central organizing tool for guiding each species' recovery process. The recovery plan is a road map to recovery – it lays out where we need to go and how best to get there. The plan organizes, coordinates, and prioritizes the many possible actions that may be taken to achieve recovery of a species. Use of a recovery plan ensures that recovery efforts target limited resources effectively and efficiently.

Recovery plans are guidance documents. No agency or entity is required by the ESA to implement a recovery plan. However, recovery plans describe how Federal agencies can best meet their responsibilities under the ESA. Specifically, section 7(a)(1) of the ESA calls on all Federal agencies to "utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species…" In addition to outlining strictly proactive measures to achieve the species' recovery, plans provide context and a framework for implementation of other provisions of the ESA with respect to a particular species, such as section (7)(a)(2) consultations on Federal agency activities, development of Habitat Conservation Plans or Safe Harbor agreements under Section 10, or special rules for threatened species under section 4(d).

## 1.3 Achieving Recovery

Federal agencies have neither the funds nor the authority to bring about all the actions necessary to sufficiently improve the condition of this species. Partnerships are a critical component of SONCC coho salmon recovery: partnerships between private landowners, tribes, and local, state, and federal government agencies; between non-governmental organizations and landowners; and between federal, state, and local agencies. A recovered ESU can provide ecosystem, recreation, and economic benefits to communities. All of these entities have a common interest in bringing healthy coho salmon populations and their ecosystems back to California's north coast and Oregon's south coast. The states of California and Oregon have been proactive in determining the recovery needs of coho salmon.

### 1.3.1 Oregon Plan for Salmon and Steelhead

The Oregon Coastal Salmon Restoration Initiative (OCSRI) is a planning process which began in 1995 with the following mission: "To restore our coastal salmon populations and fisheries to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits." In 1997, the State of Oregon released the Oregon Plan, a conservation plan designed to restore salmon to a level at which they can once again be a part of people's lives (State of Oregon 1997). The Oregon Plan included the following goals:

- Goal 1: An infrastructure will exist to provide long-term continuity in leadership, direction, and oversight of salmon restoration.
- Goal 2: Opportunities will exist for a wide range of natural resource uses that are consistent with salmon restoration.
- Goal 3: Achievement of overall OCSRI goals will be based to the greatest extent on existing laws and environmental protections, rather than new ones.
- Goal 4: An adequate funding base will be established and maintained to support the OCSRI.
- Goal 5: Oregon's expectations for sustainability of interrelated natural resources will more accurately reflect a scientific understanding of the physical and biological constraints of the ecosystem.
- Goal 6: Sufficient freshwater and estuarine habitat will be available to support healthy populations of anadromous salmonids throughout coastal river basins.
- Goal 7: Populations of salmonids in coastal river basins will achieve levels of natural production consistent with overall restoration goals.
- Goal 8: A science-based system will support evaluation of progress of the OCSRI Conservation Plan and will provide a basis for making appropriate future changes to management programs.

**Report of Oregon Expert Panel**

ODFW (2008b) convened a panel of fisheries and watershed scientists as an initial step in their development of a recovery plan for Oregon's SONCC coho salmon populations. Deliberations of the expert panel provided ODFW with initial, strategic guidance on limiting factors and threats to recovery. The panel identified limiting factors and threats affecting each SONCC coho salmon population in Oregon by considering the impacts across the entire life cycle. The results of the expert panel deliberations are described in each Oregon population profile.

### 1.3.2 Recovery Strategy for California Coho Salmon

Coho salmon north of San Francisco were listed as threatened under the California Endangered Species Act in 2002. In 2004, the California Fish and Game Commission approved the Recovery Strategy for California Coho Salmon (CDFG 2004a). The plan identified six goals to achieve delisting:

- Goal I: Maintain and improve the number of key populations and increase the number of populations and cohorts of coho salmon.
- Goal II: Maintain and increase the number of spawning adults.
- Goal III: Maintain the range, and maintain and increase distribution of coho salmon.
- Goal IV: Maintain existing habitat essential for coho salmon.
- Goal V: Enhance and restore habitat within the range of coho salmon.
- Goal VI: Reach and maintain coho salmon population levels to allow for the resumption of Tribal, recreational, and commercial fisheries for coho salmon in California.

## 1.4 Listing of Species

The SONCC coho salmon ESU was listed as threatened in 1997, and this status was reaffirmed in 2005 (62 FR 24588, May 6, 1997 and 70 FR 37160, June 28, 2005). This ESU includes all naturally spawned coho salmon populations between Punta Gorda, California and Cape Blanco, Oregon as well as three artificial propagation programs: The Cole Rivers Hatchery (ODFW stock #52), Trinity River Hatchery, and Iron Gate Hatchery coho hatchery programs. The decision to list the SONCC coho salmon ESU was largely based on information regarding decreased abundance, reduced distribution, and degraded habitat. There are far fewer streams and rivers supporting coho salmon in this ESU now compared to historical conditions, and numerous basin-specific extirpations of coho salmon have been documented (Brown et al. 1994, NMFS 1996, CDFG 2004a, Good et al. 2005, Gustafson et al. 2007). At the time of listing, the major factors in the decline of the species were thought to originate from long-standing, human-induced actions (e.g., habitat degradation, harvest, water diversions, and artificial propagation), combined with natural environmental variability (62 FR 24588, May 6, 1997).

The SONCC coho salmon ESU is made up of 45 ephemeral, dependent, and independent populations (Williams et al. 2006). Five of these populations are not part of the recovery strategy described in this plan. Three were excluded due to reductions in IP (see Appendix A), and two were determined to be too small to persist and therefore were excluded from further consideration.

According to Section 4(a)(1) of the ESA and NMFS listing regulations (50 Code of Federal Regulations [CFR] Part 424), a species may be found to be endangered or threatened based on any one or a combination of five factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or human-made factors affecting its continued existence. The effect of these factors on SONCC coho salmon was considered when the species was listed. The descriptions of each of the factors that follow summarize the final rule from the listing of the SONCC coho salmon ESU (62 FR 24588, May 6, 1997). Chapter 3, as well as Chapters 7 to 46, describes the state of current stresses and threats.

### 1.4.1 Factor A: Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range

The habitat factors for the decline of SONCC coho salmon are as follows: Channel morphology changes, substrate changes, loss of instream roughness, loss of estuarine habitat, loss of wetlands, loss/degradation of riparian areas, declines in water quality (e.g., elevated water temperatures, reduced dissolved oxygen, altered biological communities, toxics, elevated pH, and altered stream fertility), altered streamflows, fish passage impediments, elimination of habitat, and direct take (62 FR 24588, May 6, 1997). The major activities responsible for the decline of coho salmon were identified as follows: logging, road building, grazing and mining activities, urbanization, stream channelization, dams, wetland loss, beaver trapping, water withdrawals, and unscreened diversions for irrigation (62 FR 24588, May 6, 1997).

### 1.4.2 Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overfishing in non-tribal fisheries was identified as a significant factor in the decline of coho salmon (62 FR 24588, May 6, 1997). Significant overfishing occurred from the time marine survival turned poor for many stocks (ca. 1976) until the mid-1990s when harvest was substantially curtailed. This overfishing compromised escapement levels. The contribution of recreational fisheries to the decline was unknown at the time of listing. Tribal harvest was not considered to be a major factor for the decline of coho salmon in either the Klamath River basin or Trinity River basin (62 FR 24588, May 6, 1997). Collection for scientific research and educational programs was believed to have little or no impact on coho salmon populations in the SONCC coho salmon ESU at the time of listing (62 FR 24588, May 6, 1997).

### 1.4.3 Factor C: Disease or Predation

At the time of listing, disease and predation were not believed to be major factors contributing to the overall decline of coho salmon, although it was recognized that they may have had substantial impacts in local areas (62 FR 24588, May 6, 1997).

### 1.4.4 Factor D: Inadequacy of Existing Regulatory Mechanisms

**Habitat Management**

Federal lands owned by the U.S. Forest Service (in California and Oregon) and Bureau of Land Management (in California) are managed under the Northwest Forest Plan. The Northwest Forest Plan has important benefits for coho salmon, but its overall effectiveness in conserving SONCC coho salmon is limited by the extent of federal lands and the fact that Federal land ownership is often not uniformly distributed. Federal lands are often located in the upper reaches of watersheds or river basins, upstream of much of the most suitable coho salmon rearing habitat. In addition, in some areas Federal lands are distributed in a checkerboard fashion, which results in fragmented landscapes.

NMFS determined California's forest practice rules (CFPRs), which regulate timber harvest, contained provisions that can be protective of coho salmon if fully implemented, but found the ability of these rules to protect coho salmon could be improved (62 FR 24588, May 6, 1997). In particular, the CFPRs did not adequately address large woody debris recruitment, streamside tree retention to maintain bank stability, and canopy retention standards that assure stream temperatures are properly functioning for all life stages of coho salmon. NMFS was not able to assess the adequacy of the T&I rules due to the lack of published documentation that the rules are functioning to protect coho salmon (62 FR 24588, May 6, 1997). In 2010, California's Anadromous Salmonid Protection (ASP) rules replaced its Threatened or Impaired Watershed Rules, which had originally been adopted in July 2000. The ASP rules are described in Chapter 3.

NMFS (62 FR 24588, May 6, 1997) determined that Oregon's Forest Practices Act (OFPA) did not have implementing rules that adequately protect coho salmon habitat. NMFS (62 FR 24588, May 6, 1997) determined that there was a low probability that adequate LWD recruitment could be achieved under the requirements of the OFPA. The OFPA was also found to not adequately consider and manage timber harvest and road construction on sensitive, unstable slopes subject to mass wasting, nor did it address cumulative effects. In particular, the OFPA was found to not provide adequate protection for the production and introduction of large woody debris (LWD) to medium, small, and non-fish bearing streams (62 FR 24588, May 6, 1997).

The Army Corps of Engineers (ACOE ) regulates removal and fill activities under section 404 of the Clean Water Act (CWA), and the Oregon Division of State Lands (DSL) manages the state-permitted portion of the removal fill laws. At the time of listing, neither the ACOE nor the DSL had in place any process to address the additive effects of the continued development of waterfront, riverine, coastal, and wetland properties (62 FR 24588, May 6, 1997).

Implementation of the CWA was found to have not been effective in adequately protecting fishery resources, especially with respect to non-point sources of pollution (62 FR 24588, May 6, 1997). Total Maximum Daily Loads (TMDLs) are calculations of the maximum amount of pollutant (e.g., sediment, temperature) that a water body can receive and still safely meet water quality standards. TMDLs are a method for quantitative assessment of environmental problems which affect drinking water, aquatic life, recreation, and other uses of rivers, lakes, and streams. NMFS expected that TMDLs would be able to significantly protect SONCC coho salmon in the long-term, but their effectiveness was as yet unknown because few, if any, TMDLs had been developed for water bodies in the range of SONCC coho salmon at the time of listing (62 FR 24588, May 6, 1997).

At the time of listing, the impacts to fish habitat from agricultural activities had historically not been closely regulated, but Oregon's Department of Agriculture had recently completed guidance for development of Agricultural Water Quality Management Plans. It was unknown whether these agricultural management plans would adequately address salmonid habitat factors (62 FR 24588, May 6, 1997).

#### Harvest Management

The final rule described fishery regulations implemented in 1994 which are more protective of SONCC coho salmon than were historical regulations (62 FR 24588, May 6, 1997). Specifically, in 1994 the Pacific Fishery Management Council (PFMC) recommended harvest rates below those allowed at that time, and the PFMC recommended prohibiting the retention of coho salmon south of Cape Falcon, Oregon, resulting in the closure of commercial ocean fishing for coho salmon in California in 1994. Oregon began marking all hatchery fish to aid in more accurate estimates of natural returns. Oregon regulations for ocean fisheries within 3 miles of shore had generally conformed to these more protective regulations. In 1995, ocean recreational fishing for coho salmon was closed from Cape Falcon to Horse Mountain.

### 1.4.5 Factor E: Other Natural or Human-made Factors

NMFS determined that long-term trends in rainfall and marine productivity associated with atmospheric conditions in the North Pacific Ocean likely have a major influence on coho salmon production (62 FR 24588, May 6, 1997). The effects of extended drought on water supplies and water temperatures were recognized as a major concern for California populations of coho salmon. Poor ocean conditions were believed to have played a prominent role in the decline of coho salmon populations in Oregon and California (62 FR 24588, May 6, 1997).

The widespread use of artificial propagation of coho salmon was recognized to have had a significant negative impact on the production of West Coast coho salmon (62 FR 24588, May 6, 1997). Potential problems associated with hatchery programs include: genetic impacts on indigenous, naturally-reproducing populations; disease transmission; predation on wild fish; depletion of wild stock to increase brood stock; and replacement rather than supplementation of wild stocks through competition and continued annual introduction of hatchery fish. Advancement and compression of run timing has also been a common effect of hatchery programs.

## 1.5 Critical Habitat Designation

Critical habitat for SONCC coho salmon was designated as all accessible reaches of rivers (including estuarine areas and tributaries) between Cape Blanco, Oregon, and Punta Gorda, California (64 FR 24049, May 5, 1999). Critical habitat includes all waterways, substrate, and adjacent riparian zones below longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Tribal lands that were excluded in the critical habitat designation include: Big Lagoon Rancheria, Blue Lake Rancheria, Elk Valley Rancheria, Hoopa Valley Indian Reservation, Karuk Reservation, Laytonville Rancheria, Quartz Valley Reservation, Resighini Rancheria, Round Valley Reservation, Sherwood Valley Rancheria, Smith River Rancheria, and Yurok Reservation.

In the critical habitat designation, NMFS identified five essential habitat types for SONCC coho salmon: (1) spawning areas; (2) adult migration corridors; (3) juvenile summer and winter rearing areas; (4) juvenile migration corridors; and (5) areas for growth and development to adulthood. Spawning and rearing are often located in small headwater streams and side channels. Adult and juvenile migration corridors include these tributaries as well as mainstem reaches and estuarine zones. Growth and development to adulthood occurs primarily in near-and off-shore marine waters, although final maturation takes place in freshwater tributaries when the adults return to spawn (64 FR 24049, May 5, 1999). Within these areas, essential features of coho salmon critical habitat include adequate substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions. In addition, designated freshwater and estuarine critical habitat includes riparian areas that provide the following functions: shade, sediment, nutrient or chemical regulation, stream bank stability, and input of large woody debris or organic matter (64 FR 24049, May 5, 1999).

## 1.6 ESA Section 4(d) Protective Regulations

Section 9 of the ESA prohibits take of species listed as endangered. Section 4(d) of the ESA provides that, whenever any species is listed as threatened, NMFS shall issue regulations deemed necessary and advisable to provide for the conservation of such species. These protective regulations (commonly referred to as a "4(d) rule") may prohibit take of threatened species while limiting the prohibition under certain circumstances. The 4(d) rule applies to ocean and inland areas and to any authority, agency, or private individual subject to U.S. jurisdiction. NMFS initially promulgated a 4(d) protective regulation for this ESU in 2000 (65 FR 42422, July 10, 2000) and subsequently amended the regulations which are codified at 50 CFR § 223.203. This protective regulation generally prohibits the take of any SONCC coho salmon with an intact adipose fin, with limits on this general prohibition. The limits on the general prohibition of take described in 50 CFR 223.203 are summarized below.

1. Take of threatened salmonids by employees or designees of Federal agencies, CDFW, ODFW, or other governmental entity with co-management authority for the listed salmonids, if this take is necessary to 1. Aid a sick, injured or stranded salmonid, 2. Dispose of a dead salmonid, or 3. Salvage a dead salmonid which may be useful for scientific study.
2. Fishery harvest activities managed in accordance with a NMFS-approved Fishery Management and Evaluation Plan, and implemented in accordance with a letter of concurrence from NMFS.
3. Hatcheries managed under a state or Federal Hatchery and Genetics Management Plan (HGMP) which has been approved by NMFS as meeting specific criteria.
4. Scientific research activities conducted or overseen by employees or contractors of the Oregon Department of Fish and Wildlife (ODFW) or California Department of Fish and Wildlife (CDFW).

5. Habitat restoration activities conducted as part of a watershed conservation plan which has been certified by the states of California or Oregon as consistent with their watershed conservation plan guidelines. NMFS has found these state guidelines to provide for plans that meet specific criteria.
6. Physical diversion of water from a stream or lake, provided that NMFS or its authorized officer has agreed in writing that the diversion facility is screened, maintained, and operated in compliance with applicable criteria.
7. Routine road maintenance activities which contribute to the attainment and maintenance of properly functioning condition (the sustained presence of natural habitat-forming processes that are necessary for the long-term survival of salmonids through the full range of environmental variation).
8. Municipal, residential, commercial, and industrial development (including redevelopment) activities provided that such development occurs pursuant to city, county, or regional government ordinances or plans that NMFS has determined (in writing) are adequately protective of listed species.

## 1.7 Addition of hatchery stocks to SONCC coho salmon ESU

NMFS established a policy on the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204, June 28, 2005). Specifically, this policy: (1) establishes criteria for including hatchery stocks in ESUs and DPSs; (2) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (3) requires that hatchery fish determined to be part of an ESU be included in any listing of an ESU or DPS; (4) affirms NMFS' commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (5) affirms NMFS' commitment to fulfilling trust and treaty obligations with regard to the harvest of some Pacific salmon and steelhead populations, consistent with the conservation and recovery of listed salmon ESUs and steelhead DPSs.

To determine whether a hatchery program is part of an ESU or DPS, NMFS convened the Salmon and Steelhead Hatchery Advisory Group (SSHAG), which divided existing hatchery programs into categories (SSHAG 2003). Using this information and the policy described above, among other things, NMFS completed new status reviews and ESA-listing determinations for 16 ESUs of Pacific salmon, including the SONCC coho salmon ESU (70 FR 37160, June 28, 2005). This listing determination added three artificial propagation programs to the SONCC coho salmon ESU: Cole Rivers Hatchery, Trinity River Hatchery, and Iron Gate Hatchery coho salmon hatchery programs. NMFS determined these artificially propagated stocks were no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the ESU.

## 1.8 Status reviews

### 1.8.1 2005 Status Review

In 2004, NMFS convened a biological review team (BRT) to evaluate the status of SONCC coho salmon. The BRT report (Good et al. 2005) concluded that the SONCC Coho Salmon ESU should remain at a threatened status. The BRT found that data did not suggest any marked change, either positive or negative, in the abundance or distribution of coho salmon within the

SONCC coho salmon ESU. They stated that coho salmon populations continued to be depressed relative to historical numbers, and there were strong indications that breeding groups had been lost from a significant percentage of streams within their historical range (Good et al. 2005). The BRT noted that the 2001 broodyear appeared to be one of the strongest perhaps of the last decade, following a number of relatively weak years (Good et al. 2005). Risk factors identified in previous status reviews such as severe declines from historical run sizes, the apparent frequency of local extinctions, long-term trends that were clearly downward, and degraded freshwater habitat and associated reduction in carrying capacity continued to concern the BRT. The BRT noted that several risk factors had been reduced, including termination of hatchery production of coho salmon at Mad River and Rowdy Creek and restrictions on recreational and commercial harvest of coho salmon since 1994 (Good et al. 2005). A new risk identified by the BRT was the introduction of nonnative Sacramento pikeminnow (*Ptychocheilus grandis*) to the Eel River (Good et al. 2005).

### 1.8.2 2011 Status Review

The most recent status review concluded the ESU remains threatened (NMFS 2011). Monitoring indicates that abundance of coho salmon decreased for many populations in the ESU since the last status review. Population trends are downward. Additionally, a majority of independent populations are well below low-risk abundance targets, and many may also be below the high-risk depensation thresholds established by Williams et al. (2008). None of the seven diversity strata appear to support a single viable population. However, all of the diversity strata are occupied by coho salmon.

In the status review, NMFS expressed concern about these recent declines in abundance of coho salmon across the ESU, regardless of what the contributing factor(s) may have been (e.g., marine survival conditions and drought). The negative short-term trends observed in the limited number of time series were not unexpected given the apparent low marine survival in recent years (<1% for the 2004 to 2006 year classes). However, as population sizes have decreased other factors (e.g., small population dynamics) may be adversely affecting coho salmon populations in spite of the improved ocean conditions that occurred from 2007 to 2009. The declining abundance trends and low spawner abundance for most populations in the ESU underscore the importance of addressing freshwater habitat conditions across the ESU so that all populations are sufficiently resilient to withstand fluctuations in marine survival.

The threats discussed in the five factor analysis were found to be largely unchanged since the last status review with the exception of those associated with natural or manmade factors (NMFS 2011). In particular, threats from poor ocean conditions, drought, climate change, and small population size (depensation and stochastic processes) have or are likely to have increased and may be responsible for the observed declines in abundance. The marine survival of hatchery fish from the Cole Rivers Hatchery on the Rogue River was extremely low for the 2005 and 2006 brood years (i.e., 0.05% and 0.07%, respectively) and the average ocean conditions in 2010 (Peterson et al. 2013) suggest there may be poor marine survival for the 2011 spawning season. Drought conditions occurred for three consecutive years (2007-2009) that decreased instream flows and habitat conditions for juvenile coho salmon and very likely reduced their freshwater survival. Although it is unclear whether significant habitat changes are occurring from climate change, the authors expect a wide range of future detrimental changes to coho salmon habitat.

Lastly, because many coho salmon populations in this ESU are low in abundance, and may well be below their depensation thresholds, their risk of extinction may also be increasing.

## 1.9 Life-history

Coho salmon is an anadromous fish species that generally exhibits a relatively simple 3-year life cycle. Adults typically begin their freshwater spawning migration in the late summer and fall, spawn by mid-winter, and then die. The run and spawning times vary between and within populations. Depending on river temperatures, eggs incubate in ‘‘redds’’ (gravel nests excavated by spawning females) for 1.5 to 4 months before hatching as ‘‘alevins’’ (a larval life stage dependent on food stored in a yolk sac). Once most of the yolk sac is absorbed, the 30 to 35 millimeter fish (then termed “fry”) begin emerging from the gravel in search of shallow stream margins for foraging and safety (NRC 2004). Coho salmon fry typically transition to the juvenile stage by about mid-June when they are about 50 to 60 mm, and both stages are collectively referred to as “young of the year.” Juveniles develop vertical dark bands or “parr marks”, and begin partitioning available instream habitat through aggressive agonistic interactions with other juvenile fish (Quinn 2005). Juveniles rear in fresh water for up to 15 months, then migrate to the ocean as ‘‘smolts’’ in the spring. Coho salmon typically spend 2 growing seasons in the ocean before returning to their natal stream to spawn as 3 year-olds. Some precocious males, called ‘‘jacks,’’ return to spawn after only 6 months at sea.

### 1.9.1 Spawning and Incubation

Females tend to prepare their redds (gravel nests) and spawn soon after arriving on spawning grounds between November and January with spawning timing varying by watershed within the ESU (Weitkamp et al. 1995). Coho salmon generally choose spawning sites near the head of a riffle, just below a pool where there is abundant small- to medium-size gravel (Shapovalov and Taft 1954). The number of fertilized eggs deposited in each redd is based on each female’s individual fecundity and fertilization success; fecundity ranges between 1,400 to 3,000 eggs (Sandercock 1991). These eggs are dispersed among pockets within the redd (Sandercock 1991). Larger females tend to produce larger and more abundant eggs. Migration distance can also influence egg production, with longer migrations inhibiting egg size and/or quantity (Kinnison et al. 2001). All these differences drive population-specific differences in fecundity and egg size (Beacham 1982, Hjort and Schreck 1982, Taylor and McPhail 1985, Swain and Holtby 1989, Fleming and Gross 1990, Murray et al. 1990).

Once spawning is complete, the female will cover the redd with gravel and guard it until her death (approximately 4 to 15 days; Weitkamp et al. 1995). Ultimately the success of reproduction depends on a number of environmental and biological factors that occur within the redd, the spawning site, and the watershed. Many of these factors are linked to the timing of reproduction.

Embryonic development begins when an egg is fertilized, and developmental rate and incubation period are inversely related to water temperature. In most streams in Oregon and California, incubation takes place between November and April and lasts from 38 to 48 days depending on water temperature (Shapovalov and Taft 1954). Alevins are the larval stage which hatches from the egg and is dependent on food stored in a yolk sac. Alevins remain in the redd after hatching, develop into fry in the redd, then emerge. The time between hatching and fry emergence is dependent on temperature as well as dissolved oxygen levels in the redd; fry can remain in the redd for 4 to 10 weeks. The total emergence period can last between 10 and 47 days. Fry emergence takes place between March and July, with peak emergence in March and May (Shapovalov and Taft 1954, Koski 1966). Fry are approximately 30 mm in length when they emerge, with earlier emergence linked to larger size and greater growth opportunity (Mason and Chapman 1965, Sandercock 1991). The percentage of eggs and alevins that survive to emergence is dependent on stream and riverbed conditions. Winter flooding, with its associated scour and gravel movement, accounts for a high proportion of losses. Low flows, freezing, heavy silt loads, bird and insect predation, and infection can also lead to mortality. Under very harsh conditions, no eggs or alevins will survive. Under average conditions between 15 to 27 percent will survive to emergence (Neave 1949, Crone and Bond 1976) and in favorable conditions between 65 to 85 percent will survive (Shapovalov and Taft 1954). Studies from California and Oregon found average survival to be between 27.1 percent and 74.3 percent (Briggs 1953, Koski 1966).

### 1.9.2 Rearing and Outmigration

After emergence, fry seek out shallow water along stream margins. Juvenile rearing usually occurs in tributary streams with a gradient of 3 percent or less, although they may move up streams with as much as 5 percent gradient (Agrawal et al 2005, Leidy et al. 2005). Juveniles have been found in streams as small as 1 to 2 meters wide. Typical juvenile rearing habitat consists of slow moving, complex pool habitat commonly found within small, heavily forested tributary streams (Moyle 2002, Quinn 2005). When rootwads, large woody debris, or other types of cover are present, growth is bolstered (Nielsen 1992). Increased growth is essential for juveniles because larger size confers higher over-wintering survival (Quinn and Peterson 1996).

The dominant life-history pattern is for juvenile coho salmon to feed and rear within the streams of their natal watershed for a year before migrating to the ocean. However, they may spend up to two years rearing in freshwater (Bell and Duffy 2007, Ransom 2007), or emigrate to an estuary shortly after emerging from spawning gravels (Tschaplinski 1988). The occurrence of age-0 “ocean-type” coho salmon migrants to the estuary, stream-estuary ecotone, or lower main-stem reaches has been documented throughout the range of coho salmon and is thought to be an alternative life-history strategy (Chapman et al. 1961; Chapman 1962; Hartman et al. 1982; Murphy et al. 1984; Rodgers et al. 1987, Au 1972, Kahler et al. 2001, Ryall and Levings 1987, Miller and Sadro 2003, Pinnix et al. 2013). Recent studies documenting various coho salmon juvenile life histories (Bennett et al. 2011, Roni et al. 2012, Pinnix et al. 2013, Quinn et al. 2013, Bennett et al. 2014, Jones et al. 2014) suggest coho salmon juveniles may have at least four life-history strategies in some basins (Bennett et al. 2014, Jones et al. 2014; Figure 1-2).

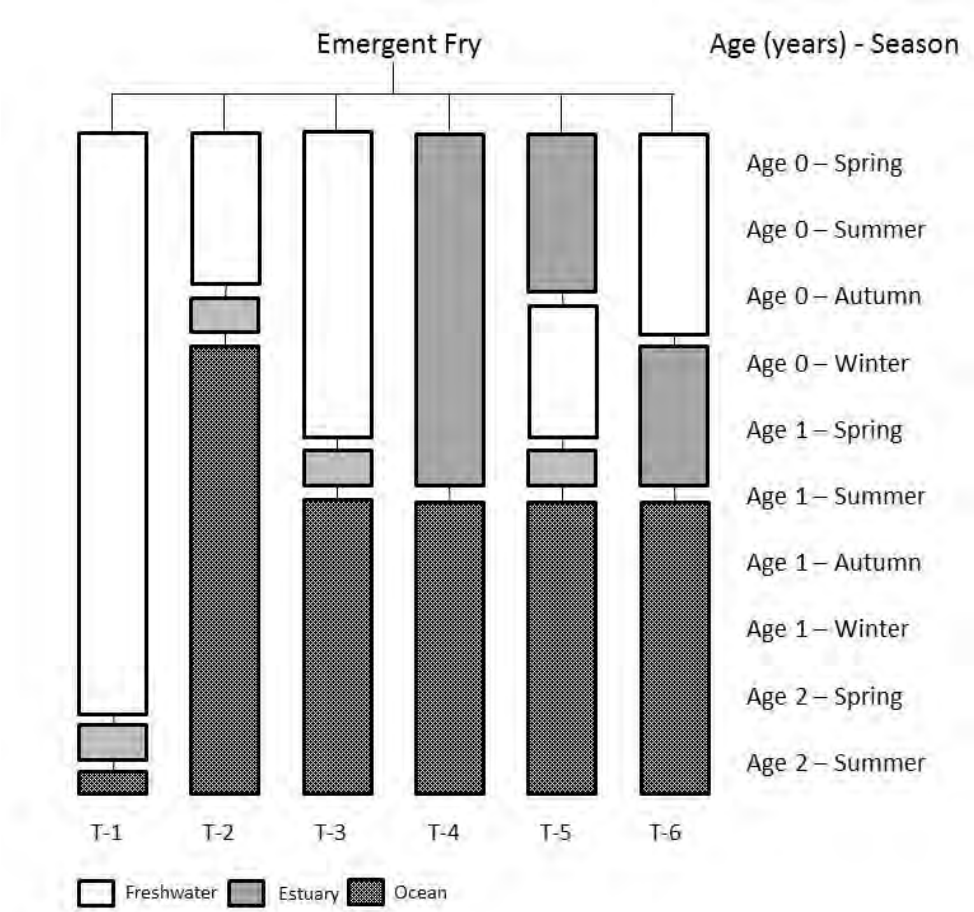



Figure 1-2. Types of life-history strategies of coho salmon juveniles. Figure modified from Jones et al. 2014.

In California and Oregon, some ocean-type coho salmon rear in the estuary during the spring, summer, and fall then return upstream to overwinter (Miller and Sadro 2003, Jones et al. 2014). This primarily occurs in watersheds with adequate estuarine rearing habitat (Merrell and Koski 1978). Extended freshwater residence in California streams has also been documented for age-1+ coho salmon (Bell and Duffy 2007, Ransom 2007). The proportion of a cohort that exhibited extended freshwater rearing ranged from 0 percent to almost 30 percent among Northern California streams and was linked most strongly to peak winter streamflow (Ransom 2007). Coho salmon also use non-natal streams for rearing, and redistribute into riverine ponds following fall rains (Peterson 1982, Ackerman and Cramer 2006, Soto et al. 2008, Hillemeier et al. 2009). For juvenile coho salmon that rear for at least a year in freshwater streams, this habitat offers the opportunity to grow prior to migration to larger rivers and the ocean. While rearing in such environments, coho salmon may grow slowly but experience a relatively low predation risk compared with downstream habitats (Quinn 2005).

Coho salmon fry may move upstream or downstream to rear after emergence. Coho salmon rearing areas include lakes, sloughs, side channels, estuaries, beaver ponds, low-gradient tributaries to large rivers, and large areas of slack water (PFMC 1999). During the rearing period, juveniles set up territories for feeding, especially in pool areas of streams (Hartman

1965). The abundance of coho salmon in streams is limited by the number of suitable territories available; streams with more complex habitat support larger numbers of fry (Scrivener and Andersen 1982, Larkin 1977).

During summer, juvenile coho salmon move into deep pools and areas with dense shade and large woody debris (LWD) for refuge from high water temperatures (Nickelson et al. 1992; Brown et al. 1994). A study of coho salmon occurrence in tributaries of the Mattole River suggested that a MWMT (maximum weekly maximum temperature) greater than 18.1 °C or a MWAT (highest average of mean daily temperature over any seven-day period) greater than 16.8 °C would preclude the occurrence of coho salmon. Lethal temperatures range from 24 to 30 ºC (McCullough 1999), but coho salmon can survive at high daily maximum temperatures if (1) high quality food is abundant, (2) thermal refugia are available, and (3) competitors or predators are few (NRC 2004).

In the winter, juvenile coho salmon avoid being washed out of their habitat by high flows by utilizing flow refugia including smaller tributary streams, intermittent streams, deeper pools, and large woody debris (Tripp and McCart 1983, Skeesick 1970, Narver 1978, Quinn and Peterson 1996, Solazzi et al. 2000). Ebersole et al. (2006 and 2009) found that coho salmon in a Washington stream moved into seasonally dry areas shortly after fall rains, and that these fish as well as those that moved into tributaries had higher survival than those that remained in the mainstem. In the Washington stream, off-channel ponds, large woody debris, and other floodplain habitat were scarce due to past land-use and geology, conditions shared across much of the SONCC coho salmon ESU. Ebersole et al. (2009) found that much of the variation in overwinter survival in this system was associated with winter discharge and the effects of high winter streamflows, emphasizing the need for high flow refugia. Large woody debris and other instream cover are heavily used by coho salmon in systems where these habitat features are more abundant (Nielsen 1992, Hardy et al. 2006), indicating the importance of access to cover while rearing.

The synchrony of arrival timing in coastal waters and the availability of food is especially critical for determining the survival rates of different cohorts (Walters et al. 1978). Many studies have shown that the timing of outmigration can have a large impact on the survival of coho salmon at sea (Pearcy 1992). Spence and Hall (2010) found patterns in outmigration of coho salmon smolts at 54 locations from central California to Kodiak Island, Alaska. They observed latitudinally-associated differences in duration, season, and variability in timing of migration across years, which they attributed to regional differences in the predictability and timing of favorable marine conditions. Spence and Dick (2014) examined short-term probability of migration of four coho salmon populations in the North Pacific (Canada and Oregon) that entered the ocean in different ocean production domains. Two factors, amount of daylight and water temperature, explained migration timing in the farthest northern location, while migration in Oregon sites was tied to numerous environmental factors [amount of daylight, water temperature (absolute and change), flow (absolute and change), and lunar phase] and migration in the southern Canadian site, was influenced by all these factors except lunar phase. There is likely selective pressure on coho salmon smolts to begin smoltification and to enter the ocean at times when ocean conditions will be most favorable, and there is latitudinal variability in how predictable these ocean conditions are due to different ocean production domains (Spence and Dick 2014). The southernmost populations, closest to the SONCC coho salmon ESU, responded to the most environmental cues, suggesting that the timing and predictability of ocean conditions in these areas was less predictable than in areas to the north.

Downstream migration of coho salmon in the SONCC coho salmon ESU begins in the spring sometime between April and May and continues into June. Most smolts measured between 90 and 115 mm fork length. Factors affecting the onset of emigration include the size of the fish, flow conditions, water temperature, dissolved oxygen (DO) levels, day length, and the availability of food (Shapovalov and Taft 1954). Smolt migration timing is affected by anthropogenic activities, including habitat degradation (Moring and Lantz 1975, Scrivener and Andersen 1984, Holtby and Scrivener 1989), and habitat restoration (Johnson et al. 1993, Rodgers et al. 1993). Beeman et al. (2012) documented a positive relationship between flow volume and travel time and survival of juvenile coho salmon in the mainstem Klamath River. The anthropogenic activities listed above may influence migration timing by affecting environmental factors such as temperature (Scrivener and Anderson 1984) and flow (Beeman et al. 2012).

A juvenile's downstream migration to the ocean is accompanied by a series of internal changes in morphology, physiology, and behavior needed for a transition to saltwater. Travel rates to reach the ocean are determined by flow rates, date, and distance as well as individual based characteristics such as the extent of parr-smolt transformation. Travel rates increase with flow rates and travel distance. Fish migrating later in season also move faster than fish migrating earlier in the year (Dawley et al. 1986). Mortality from downstream migration is positively correlated to the distance traveled and has been linked to predation and hydropower operations in past studies (Quinn 2005).

Once juveniles reach the estuary, they will spend a variable amount of time completing the juvenile-to-smolt transformation. Estuarine residence is dependent on variety of factors, many of which remain unknown for this species of salmon. Growth rates in estuaries are generally higher than in freshwater habitats, and many juvenile coho salmon take advantage of feeding opportunities and time to transition to salt water while in the estuary. Depending on the opportunity and capacity of the estuary, coho salmon on the Oregon and California coast will spend a few days to a few weeks in the estuary (Miller and Sadro 2003, Clements et al. 2012, Pinnix et al. 2013, Jones et al. 2014).

Large smolts have higher ocean survival than small smolts (Bilton et al. 1982, Henderson and Cass 1991, Lum 2003, Quinn 2005, Jokikokko et al. 2006, Muir et al. 2006). In addition, larger smolts produce larger adults (Lum 2003, Henderson and Cass 1991), which have higher fecundity than smaller adults (Weitkamp et al. 1995, Fleming 1996, Heinimaa and Heinimaa 2004). The average size of outmigrating coho salmon is approximately 128 mm with the largest smolts originating from the Trinity River (mean 147 mm) and the smallest originating from Blue Creek on the Klamath River (mean 104 mm). The large sizes of Trinity River smolts likely results from hatchery operations in that basin, which produce larger than average smolts. The range of smolts sizes in the SONCC coho salmon ESU is between 90 and 200 mm (Weitkamp et al. 1995).

SONCC coho salmon have evolved multiple life-history strategies, which encompass a range in timing of outmigration and amount of time spent in the river or estuary by migrating smolts. The earliest outmigration in the SONCC coho salmon ESU occurs in Roach Creek on the Klamath River and Ten Mile Creek on the Eel River (March or earlier). The latest occur in the South Fork of the Eel River (mid-June or later). Because of this, the Eel River has the broadest range of outmigrant timing (March to August; Weitkamp et al. 1995).

### 1.9.3 Ocean Migration

Early ocean migration patterns of young coho salmon have been described in a number of studies (e.g., Weitkamp et al. 1995, Weitkamp et al. 2004, Van Doornik et al. 2007). By the beginning of their first winter at sea, coho salmon begin to move into feeding grounds. Studies using coded wire tags (CWT) have shown that this dispersal at sea is regionally specific, with coho salmon from northern California and Oregon south of Cape Blanco dispersing locally (Weitkamp and Neely 2002). These fish were recovered primarily in California (65 to 92 percent), with some recoveries in Oregon (7 to 34 percent) and almost none (<1 percent) further north. Compared with other coho salmon populations, the SONCC coho salmon ESU has a comparatively small marine distribution. Coho salmon occur in the upper part of the water column in the open ocean, at observed depths of from about 10 to 25 m (summarized by Quinn 2005).

One potential reason SONCC coho salmon do not move farther north is the productivity associated with upwelling areas off the coast of California, which provide high densities of food (Moyle 2002). When they first enter coastal areas, coho salmon feed primarily on marine invertebrates; as they grow larger, they shift to more piscivorous diets (Shapovalov and Taft 1954). Coho salmon feed opportunistically on a variety of prey including small pelagic fishes, shrimp, crab and crab larvae, and other pelagic invertebrates (Sandercock 1991). Growth associated with feeding opportunities at sea is rapid and most fish can double their length and increase their weight more than tenfold their first summer.

While there are many opportunities for growth at sea, coho salmon experience high predation pressures and steep mortality. Studies of smolt-to-adult survival place estimates between 1 percent and 10 percent with the greatest mortality during the first summer at sea. Factors such as size, physiological condition, migration date, and ocean conditions can all influence mortality, and under optimum conditions survival can be as high as 40 percent (Sandercock 1991). In addition to ocean entry timing as a factor influencing survival (as discussed above), size is also important in minimizing mortality since much of the predation that occurs at sea is size-selective (McGurk 1996, Shapovalov and Taft 1954). Generally, small fish have higher mortality rates than larger fish up until about 100 mm (Koenings et al. 1993). Predation is thought to be an important cause of mortality on smaller fish in their first year at sea and has less of an impact on adult populations.

### 1.9.4 Maturation

The growth and survival of adult coho salmon is closely linked to marine productivity, which is controlled by complex physical and biological processes that are highly dynamic and vary greatly over space and time. Shifts in salmon abundance due to climatic variation are known to be large and sudden (Beamish et al. 1999). Short and long-term cycles in climate [e.g., El Niño/La Niña and the Pacific Decadal Oscillation] are thought to affect adult coho salmon size, abundance, and distribution at sea, as does inherent year-to-year variation in environmental conditions not associated with climatic cycles. Several studies have related ocean conditions specifically to coho salmon production (Cole 2000), survival (Ryding and Skalski 1999, Koslow et al. 2002), and spatial and temporal patterns of survival and body size (Hobday and Boehlert 2001, Wells et al. 2006). The link between survival and climate could be operating via the availability of nutrients regulating the food supply and hence competition for food (Beamish and Mahnken 2001). For example, the 1983 El Niño event off the Pacific coast of North America resulted in increased adult mortality and decreased average size for Oregon's returning coho salmon. Juvenile coho salmon entering the ocean in the spring of 1983 also had low survival, resulting in low adult returns in 1984 (Johnson 1988). Larger-scale decadal to multi-decadal events also have been shown to affect ocean productivity and coho salmon (Hare and Francis 1995; Mantua et al. 1997; Beamish et al. 1997a; Beamish et al. 1999; Pearcy 1992; Lawson 1993). Although salmon evolved in this variable environment and are well suited to withstand climactic changes, the resiliency of the adult population has been reduced by the loss of life-history diversity, lower population abundance, cohort loss, and fragmentation of the spatial population structure. Changes in the freshwater environment (e.g., loss and degradation of habitat) have also weakened the ability of coho salmon to respond to the natural variability in ocean conditions.

The age composition and size of coho salmon at maturity is influenced by a number of factors including growth rate, sex, origin (either hatchery or wild and population), and genetic makeup (Quinn 2005). Due to variation in these factors, coho salmon exhibit a range of ages and sizes at maturation. The most common life-history strategy for coho salmon in the SONCC coho salmon ESU is a fairly strict 3-year life cycle, with most coho salmon spending approximately 18 months at sea before returning to their natal rearing grounds to spawn (Gilbert 1912, Briggs 1953, Shapovalov and Taft 1954, Loeffel and Wendler 1968, Weitkamp et al. 1995). The most recent data show that the average size of returning adults in Oregon and California is between 56.4 and 64.6 cm (average 62.7). Variations to this life-history do exist and some fish return after only 5 to 7 months at sea. These "jacks" that return early keep runs from being genetically isolated based on a strict 3-year return year. In general, coho salmon that migrate earlier than average and at a size larger than average are believed to produce a higher rate of jack returns (Bilton et al. 1984). Studies have shown highly variable numbers of returning jacks to Oregon and California streams, possibly due to the influence of hatchery fish. Jacks in the Klamath River made up to 97 percent of returns in one year between 1984 and 1987 (average 59 percent) (Hopelain 2001). Other studies have shown the jacking rate ranges from 7 percent to 34 percent (e.g., Murphy 1952).

The size of coho salmon when they reach maturity also exhibits spatial and temporal variability along with the age at maturity. Size is dependent on factors related to growth and genetic heritage with the sex, origin, age, and run timing all influencing the size of a fish when it reaches maturity. In general, coho salmon in later runs tend to be larger than those in earlier runs (Sandercock 1991), coho salmon from mainstem areas are often larger than those spawning in tributaries (Lister et al. 1981), males tend to be larger than females, and older fish are larger than younger fish. Of available data from southern Oregon and northern California streams and rivers, the smallest spawners tend to come from the Rogue River (average 56 cm between 1976 to 1986) and the largest tend to come from Redwood Creek (average 76.1 cm between 1950 to 1951). The range for this area is between 30 and 91 cm (Weitkamp et al. 1995).

One overall trend across the range of coho salmon is the observed decrease in size of mature fish over the past 50 years. Harvest practices, effects of fish culture, declining ocean productivity, and density-dependent effects in the marine and freshwater environments attributable to large numbers of hatchery releases are potential factors leading to this decline. Weitkamp et al. (1995) noted that the rate of this decline are population, or area, specific with the highest rates of decline in Oregon and California being observed in Rogue River spawners (Slope = -1.50). The CA and OR troll data on coho size also supports a regional decline in size (Slope = -0.05). In the few creeks within the SONCC coho salmon ESU with historical and current data for comparison, average declines averaged between 1.1 and 4.2 cm per decade. These declines in adult size have direct implications for individual reproductive success and population viability because smaller spawners have lower fecundity.

### 1.9.5 Homeward Migration and Spawning

Timing and location of reproduction are two of the most critical adaptations salmon populations make to their environment. Salmon are uniquely evolved in their ability to take advantage of feeding and growth opportunities at sea and optimal spawning conditions in freshwater streams and rivers. Once a salmon starts the process of maturation, it begins a homeward migration to the location in which it was spawned. Once adult coho salmon reach nearshore and estuarine waters they are able to use imprinted chemical cues to help guide them. Imprinting in fry occurs shortly after emergence and is based on stream-specific or population-specific characteristics of their natal stream.

About 95 to 99 percent of all salmon return to their natal stream using these imprinted cues, however a small percentage (the magnitude of which varies temporally and by population) are “strays,” meaning they spawn in streams they were not born in (Quinn 2005). Whether this characteristic of adult coho salmon is genetically, behaviorally, or environmentally influenced is unknown, but ultimately the occurrence of straying contributes to the persistence and distribution of populations and the entire ESU. As a general rule, straying is linked to the stability and degree of specialization of a population or its spawning habitat. Populations occupying “flashy” or steep, unstable coastal streams are more likely to exhibit non-natal rearing as are small coastal streams that require little or no specialization for spawning. Information on straying rates for coho salmon in California is sparse, but Shapovalov and Taft (1954) reported values between 15 percent and 27 percent for Scott and Waddell Creek. Other genetic studies of California coho salmon populations show differences among populations that suggest lower effective straying rates. Fish that do stray are most commonly found in spawning areas near their natal stream (Shapovalov and Taft 1954, Jacobs 1988, Labelle 1992).

Upriver migration of adults to spawning areas normally occurs from October to March for populations in the SONCC coho salmon ESU, with a peak between November and January. For most populations, the duration of spawning migration is at least three months or more. Coho salmon river entry timing is influenced by many environmental and genetic factors, the most important of which is river flow (Shapovalov and Taft 1954, Salo and Bayliff 1958, Sumner 1953, Eames et al. 1981, Lister et al. 1981). Coho salmon generally wait for freshets before entering rivers, so a delay in fall rains delays river entry and, potentially, spawn timing as well. Many of the small coastal streams in California are barred over by sand at their mouths, and coho salmon in these streams have to wait to ascend until the sand barriers are breached by high stream flows that follow heavy winter rains. Once a fish enters a river, if conditions in the stream are unsuitable for entry, fish will often wait (or "hold") in the vicinity of the stream mouth for conditions to change, usually marked by a decreasing temperature and increasing flow. This holding allows coho salmon to reach further into headwater streams where good spawning and rearing conditions may exist.

Because of the influence of environmental drivers, run timing shows considerable spatial and temporal variability. Large river systems are especially diverse in terms of coho salmon run timing. For example coho salmon runs in the Klamath River can last over four months with various populations entering the system from late August to mid-January (Washington Department of Fisheries (WDF) 1951, Leidy and Leidy 1984, WDF et al. 1993, Polos 1994). In terms of large-scale spatial patterns in run timing, Weitkamp et al. (1995) found some regional patterns that define the SONCC coho salmon ESU. Coho populations in southern Oregon and northern California tend to have later run timing than population to the north. There also appears to be a wider range of timing, with some runs starting in late August (Klamath) and most lasting into mid-February.

Once conditions are favorable, adult coho salmon migrate into spawning areas along the coast and in small tributaries of larger rivers. Coho salmon migrate further upstream than chum salmon but not usually as far as Chinook. In general, coho spawning grounds are within 240 km of the coast (Godfrey 1965). Large river systems like the Klamath, Trinity, Eel, and Rogue Rivers historically supported coho salmon in their upper tributaries (Williams et al. 2006). Once adult fish reach the spawning grounds, they can spend days, weeks, or months waiting to spawn. During this time salmon are subject to predation and disease prior to spawning.

This page intentionally left blank.

# 2. Structure, Viability, and Status of the SONCC Coho Salmon ESU

The SONCC coho salmon ESU must meet the criteria described in Chapter 4 for NMFS to determine it has recovered to the extent that the protections of the Federal Endangered Species Act could be removed,. Chapter 2 describes the underpinnings of these population-related criteria. These criteria are based on guidance provided in two NOAA Technical Memoranda, which describe the historical population structure and biological viability criteria, respectively, for the SONCC coho salmon ESU (Williams et al. 2006, Williams et al. 2008).

## 2.1 Intrinsic Potential

### 2.1.1 Modeling Intrinsic Potential of Historical Habitats

Spawner abundance serves as an important indicator of viability and extinction risk, and for salmon it is heavily influenced by the extent and quality of available freshwater habitat. An estimate of historical habitat carrying capacity can serve as an indirect means of estimating the number of adults needed to reach viability. Because of degraded current freshwater habitat conditions, which often differ from historical conditions, recovery planners need a method that estimates the extent and capacity of watersheds to support coho salmon prior to the major anthropogenic impacts to habitat which began in the mid-1800s. Williams et al. (2006) characterized the historical extent and carrying capacity of SONCC coho salmon streams by using a GIS-based model. This “IP” model “…predicts the potential for a stream reach to exhibit habitat characteristics suitable for rearing juvenile coho salmon, as a function of the underlying geomorphic and hydrologic characteristics of the landscape (Williams et al. 2006).” The IP model provides recovery planners with a framework to develop a recovery strategy for the SONCC coho salmon ESU.

To account for differences in habitat suitability across the landscape, three habitat components were modeled to serve as predictors of historical habitat suitability (Figure 2-1): stream gradient, valley constraint, and average annual discharge (based on catchment area and localized precipitation data). For each stream reach (50-200 m) in the SONCC coho salmon ESU, each of the three attributes was scored from zero to one and the geometric mean of the scores was calculated. A score of one indicates reaches with the most intrinsic potential to support rearing juvenile coho salmon, and a score of zero indicates areas with no such potential. For example, a narrow and steep stream reach with little predicted flow has low potential to support quality rearing habitat and would likely score close to zero, while a low-gradient stream with a bigger floodplain and more predicted flow has more potential to support quality rearing habitat and would score closer to one. The IP score for each reach in a population area was multiplied by its respective reach length and the values for each reach in a population were added to identify the total integrated IP in kilometers (km) for that population (Figure 2-2). The number of IP-km in a population was used to classify each population (Williams et al. 2006) and to calculate spawner abundance targets (Williams et al. 2008).

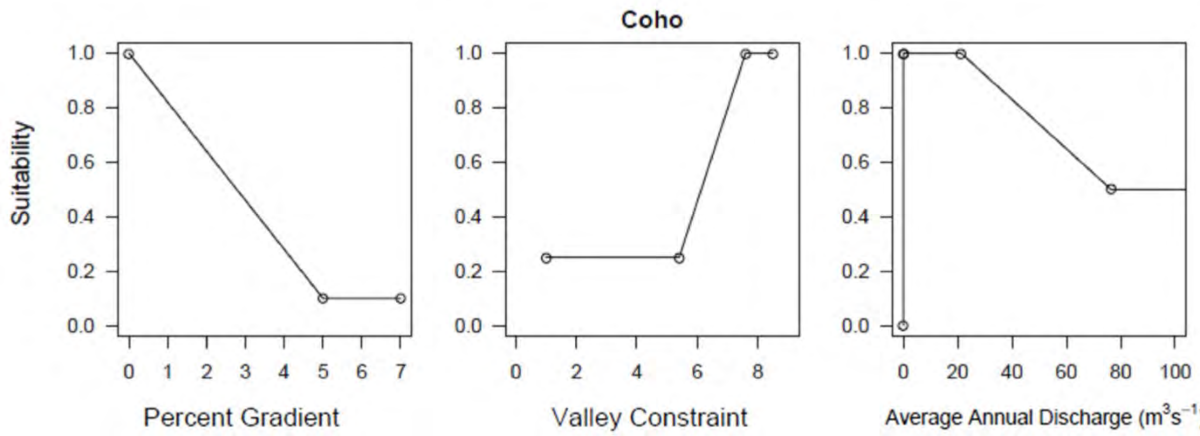
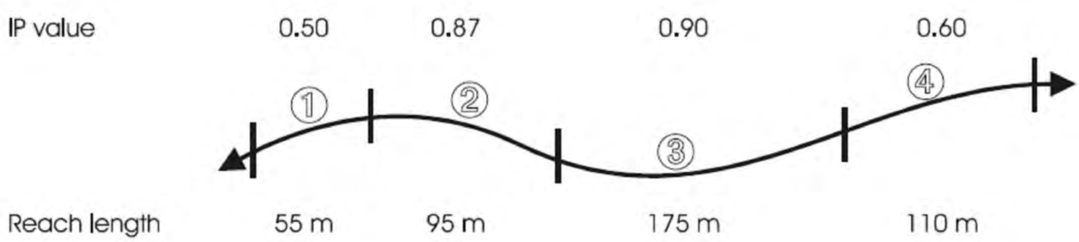



Figure 2-1. Suitability curves for each of the three IP components (Gradient, Valley Constraint, and Discharge). Source: Agrawal et al. 2005.




| No. | Reach length (m) | IP value | Integrated IP (IP m) |
|---|---|---|---|
| 1 | 55 | 0.50 | 27.5 |
| 2 | 95 | 0.87 | 82.65 |
| 3 | 175 | 0.90 | 157.50 |
| 4 | 110 | 0.60 | 66.00 |
| Total | 435 | - | 333.65 |

Figure 2-2. Calculation of integrated intrinsic potential (IP) from reach-specific IP values. Source: Williams et al. 2006.

Summer water temperatures in the interior portions of some large drainages in the ESU (i.e., Rogue, Klamath, Trinity, and Eel rivers) can approach or exceed the tolerable limits for juvenile coho salmon (Eaton et al. 1995). Where this occurs, temperature might preclude coho salmon from using areas that, based on geomorphic and hydrologic characteristics, would otherwise be suitable. Comprehensive data on water temperatures were not available for the ESU, and the available water temperature data was likely influenced by land-use practices that altered temperature regimes in comparison to historical conditions. Therefore, to identify areas where temperature might limit the distribution of coho salmon, Williams et al. (2006) combined information on the historical distribution of coho salmon and mean August air temperature to identify a threshold temperature above which juvenile coho salmon generally do not occur. This analysis found that coho salmon were rarely reported as present in watersheds where the lowest mean August air temperature in the basin exceeded 21.5 °C (Agrawal et al. 2005); this temperature is comparable to the maximum tolerable water temperature for coho salmon reported by Eaton et al. (1995). Therefore, a 21.5 °C threshold (i.e., temperature mask was used to modify results from the IP model by identifying IP-km in areas where coho salmon are likely to be excluded by warm temperature, and excluding these IP-kms from calculation of spawner targets.

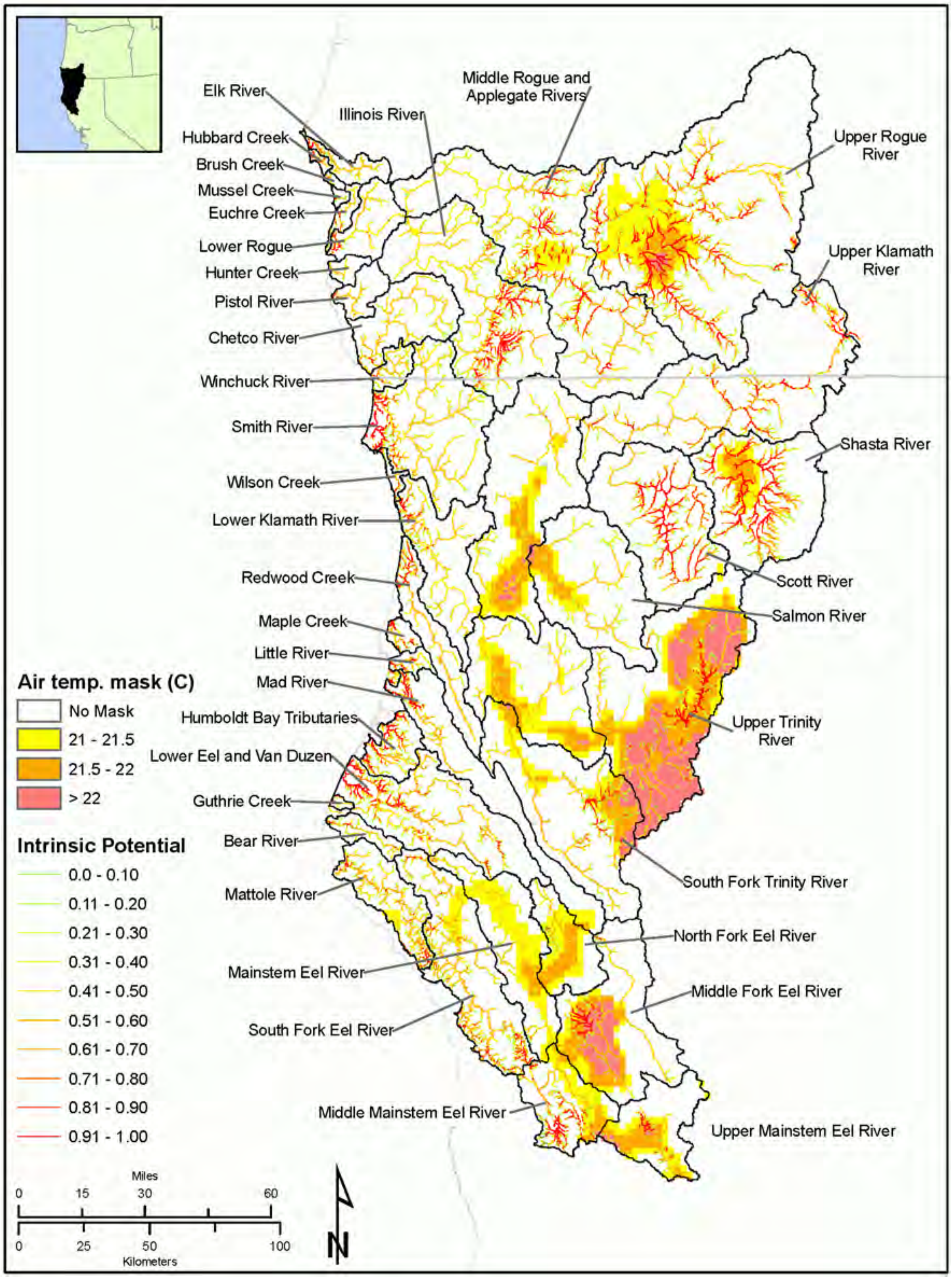



Figure 2-3. Intrinsic Potential for coho salmon across the SONCC Coho Salmon ESU, including areas where coho salmon are likely to be excluded by warm temperature indicated by temperature mask (from Williams et al. 2006).

### 2.1.2 IP Model Assumptions and Uncertainty

Williams et al.'s (2006) use of the IP model to identify potentially suitable coho salmon habitat rests on two assumptions. The first assumption is that the suitability curves (Figure 2-1), which translate geomorphic and hydrologic characteristics into IP, apply to watersheds in the SONCC Coho Salmon ESU as they do for the Oregon Coast Range where the model was originally developed. Williams et al. (2006) lacked local data from which to develop region-specific suitability curves and therefore "…assumed that either the suitability curves based on data from the Oregon Coast Range applied to watersheds in southern Oregon and northern California, or that the relationship between watershed characteristics and habitat potential throughout the SONCC Coho Salmon ESU differed from that observed in Oregon in a uniform and consistent way." An extensive literature search provided no basis for choosing alternative suitability curves for the SONCC coho salmon ESU (Agrawal et al. 2005).

The second assumption was that differences in geomorphic structure and processes between the Oregon Coast Range and the SONCC Coho Salmon ESU, although present, do not require modification of the IP components (gradient, discharge, valley-width constraint) (Williams et al. 2006). One of the most substantial differences among coastal watersheds in Oregon and California could be the amount and timing of precipitation, especially as one moves south along the coast (Williams et al. 2006). Williams et al. (2006) attempted to account for this variation by estimating regional models for mean annual discharge as a function of catchment area and mean annual precipitation (Agrawal et al. 2005). The relationships estimated for coastal watersheds north of Cape Mendocino were almost identical to that reported for coastal Oregon watersheds. Following an extensive literature search, Williams et al. (2006) found little to suggest the need to modify the IP components calculated for the Oregon Coast Range before using them for the SONCC Coho Salmon ESU.

NMFS is aware that the modeling approach used to estimate historical capacity of a stream reach may result in estimates that can be biased (i.e., can under- or over-estimate historical capacity). Recently updated coho salmon distribution datasets (Garwood 2012 and Bowers 2013) report documented coho salmon presence extending upstream of IP habitat in several populations. For example, coho salmon are distributed in the lower 8.4 miles of Bluff Creek in the Middle Klamath, none of which was identified as IP. Conversely, habitat believed to be unsuitable for coho salmon due to geologic conditions was modeled as IP habitat (and subsequently removed, see Appendix A) in the Big Springs Complex of the Shasta River (Appendix A). Recent research in Oregon (Steel et al. 2012, Flitcroft et al. 2013a) identified IP as a significant predictor of coho distribution for areas that support a large number of fish. The IP model as a whole provides the best available scientific information on the historical population structure of the ESU and on appropriate targets for a recovered SONCC coho salmon ESU.

IP-based viability criteria are ***not*** estimates of historical abundance. Rather, the criteria describe the number of spawners that are likely to lead to viable populations in terms of abundance and spatial structure. Comparisons of historical abundance estimates and IP model-driven density-based abundance targets for coastal watersheds in Oregon and the South Fork Eel River in California suggest that the methods used in Williams et al. (2006) do not overestimate the historical carrying capacities of coho salmon populations. In all instances, the target abundance is between 3% and 12% of the estimated historical abundance. As ESU- and population-specific research and monitoring occur, changes to the model and the resulting population thresholds could be warranted (Williams et al. 2008), and the recovery plan will be updated with the best available information.

NMFS acknowledges there is uncertainty regarding the IP model's ability to predict the potential of habitat to support rearing SONCC coho salmon. Several co-managers and members of the public have expressed concern that the IP model likely over-estimates the potential of particular streams, and that the use of the IP model to develop spawner targets in particular populations is not appropriate. The IP model and associated habitat suitability curves, temperature mask, and spawner density criteria provide an initial framework for recovery planners that can be adjusted or replaced as the best available information relevant to SONCC coho salmon habitat utilization and viability parameters improves over time. For example, if new research demonstrates SONCC coho salmon can tolerate higher temperatures than current information suggests, NMFS may update the temperature mask. Additionally, if new information suggests spatial structure and diversity needs of SONCC coho salmon can be realized at lower spawner densities than this Plan currently requires, NMFS may update the spawner density criteria.

IP habitat should not be confused or associated with modeled critical habitat. IP habitat is identified using a coarse-scale model which is one of many tools one can use to estimate the current or historical extent of anadromy. Although a useful tool to visualize the estimated historical range of SONCC coho salmon, other approaches can be used to provide greater insight into the possible presence of migration barriers. The IP model depends on appropriate and accurate Digital Elevation Models (DEM) which are subject to improvement (i.e., finer resolution) or refinement/corrections (e.g., a road crossing with culvert may appear as a natural barrier in DEM). Modeled IP habitat lacks the precision needed to determine whether a specific reach meets the description of designated critical habitat for the SONCC coho salmon ESU "to include all river reaches accessible to listed coho salmon between Cape Blanco, Oregon and Punta Gorda, California" (50 CFR 226.210(b)). Therefore, alterations to the extent of modeled IP habitat for use in this Plan, such as removal of IP habitat above a probable natural barrier, would not necessarily modify designated critical habitat for the SONCC coho salmon ESU.

#### Oregon Department of Fish and Wildlife concerns with recovery framework

The Oregon Department of Fish and Wildlife (ODFW) has concerns that the methods used to produce Williams et al. (2006) may overestimate the extent of historical coho production in the populations within the Northern Coastal and Interior Rogue diversity strata. Further, ODFW believes these methods may have led to inaccurate characterizations of historical populations as larger than they likely were. Finally, ODFW believes the low-risk targets for core populations may not need to be achieved if the other 3 VSP criteria are being met. This has been identified as a critical research need in Chapter 5 and NMFS intends to work with partners to reevaluate the population structure, and associated recovery criteria, within the Northern Coastal and Interior Rogue diversity strata as part of a conservation planning process. ODFW is in general agreement with NMFS on the recovery actions needed for Oregon populations, including a recovery action (present in all populations) that calls for refinement of the methods used to delineate populations and set population targets.

## 2.2 Historical Structure and Function of the ESU

### 2.2.1 Classifying Populations

Williams et al. (2006) describes the population structure of SONCC coho salmon based on the location and amount of potential coho salmon habitat and identifies all the populations in the ESU and their demographic characteristics. A population is defined as a group of fish of the same species that spawns in a particular location at a particular season and does not interbreed substantially with fish from any other group (McElhany et al. 2000). An integral element of determining the historical population structure for the ESU was estimating the distribution of potential juvenile rearing habitat within each basin. This was accomplished using both historical records and the IP model (Williams et al. 2008).

Watersheds across the ESU vary greatly in size. Large basins, such as the Klamath River watershed, support multiple populations because they contain several large rivers or streams which vary in terms of their environmental conditions and each support populations. Small watersheds probably did not historically support viable populations, but are not necessarily a part of a larger population. In the development of the historical population structure, Williams et al. (2006) recognized the full range of coho salmon habitat in the SONCC coho salmon ESU.

Williams et al. (2006) adopted a population classification system based on two factors: self-recruitment and viability-in-isolation. Self-recruitment reflects the proportion of a population's spawners that are native (not strays), and is a function of the size of the population, the size of potential donor populations, and the distance between populations. Viability-in-isolation is based on the probability of extinction for a population in complete isolation from all other populations. A population that has a low (<5%) probability of extinction over 100 years would be viable-in-isolation. Viability-in-isolation is assessed as a function of population size using IP-km as a proxy.

Williams et al. (2006) treated self-recruitment and viability-in-isolation as two axes, resulting in four types of historical populations depending on the estimated values of these two factors (Figure 2-4).

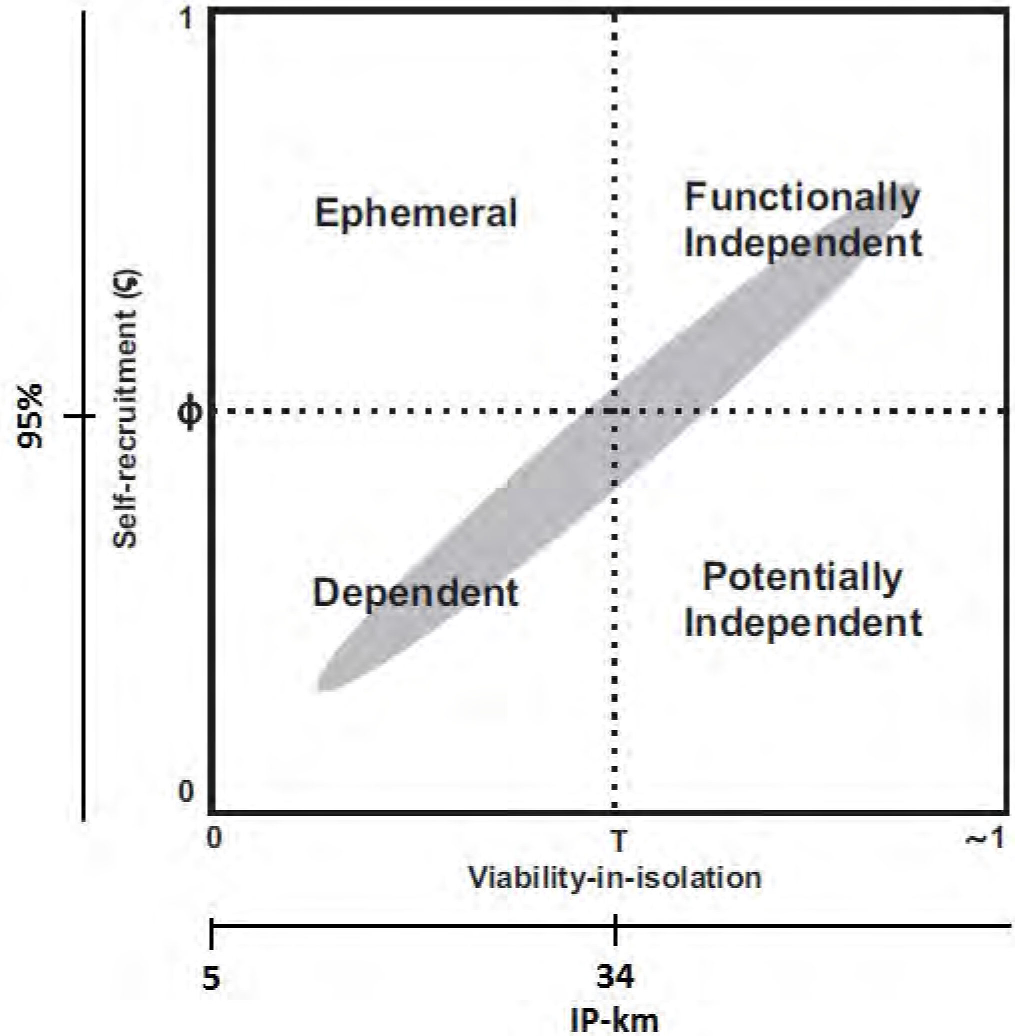



Figure 2-4. Population type as a function of viability-in-isolation and self-recruitment. Figure modified from Williams et al. (2006).

Those populations that are viable-in-isolation are potentially or functionally independent populations. Those which are not viable-in-isolation are either dependent or ephemeral. The boundary between independent and dependent populations is determined by the habitat capacity [estimated using IP-km]), below which there is a low likelihood of a population persisting without migrants from other populations. Populations that have at least 5 but less than 34 IP-km have relatively lower viability-in-isolation and are designated as dependent if they have less than 95 percent fidelity (0.95 self-recruitment) or ephemeral if they have more than 95 percent fidelity. Basins with less than 5 IP-km are not recognized as populations. Independent populations that have 95 percent fidelity (0.95 self-recruitment) are designated as functionally independent, while populations that have less than 95 percent fidelity are potentially independent. Williams et al. (2006) describes in detail the values assigned to each population.

Although Williams et al. (2006) recognized 45 populations in the ESU, due to subsequent modifications to the IP-km for several populations, and exclusion of populations that are too small to be dependent, this recovery plan considers 40 populations. Modifications to IP are described in Appendix A.

The type of each population is as follows:

*Functionally Independent Populations* are those with a high likelihood of persisting in isolation over a 100-year time scale and are not substantially altered by exchanges of individuals with other populations.

*Potentially Independent Populations* have a high likelihood of persisting in isolation over a 100-year time scale, but are too strongly influenced by immigration from other populations to exhibit independent dynamics.

*Dependent Populations* have a substantial likelihood of going extinct within a 100-year time period in isolation, yet receive sufficient immigration to alter their dynamics and extinction risk, and presumably increase persistence or occupancy.

*Ephemeral Populations*[3] do not have a high likelihood of sustaining themselves over a 100-year time period in isolation, and do not receive sufficient immigration to affect this likelihood. Habitats that support such populations are expected to be occupied only rarely. This type of population is not included in this recovery plan and is not considered further.

Dependent populations, although not expected to persist in the long-term (100 years) without strays from other populations, serve at least two roles within an ESU (Williams et al. 2006). If an independent population is extirpated, dependent populations can provide a nearby source of colonists to repopulate the area. Dependent populations are also critically important for bridging spatial gaps to allow dispersal of spawners between independent populations, and so increase connectivity.

### 2.2.2 Grouping Populations into Diversity Strata

Williams et al. (2006) separated populations into seven diversity strata. Populations in each diversity stratum likely exhibit genotypic and phenotypic similarity to each other due to exposure to similar environmental conditions, common evolutionary history, and location relative to each other (Table 2-1; Williams et al. 2006). Figure 2-5 shows the historical structure and function of the SONCC coho salmon ESU as described in Williams et al. (2006).

[3] Ephemeral populations were not considered when developing the recovery strategy for SONCC coho salmon described in this recovery plan and will not be discussed further.

Table 2-1. Arrangement of historical populations of the SONCC coho salmon ESU. Population types are functionally independent (F), potentially independent (P), and dependent (D).

| Diversity Stratum | Population Type | Population Unit |
|---|---|---|
| Northern Coastal Basins | F | Elk River |
| | P | Lower Rogue River |
| | F | Chetco River |
| | P | Winchuck River |
| | D | Brush Creek |
| | D | Mussel Creek |
| | D | Hunter Creek |
| | D | Pistol River |
| Central Coastal Basins | F | Smith River |
| | F | Lower Klamath River |
| | F | Redwood Creek |
| | D | Maple Creek/Big Lagoon |
| | P | Little River |
| | F | Mad River |
| | D | Elk Creek |
| | D | Wilson Creek |
| | D | Strawberry Creek |
| | D | Norton/Widow White |
| Southern Coastal Basins | F | Humboldt Bay Tributaries |
| | F | Low. Eel/Van Duzen Rivers |
| | P | Bear River |
| | F | Mattole River |
| | D | Guthrie Creek |
| Interior Rogue River | F | Illinois River |
| | F | Mid. Rogue/Applegate Rivers |
| | F | Upper Rogue River |
| Interior Klamath River | P | Middle Klamath River |
| | F | Upper Klamath River |
| | P | Salmon River |
| | F | Scott River |
| | F | Shasta River |
| Interior Trinity River | F | South Fork Trinity River |
| | P | Lower Trinity River |
| | F | Upper Trinity River |
| Interior Eel River | F | South Fork Eel River |
| | P | Mainstem Eel River |
| | P | North Fork Eel River |
| | P | Mid. Fork Eel River |
| | F | Mid. Mainstem Eel River |
| | P | Upper Mainstem Eel River |

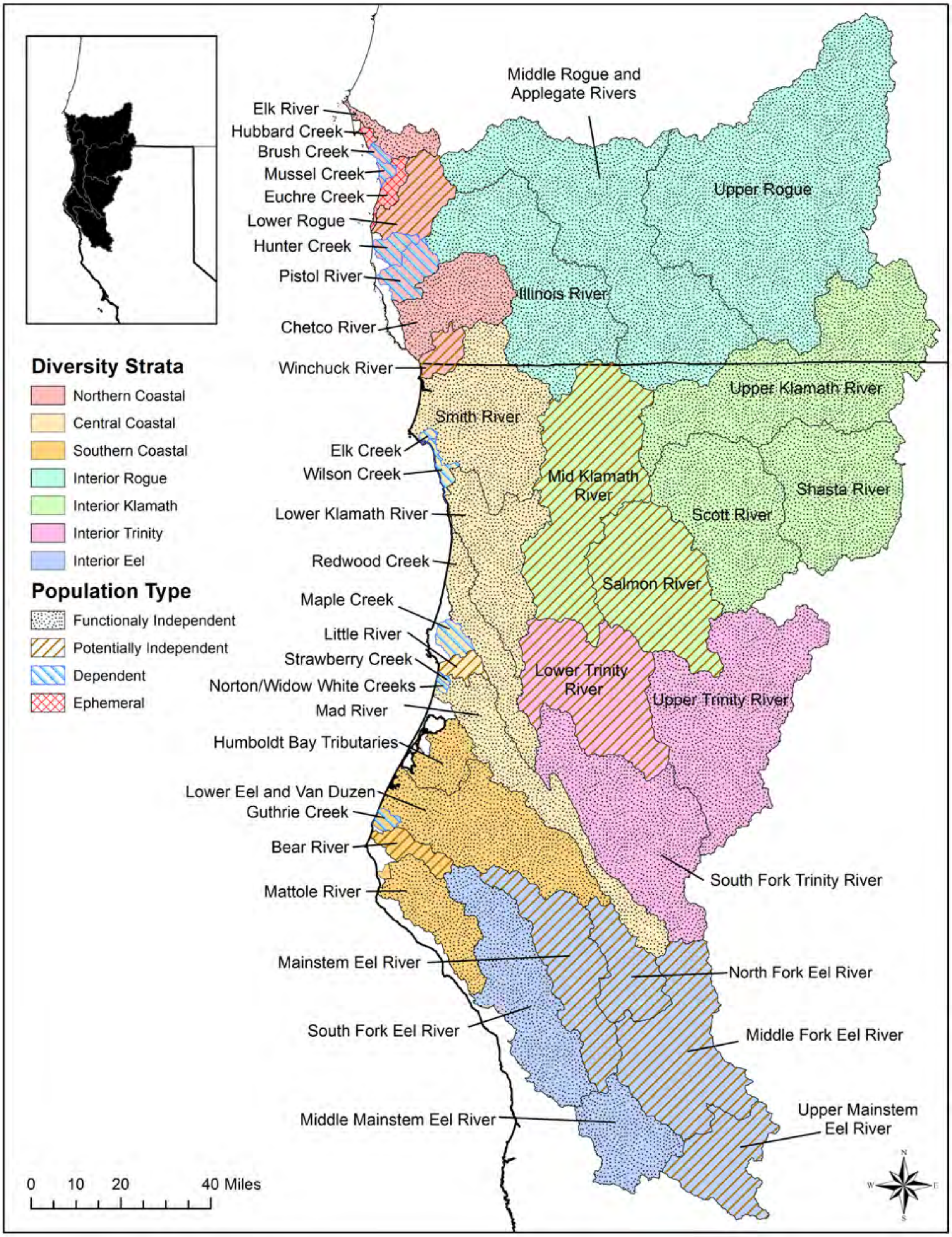



Figure 2-5. Historical population structure of the SONCC coho salmon ESU, as described in Williams et al. (2006).

## 2.3 Viability Criteria

Viability is the likelihood that a population will sustain itself over a 100-year time frame (McElhany et al. 2000). Viability criteria are the means by which a viable ESU is defined, and by which extinction risk is evaluated. Viability criteria are used to develop the delisting criteria described in Chapter 4.

### 2.3.1 ESU

The viability of an ESU depends on several factors, including the number and status of populations, spatial distribution of populations, the characteristics of large-scale catastrophic risk, and the collective diversity of the populations and their habitat (Lindley et al. 2007). In order for the SONCC coho salmon ESU to be viable, in each diversity stratum at least 50 percent of the independent populations (i.e., Functionally Independent or Potentially Independent) must be viable, and the abundance of these viable independent populations collectively must make up at least 50 percent of the total abundance modeled for all of the independent populations in that stratum (Williams et al. 2008). The independent populations that are chosen to meet the population viability criteria are called “core.” NMFS’ rationale for its choice of core populations is explained in Appendix C and is based on NMFS’ assessment of which populations are most likely to achieve those criteria most quickly. Many recovery scenarios with different core populations could result in a recovered ESU. Based on new information about population status or habitat conditions, NMFS’ designation of core and non-core populations may change to achieve recovery more quickly or efficiently. Although not all populations are required to be viable, the ESU viability criteria are intended to ensure representation of the diversity throughout the ESU, buffer the ESU against potential catastrophic risks, and provide sufficient connectivity among populations to maintain long-term demographic and genetic processes.

The ESU viability criteria incorporate the principles of representation, redundancy, and connectivity (Table 2-2). Representation relates to the genetic and life-history diversity of the ESU, which is needed to conserve its adaptive capacity. Redundancy addresses the need to have a sufficient number of populations so the ESU can withstand catastrophic events (Williams et al. 2008). Connectivity refers to the dispersal capacity of populations to maintain long-term demographic and genetic processes. The overarching goal of these rules was to determine an appropriate number and arrangement of populations that allow populations to track changes in environmental conditions (Williams et al. 2008).

Table 2-2. ESU viability criteria for SONCC coho salmon. Source: Williams et al. 2008.

| ESU Viability Characteristic | Criteria |
|---|---|
| Representation | 1. All diversity strata should be represented by viable populations |
| Redundancy and Connectivity | 2. a) At least fifty percent of historically independent populations in each diversity stratum should be demonstrated to be at low risk of extinction according to the population viability criteria.<br>AND<br><br>2. b) Total aggregate abundance of the populations selected to satisfy 2a must meet or exceed 50% of the aggregate viable population abundance predicted for the stratum based on the spawner density.<br><br>3. All dependent and independent populations not expected to meet low-risk threshold within a stratum should exhibit occupancy indicating sufficient immigration is occurring from the “core populations”.<br><br>4. The distribution of extant populations, both dependent and independent, needs to maintain connectivity across the stratum as well as with adjacent strata. |

Williams et al. (2008) writes about Criterion 3 (Table 2-2): “We propose that recovery planners place a high priority on populations that are remnants of historically independent populations **with a minimum standard that most historically independent populations should be at no greater than moderate risk of extinction (i.e., not at high risk) when evaluated as independent populations** [Emphasis added]”. This recommendation would require a higher standard for occupancy than just presence of individuals. It should be recognized that these independent populations no longer fulfill their historical role within the ESU, but they can play a critical role in connectivity and have the potential for representing critical components of the evolutionary legacy of the ESU.”

The depensation threshold is the number of spawning adults below which a population is subject to depensatory effects such as not being able to find a mate, or having all adults eaten by predators before they can reproduce. To meet Williams’ recommendation above, most non-core independent populations would be at moderate (not high) risk of extinction in a recovered ESU and so would consistently have more spawners than the depensation threshold (Table 2-3). These populations are called “Non-Core 1”. “Non-Core 2” populations were identified in response to the requirement that “most” (not all) independent populations should be at moderate risk of extinction, which allows that some independent populations do not need to be either at moderate risk or low risk. For some independent populations, there is little to no documentation of coho salmon presence in the last century, and prospects are low for the population to recover to numbers at least four spawners per IP-km. These populations are categorized as Non-Core 2 populations, and so have a lower threshold (juvenile occupancy) than if they were Non-Core 1 populations. This threshold is the same as for dependent populations: these populations should exhibit occupancy patterns that indicate sufficient emigration is occurring from the core populations, in order to maintain connectivity within and among diversity strata (Table 2-2).

### 2.3.2 Population

Williams et al. (2008) builds on the Viable Salmonid Population (VSP) concept (McElhany et al. 2000) to establish viability criteria at the population and ESU level. The population viability criteria represent an extension of an approach developed by Allendorf et al. (1997), and include metrics related to population abundance (effective population size), population decline, catastrophic decline, spawner density, hatchery influence, and population viability assessment. Populations that fail to satisfy several viability metrics are likely at greater risk than those that fail to satisfy a single metric. A viable population must have a low extinction risk for all the population metrics (Table 2-3). For a population to be at moderate risk of extinction, it must meet the moderate risk description for each of the criteria shown in Table 2-3. To align with the ESU viability criteria described in Table 2-2, NMFS identified four population categories with different targets based on their role in meeting these criteria. Core populations are those needed to meet Criteria 2a and 2b in Table 2-2. These populations must be at low risk of extinction, or viable, in order to delist. Non-Core 1 populations are those independent populations needed to meet Criterion 3, and should be at no greater than moderate risk of extinction for the ESU to be viable. Non-Core 2 populations are those independent populations that may be at higher than moderate risk of extinction in a recovered ESU, because there is no evidence they supported coho salmon, or because the amount of IP habitat in them is very low. Non-Core 2 and Dependent populations must meet Criterion 3 for the ESU to be viable. Non-Core 2 populations and dependent populations have no target extinction risk.

Table 2-3. Viability criteria used to assess extinction risk for SONCC coho salmon populations. For a given population, the highest risk score for any category determines the population's overall extinction risk. Source: Williams et al. 2006.

| **Criterion** | **Extinction risk** | | |
|---|---|---|---|
| | High | Moderate | Low |
| | - any One of - | - any One of - | - all of - |
| Effective population size[a] | $N_e \leq 50$ | $50 < N_e < 500$ | $N_e \geq 500$ |
| *- or -* | *- or -* | *- or -* | *- or -* |
| Population size per generation[b] | Ng ≤250 | $250 < N_g < 2500$ | $N_g \geq 2500$ |
| *- or -* | *- or -* | *- or -* | *- or -* |
| Population size per year[b] | *Average* $N_a \leq 83$ | *83 < Average* $N_a < 830$ | *Average* $N_a \geq 830$ |
| Population decline[c] | Precipitous decline[d] | Chronic decline or depression[e] | No decline apparent or probable |
| Catastrophic decline | Order of magnitude decline within one generation | Smaller but significant decline[f] | Not apparent |
| Spawner density (adults/IP-km) | $N_a$*/IP-km* ≤ 1 | 1 < $N_a$*/IP-km* ≥ MRSD[g] | $N_a$*/IP-km* ≥ MRSD[g] |
| Hatchery influence | | | Hatchery fraction <5% |
| *-in addition to above-* | | | |
| Extinction risk from PVA | ≥20% within 20 years | ≥5% within 100 years but <20% within 20 years | <5% within 100 years[h] |

[a] The effective population size ($N_e$) is the number of breeding individuals in an idealized population that would give rise to the same variance in gene frequency under random genetic drift or the same rate of inbreeding as the population under consideration (Wright 1931).
[b] The generation time for coho salmon is approximately three years, therefore the number of spawners per generation $N_g = 3\ N_a$ where $N_a$ is the annual number of spawners.
[c] The population decline criteria require the calculation of two parameters, $N_a$ and the population trend ($T$). Williams et al. (2008) recommends using the geometric mean of the most recent four generations (i.e., 12 years) to estimate annual population abundance, so $N_a$ is equal to the geometric mean of 12 years of spawner abundance.
[d] Population has declined within the last two generations or is projected to decline within the next two generations (if current trends continue) to annual run size of $N_a \leq 500$ spawners (historically small but stable populations not included) or $N_a > 500$ but declining at a rate of ≥10% per year over the last two-to-four generations.[e] Annual spawner abundance $N_a$ has declined to ≤500 spawners, but now stable **or** number of adult spawners ($N_a$) > 500 but continued downward trend is evident.
[f] Annual spawner abundance decline in one generation < 90% but biologically significant (e.g., loss of year class).
[g] MRSD, or minimum required spawner density, is the number adults divided by the amount of IP-km in a population. For high extinction risk, the MRSD is the same number as the depensation threshold.
[h] For populations to be considered at low-risk of extinction, all criteria must be satisfied (i.e., not just a PVA). A population viability analysis (PVA) can also be included for consideration, but must estimate an extinction risk <5% within 100 years *and* all other criteria must be met. If discrepancies exist between PVA results and other criteria, results need to be thoroughly examined and potential limitations of either approach carefully identified and examined.

### The risks of small population size

Population size is extremely important to recovery of species because the time-to-extinction decreases as the population size decreases (Caughley 1994, Fagan and Holmes 2006). This longstanding theoretical prediction and empirically observed phenomenon of small populations (Fagan and Holmes 2006) highlights the importance of keeping currently healthy salmonid populations from reaching low abundance levels. In addition, it adds urgency to recovery efforts for those populations that are depressed. The effects of stochastic pressure due to small population size are discussed in the 2011 status review for SONCC coho salmon (Ly and Ruddy 2011).

Extinction is theorized to occur in stages. In the first phase of extinction, population instability occurs with population abundance fluctuating with a higher than normal amplitude. Anadromous salmonid populations are known to have large swings in abundance that are usually linked to variations in ocean productivity (Northcote and Atagi 1997; also see Chapter 3). This makes identifying the instability stage difficult for fisheries managers because they rarely have sufficient population abundance data with which to distinguish between population instability and natural population variability. In the decline phase there is a sustained period in which death rates exceed birth rates within one or more populations (Figure 2-6). Depending on the robustness of the data and length of the dataset, the decline in the phase may or may not be evident by examining the trend in abundance over time. The collapse phase is characterized by reductions in the number or extent of occurrence of a species. The extent of the occurrence of a species may erode from the edges (i.e., range contraction) or from gaps closer to the center of its range (i.e., fragmentation; Ewers and Didham 2005). In the terminal phase (Figure 2-6), a population is not likely to increase in abundance over any time interval before extinction (Fagan and Holmes 2006). Any increases in abundance are likely to be very short-lived (Fagan and Holmes 2006) and the reproductive success of the population depends on the success of a small number of individuals (Caughley 1994, Fagan and Holmes 2006). The longer a population stays in the small dynamics phase (Figure 2-6), the more likely it will go extinct.

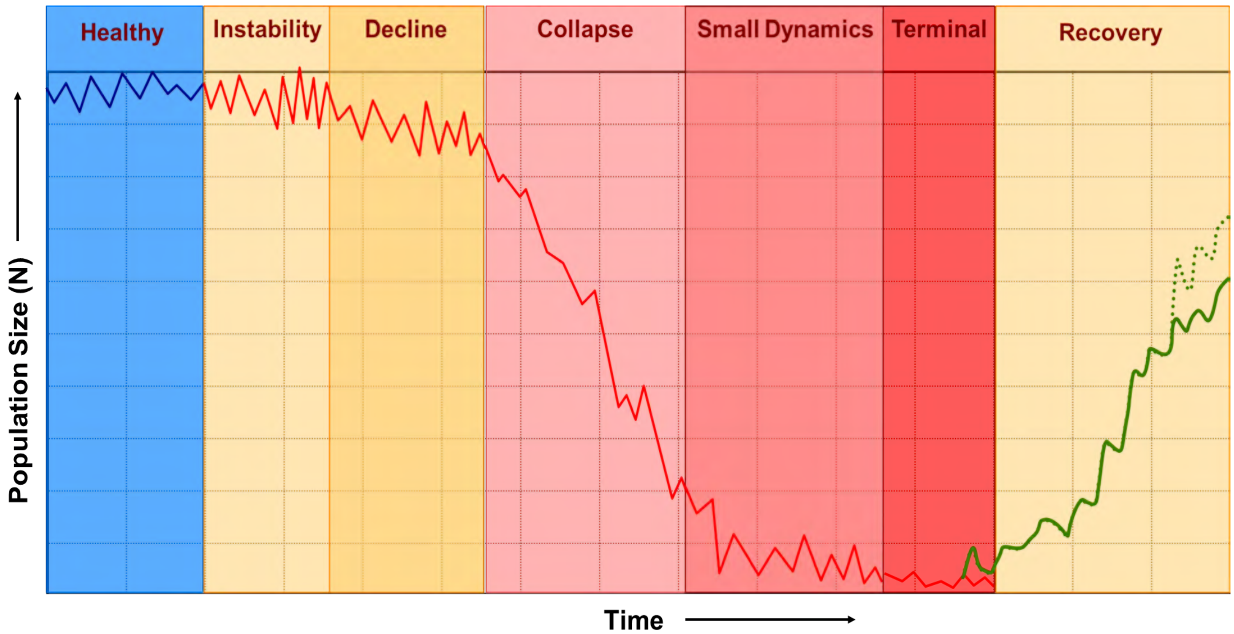



Figure 2-6. Conceptual diagram of the demographic extinction process. Diagram shows the size of a population over time through different stages. In the terminal phase, two possible trajectories for the population are extinction or recovery. Figure adapted from C. Johnson, pers. comm., 2010.

For Snake River coho salmon, which were monitored for 20 years preceding their extinction, the population size at which the final decline began (terminal phase) was 404 individuals (Fagan and Holmes 2006). After the population reached 233, there were no increases in the population in subsequent years, with a final population size preceding extinction of 6 individuals (Fagan and Holmes 2006).

In terms of recovery of small populations (those with fewer individuals than the depensation threshold) of anadromous salmonids, it is important to recognize that these populations are subject to random environmental and demographic changes. This is unlike large populations which are, in general, only subject to environmental stochasticity (Lande 1993). Because small populations can be affected by more than one form of stochasticity, they have a much greater probability of extinction than large populations (Lande 1993, Caughley 1994, Melbourne and Hastings 2008). Once a population enters the small population dynamics phase it is equally important, if not more so (Melbourne and Hastings 2008), to recognize and consider that the population is at a substantial risk of extinction resulting from the demographic factors originating from within the population.

### Depensation Threshold

Population size provides an indication of the type of extinction risk that a population faces. For instance, smaller populations are at a greater risk of extinction than large populations because the processes that affect populations operate differently in small populations than in large populations (McElhany et al. 2000). One risk of low population size is the population effects of depensation. Depensatory effects occur when populations are reduced to very low densities and individual growth rates decrease as a result of a variety of mechanisms [e.g., failure to find mates and therefore reduced probability of fertilization and failure to saturate predator populations (Liermann and Hilborn 2001)]. Depensation, and its resultant effects, results in negative feedback that accelerates a decline toward extinction (Williams et al. 2008).

The depensation threshold is the number of spawners below which a population is subject to depensatory effects. Williams et al. (2008) defined the depensation threshold as 1 spawner per IP-km. A population below the depensation threshold is at high risk of extinction (Table 2-3). The depensation threshold for each independent population is shown in Table 2-6. In order for the ESU to be viable, all independent populations which aren't extirpated must not be at high risk of extinction, and so their spawner numbers must be greater than the depensation threshold.

## 2.4 Current Status of the ESU

In order to determine the current risk of extinction of the SONCC coho salmon ESU, NMFS utilized the population viability criteria (Table 2-3) and the concept of Viable Salmonid Populations (VSP) to evaluating populations described by McElhany et al. (2000). A viable salmonid population is defined as one that has a negligible risk of extinction over 100 years. Viable salmonid populations are described in terms of four parameters: abundance, population productivity, spatial structure, and diversity. These parameters are predictors of extinction risk, and reflect general biological and ecological processes that are critical to the growth and survival of salmon (McElhany et al. 2000). In a recovered ESU, viability criteria for all four parameters would be met.

The productivity of a population (i.e., production over the entire life cycle) can reflect conditions (e.g., environmental conditions) that influence the dynamics of a population and determine abundance. In turn, the productivity of a population allows an understanding of the performance of a population across the landscape and habitats in which it exists and its response to those habitats (McElhany et al. 2000). In general, declining productivity equates to declining population abundance.

Understanding the spatial structure of a population is important because the population structure can affect evolutionary processes and, therefore, alter the ability of a population to adapt to spatial or temporal changes in the species' environment (McElhany et al. 2000). Spatial structure and the distribution of appropriate amounts and types of habitat (and ecological processes) should be considered the foundation of population and ESU viability.

Diversity, both genetic and behavioral, is critical to success in a changing environment. Salmonids express variation in a suite of traits, such as anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, and physiology and molecular genetic characteristics. The more diverse these traits (or the more these traits are not restricted), the more diverse a population is, and the more likely that individuals, and therefore the species, would survive and reproduce in the face of environmental variation (McElhany et al. 2000). However, when this diversity is reduced due to loss of entire life-history strategies or to loss of habitat used by fish exhibiting variation in life-history traits, the species is in all probability less able to survive and reproduce given environmental variation.

Because some of the parameters are related or overlap, the evaluation is at times necessarily repetitive. Viable ESUs are defined by some combination of multiple populations, at least some of which exceed "viable" thresholds, and that have appropriate geographic distribution, protection from catastrophic events, and diversity of life histories and other genetic expression. The following subsection provides the evaluation of the risk of extinction for SONCC coho salmon based the four VSP parameters. For more information on the status of specific populations, refer to Chapters 7 to 46. The upcoming status review for SONCC coho salmon may not consider all the time series data presented here, because at least 9 to 12 years of time series data are needed for rigorous application of the criteria described in Williams et al. (2008) in the status review (Williams et al. 2011).

### 2.4.1 Population Abundance

Quantitative population-level estimates of adult spawner abundance spanning more than 9 years are scarce for SONCC coho salmon. New data since publication of the previous status review (Williams et al. 2011) consists of continuation of a few time series of adult abundance, expansion of efforts in coastal basins of Oregon to include SONCC coho salmon populations, and continuation and addition of several "population unit" scale monitoring efforts in California. The following text summarizes the available data for adult coho salmon abundance in the SONCC coho salmon ESU. Although long-term data are scarce, the available monitoring data indicate that spawner abundance has generally declined for populations in this ESU.

Unless otherwise noted, Figure 2-7 to Figure 2-16 show the observed or estimated number wild adult coho salmon populations of the SONCC coho salmon ESU. The data from Redwood Creek, the Smith River, Freshwater Creek, and Bogus Creek do not reflect escapement to the entire watershed. In some cases, one year class appears to be stronger or weaker than the others (i.e., the Scott River, the Shasta River, and Redwood Creek's Prairie Creek). The Huntley Park seine estimates provide the best overall assessment of naturally produced coho salmon spawner abundance in the Rogue River basin (Oregon Department of Fish and Wildlife [ODFW] 2005a). Four independent populations contribute to this count (Lower Rogue River, Illinois River, Middle Rogue and Applegate rivers, and Upper Rogue River).

For the high-risk threshold related to depensation, Williams et al. (2008)'s viability criteria are based on an estimate of average spawner density in the three consecutive years of lowest abundance within the last four generations (i.e., 12 years). For this analysis, the average spawner density was obtained by dividing the number of spawners by the amount of IP-km, as the depensation threshold is set at 1 spawner per IP-km. A ratio less than one indicates the population is at high risk of extinction for this parameter, while a ratio greater than one indicates the population is at moderate risk of extinction for this parameter. Among those locations described above, where the number of adults has been observed or estimated for a watershed, this ratio is less than one for the Little River (0.76, Figure 2-9) and the Shasta River (0.15, Figure 2-12). The ratio of the average abundance of the lowest three year classes over the amount of IP-km is greater than one for the Upper Rogue River (2.67, Figure 2-15), the Rogue River (from

Huntley Park; 1.36, Figure 2-16), Upper Trinity River (3.10, Figure 2-11), and Scott River (1.45, Figure 2-13).

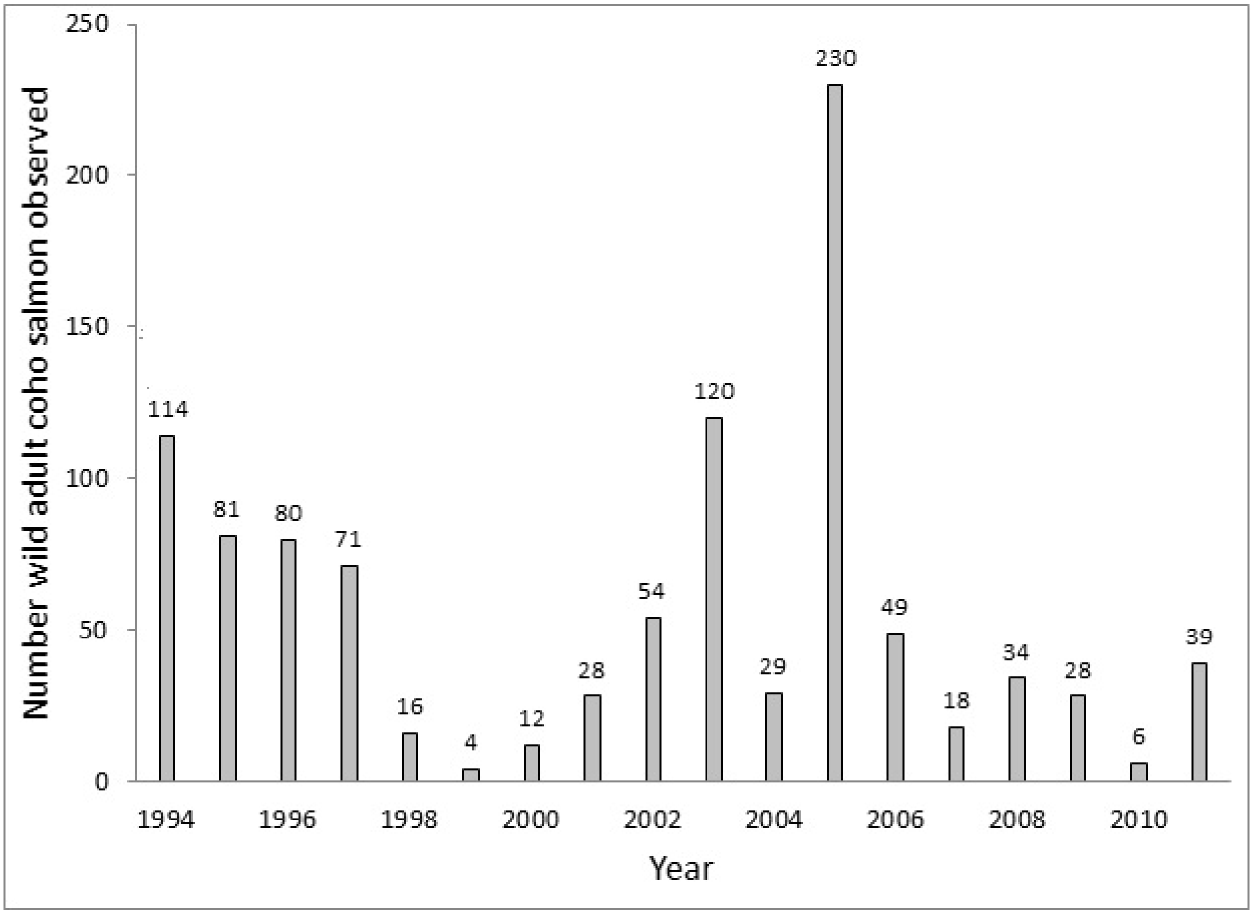



Figure 2-7. Number of wild adult coho salmon observed in Mill Creek, a tributary of the Smith River basin, 1994 through 2011. Slope of LN-transformed values = -0.046, 95% C.I = -0.148, 0.055 (Data source: Larson 2012).

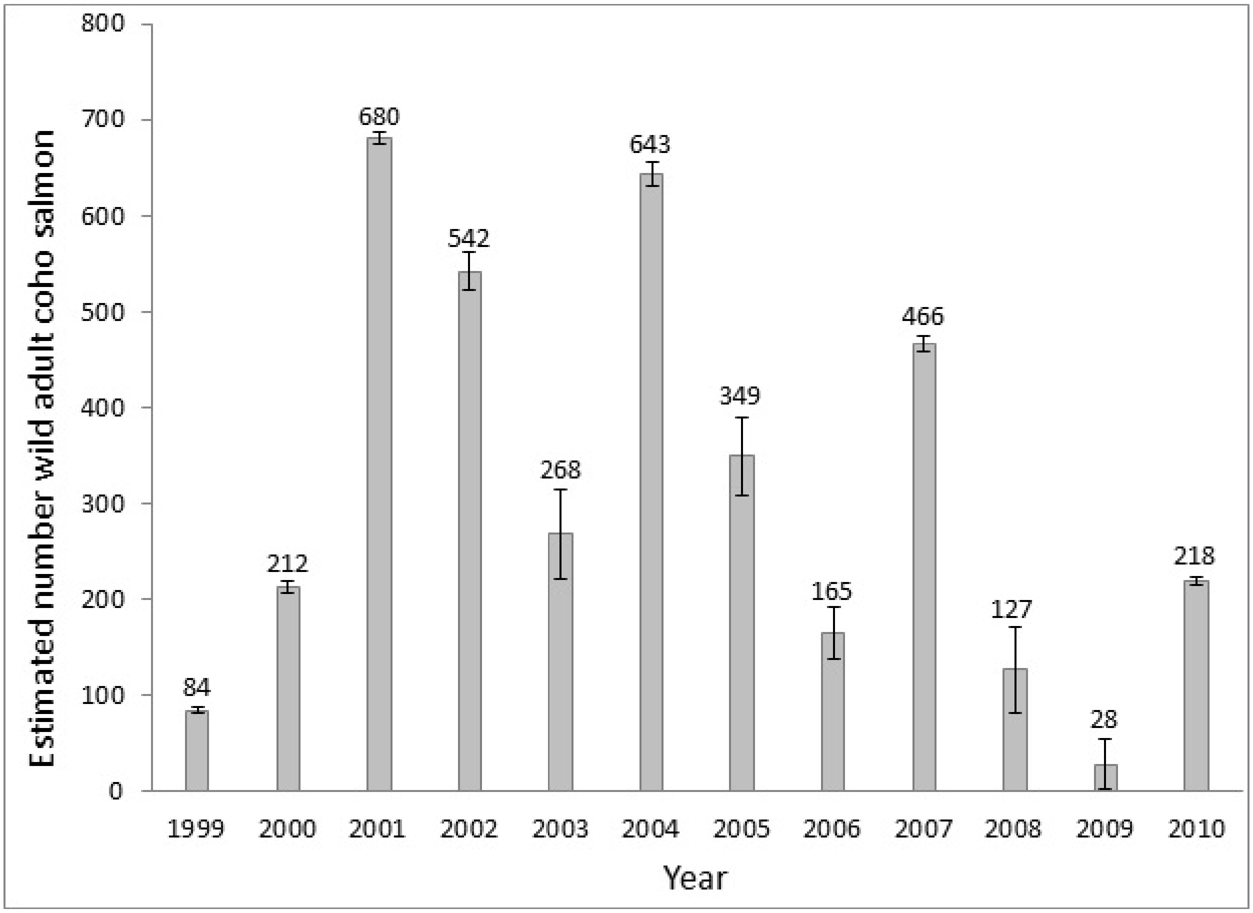



Figure 2-8. Estimated number adult coho salmon in Prairie Creek, a tributary to Redwood Creek (Humboldt County, California). Slope of LN-transformed values = -0.014, 95% C.I. = -0.181, 0.152 (Data source: Duffy 2011).

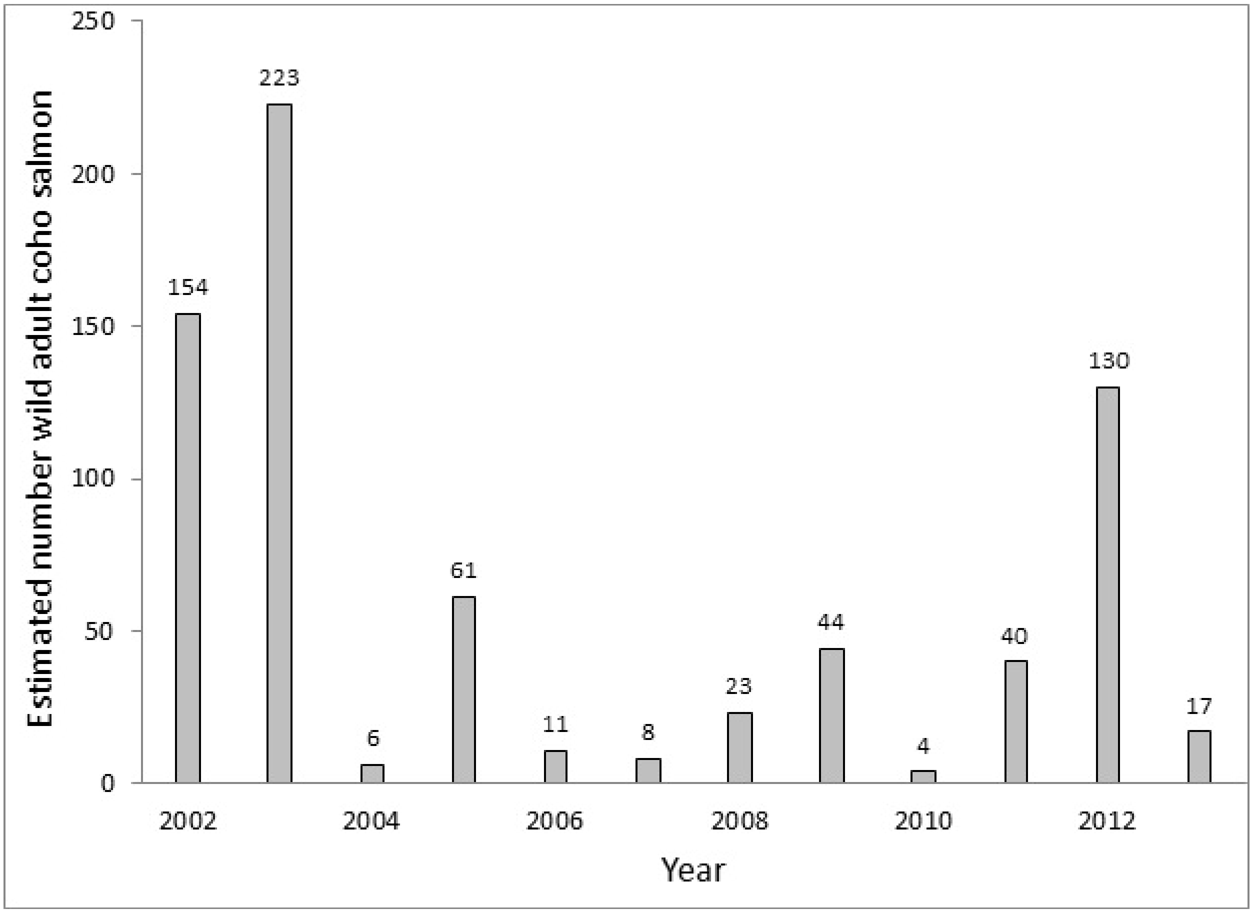



Figure 2-9. Estimated number wild adult coho salmon in the Little River. Slope of LN-transformed values = 0.44, 95% C.I. = -0.135, 0.223 (Data source: Bourque, R., pers. comm. 2013).

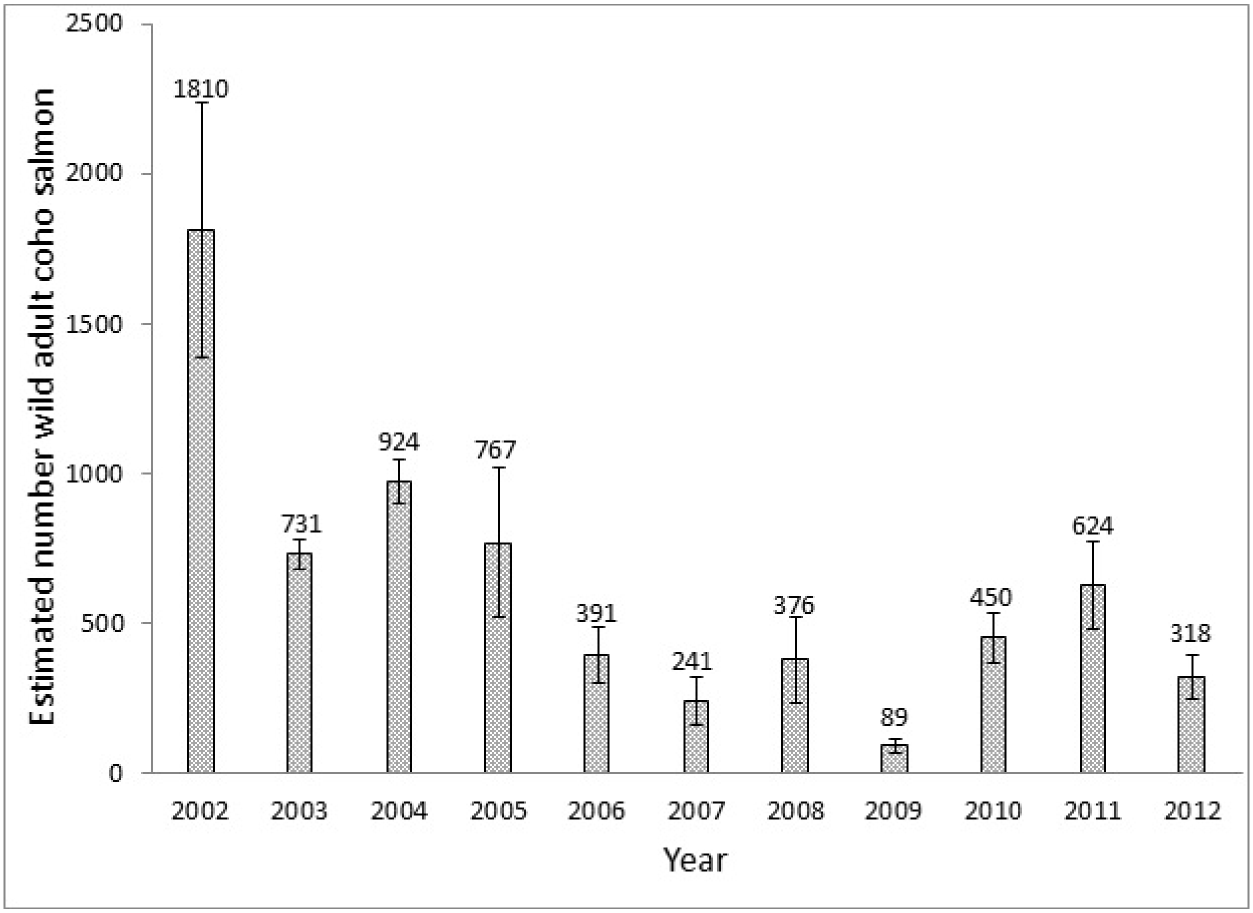



Figure 2-10. Escapement estimates for adult coho salmon in Freshwater Creek, a tributary to Humboldt Bay. Slope of LN-transformed values = -0.145, 95% C.I. = -0.280, -0.011. (Data source: Moore and Ricker 2012).

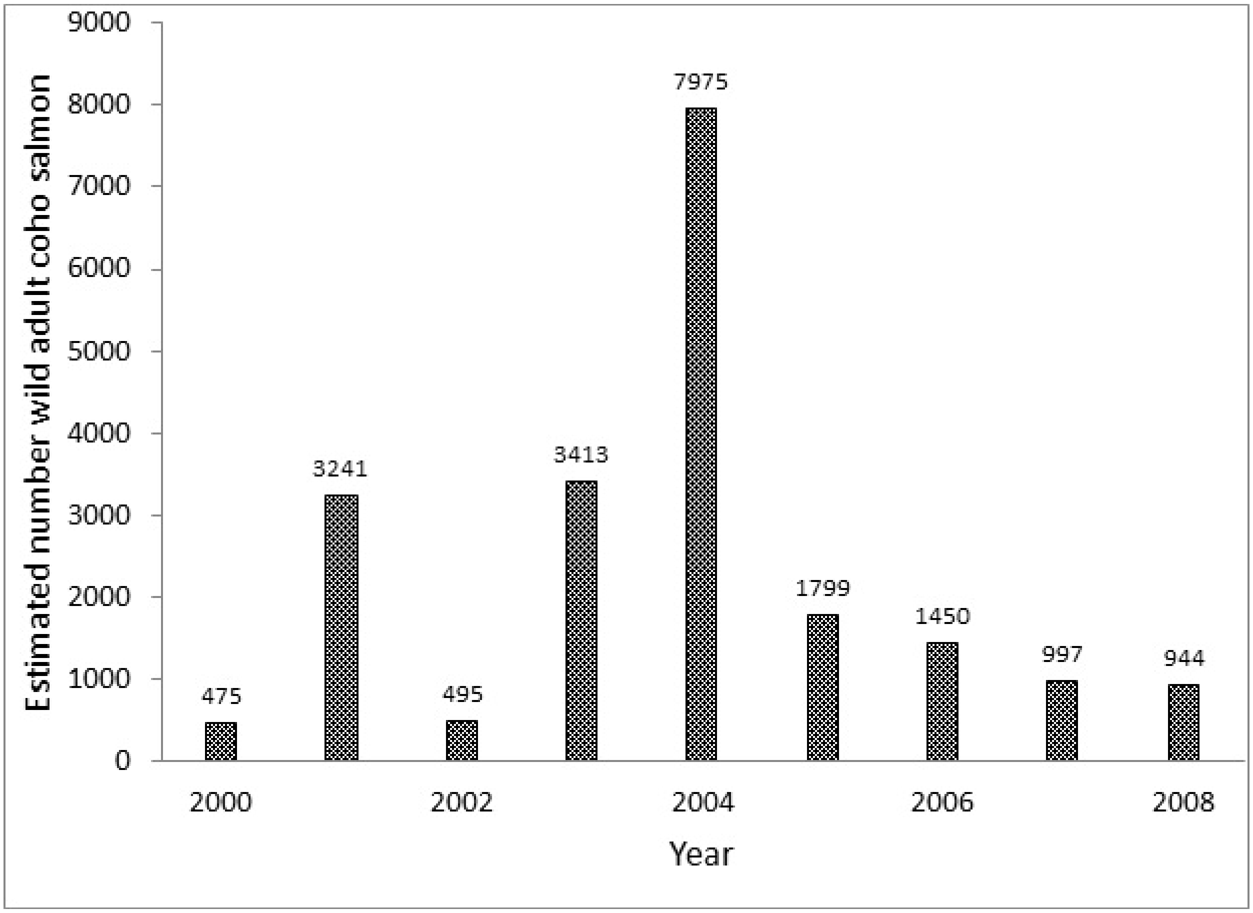



Figure 2-11. Estimated number wild adult coho salmon upstream of Willow Creek weir in the Trinity River. Slope of LN-transformed values = 0.012, 95% C.I. = -0.28, 0.30. Data source: CDFG 2009.

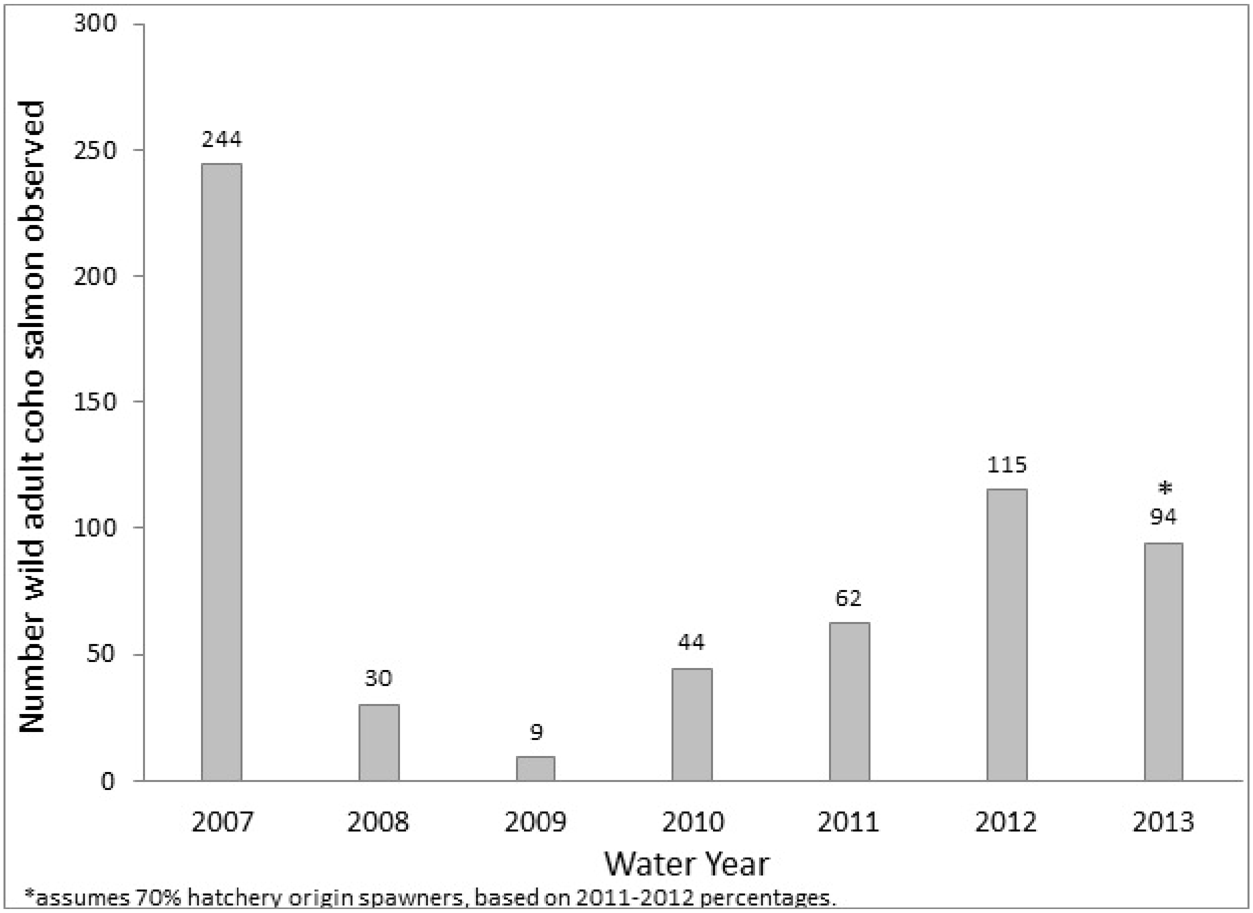



Figure 2-12. Estimated number wild coho salmon observed at video weir on the Shasta River Does not include hatchery origin fish on spawning grounds. Slope of LN-transformed values = 0.063, 95% C.I. = -0.542, 0.667. (Data source: 2007-2012 Chesney and Knechtle 2013a, 2013 Knechtle, M. pers. comm. 2014).

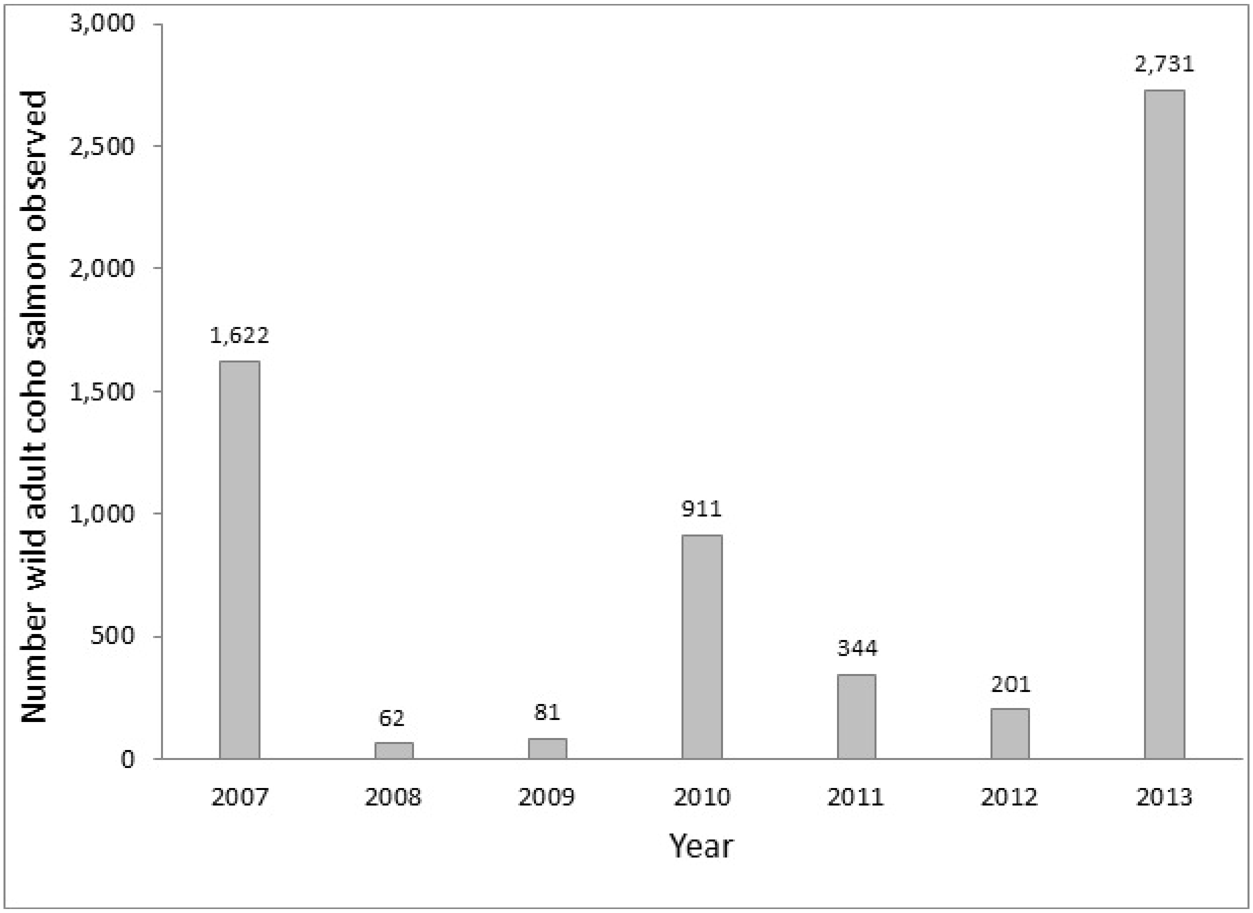



Figure 2-13. Number wild adult coho salmon observed at the Scott River fish counting facility at River Mile 18, 2007 to 2013. Does not include hatchery origin fish on spawning grounds. Slope of LN-transformed values = 0.191, 95% C.I. = -0.556, 0.939. (Data source: 2007-2012 data Knechtle and Chesney 2013a, 2013 data pers. comm. M. Knechtle, CDFW, 2014).

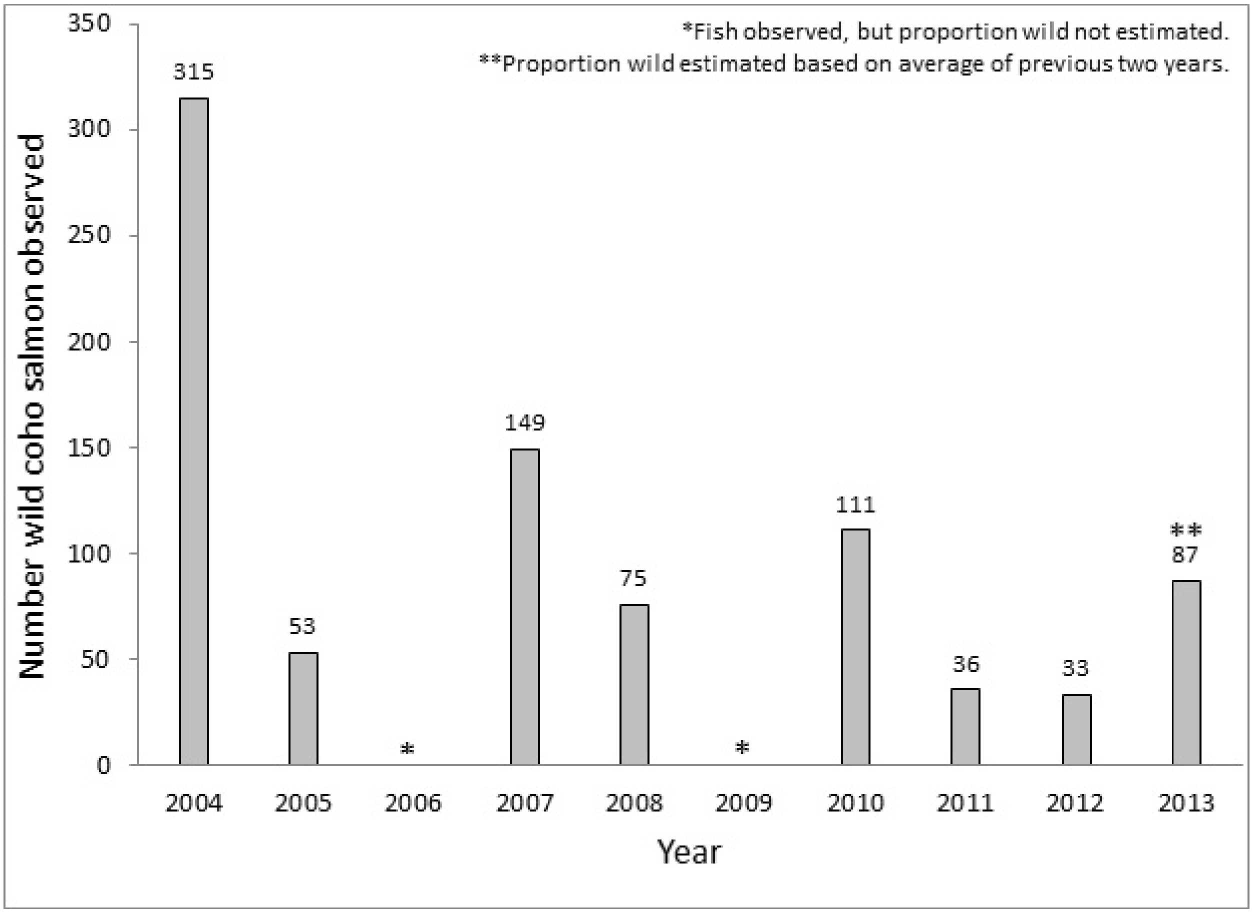



Figure 2-14. Number wild adult coho salmon observed in Bogus Creek, a tributary of the Upper Klamath River. Does not include hatchery origin fish on spawning grounds. Slope of LN-transformed values = -0.13, 95% C.I. = -0.329, 0.066. (Data source: 2007-2012 data Knechtle and Chesney 2013b, 2013 data pers. comm. M. Knechtle, CDFW, 2014).

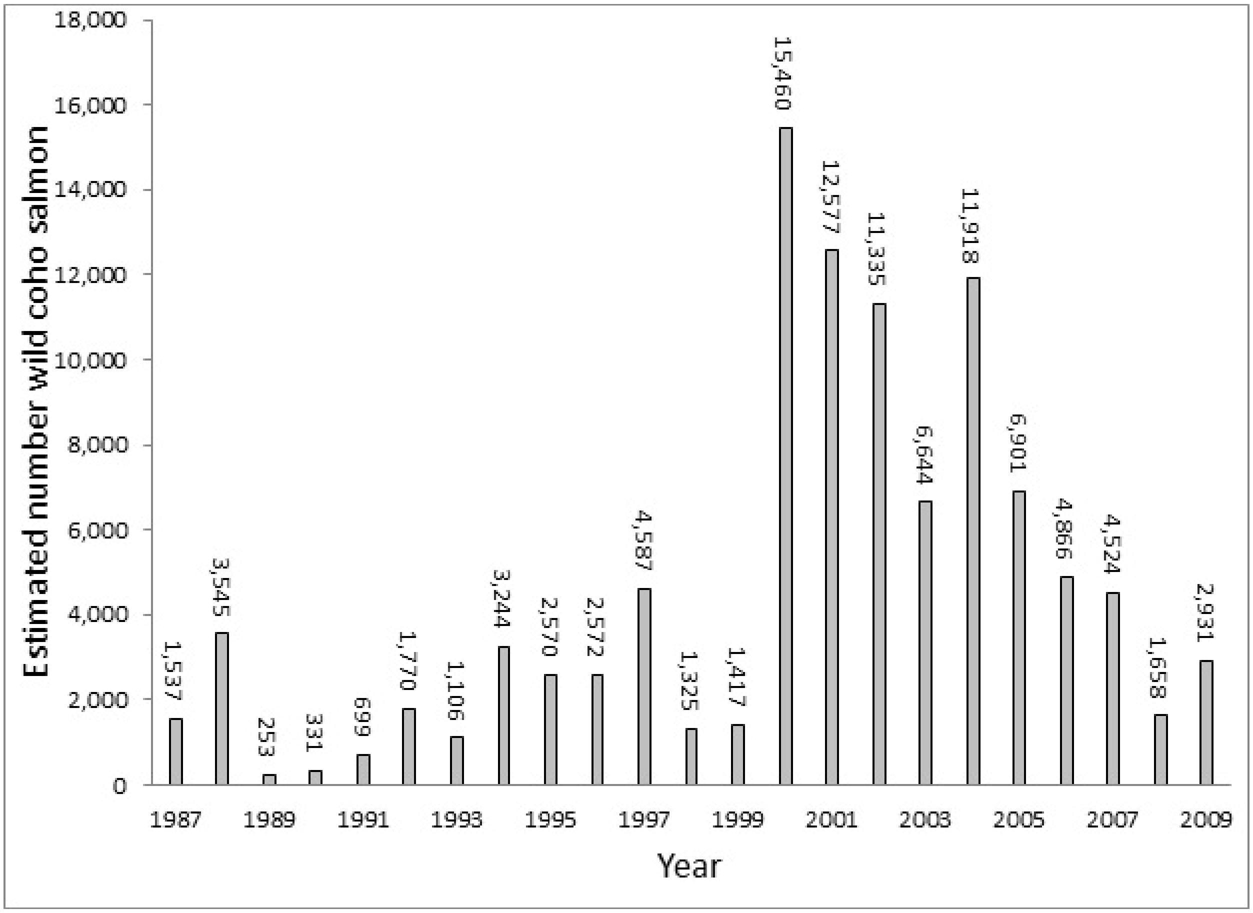



Figure 2-15. Number adult wild coho salmon observed at Gold Ray Dam on the Upper Rogue River. Slope of LN-transformed values = 0.094, 95% C.I. = 0.035, 0.154. Data source: ODFW 2010.

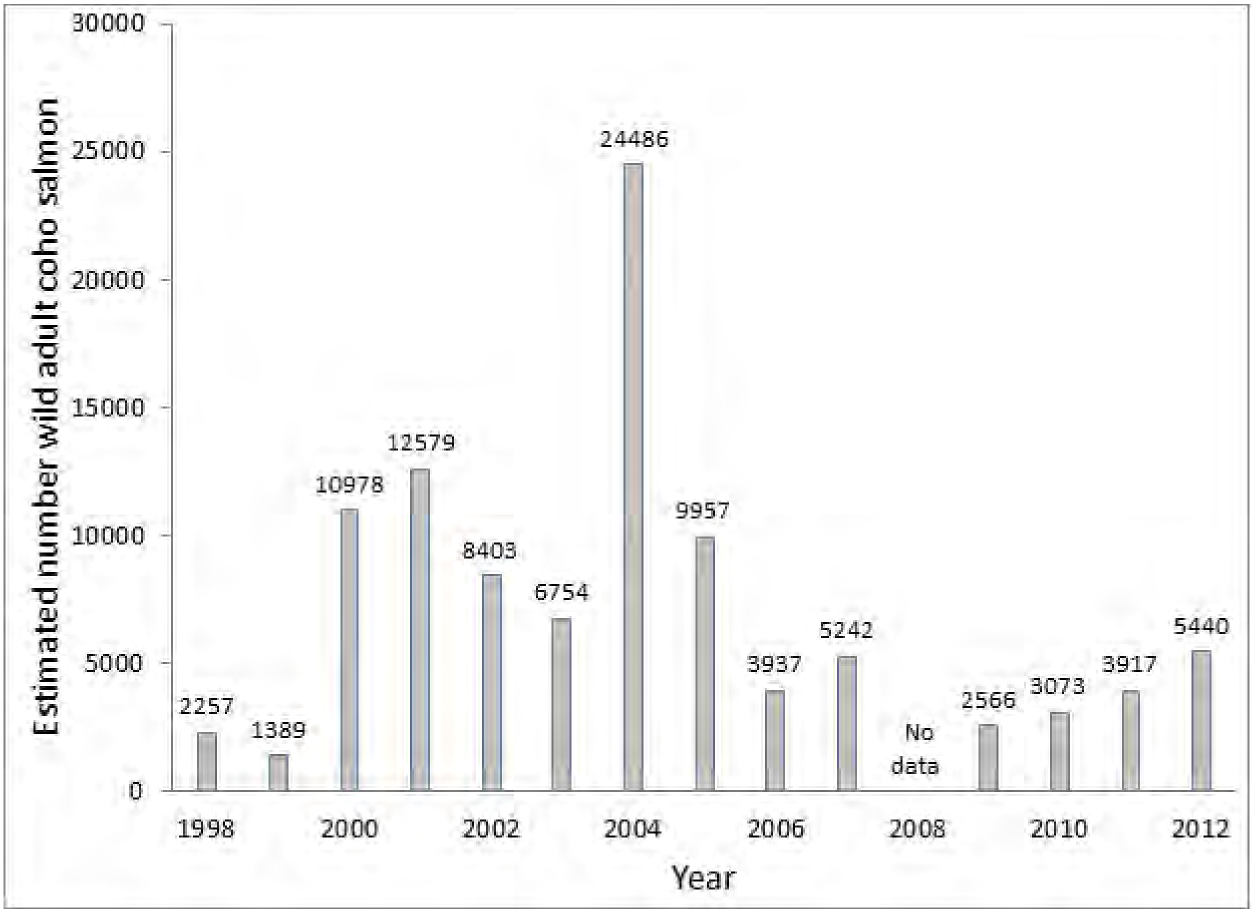



Figure 2-16. Estimated number of wild adult coho salmon in the Rogue River basin. (Huntley Park sampling), 1998 to 2012[4]. Slope of LN-transformed values = -0.023, 95% C.I. = -0.1469, 0.100 (Data source: ODFW 2012).

Though population-level estimates of abundance for most independent populations are lacking, the best available data indicate that none of the seven diversity strata appears to support a single viable population (one at low risk of extinction) as defined by in the viability criteria (Table 2-3). In fact, most of the 30 independent populations in the ESU are at high risk of extinction for abundance because they are below or likely below their depensation threshold (Table 2-6).

Populations that are below depensation have increased likelihood of being extirpated. Coho salmon spawners in the Eel River watershed, which historically supported significant spawners (e.g., 50,000 to 100,000 per year; Yoshiyama and Moyle 2010), have declined in number. Yoshiyama and Moyle (2010) concluded that coho salmon populations in the Eel River basin appear to be headed for extirpation by 2025. One of the four independent populations in this basin has already been extirpated (i.e., Middle Fork Eel River; Moyle et al. 2008, Yoshiyama and Moyle 2010) and one population contains critically low numbers (i.e., Upper Mainstem Eel

[4] 2008 data were excluded from consideration because the extremely low numbers were not consistent with that seen upstream at Gold Ray Dam, suggesting other reasons (sampling issues, data errors, etc.) for the dramatic drop in fish numbers from 2007 to 2008.

River, with only a total of seven adult coho salmon counted at the Van Arsdale Fish Station in over six decades; Jahn, J., pers. comm. 2010). Although long term spawner data are not available, both NMFS and CDFW believe the Lower Eel/Van Duzen River (Chapter 26), Middle Mainstem Eel River population (Chapter 44) and Mainstem Eel River population (Chapter 42) are very likely below the depensation threshold, and thus are at a high risk of extinction (rationale provided in referenced chapters). The only population in the Eel River basin that is likely to be above its depensation threshold is the South Fork Eel River (Chapter 41), which has also declined from historical numbers in the tens of thousands before 1950 (Taylor 1978; Figure 2-17).

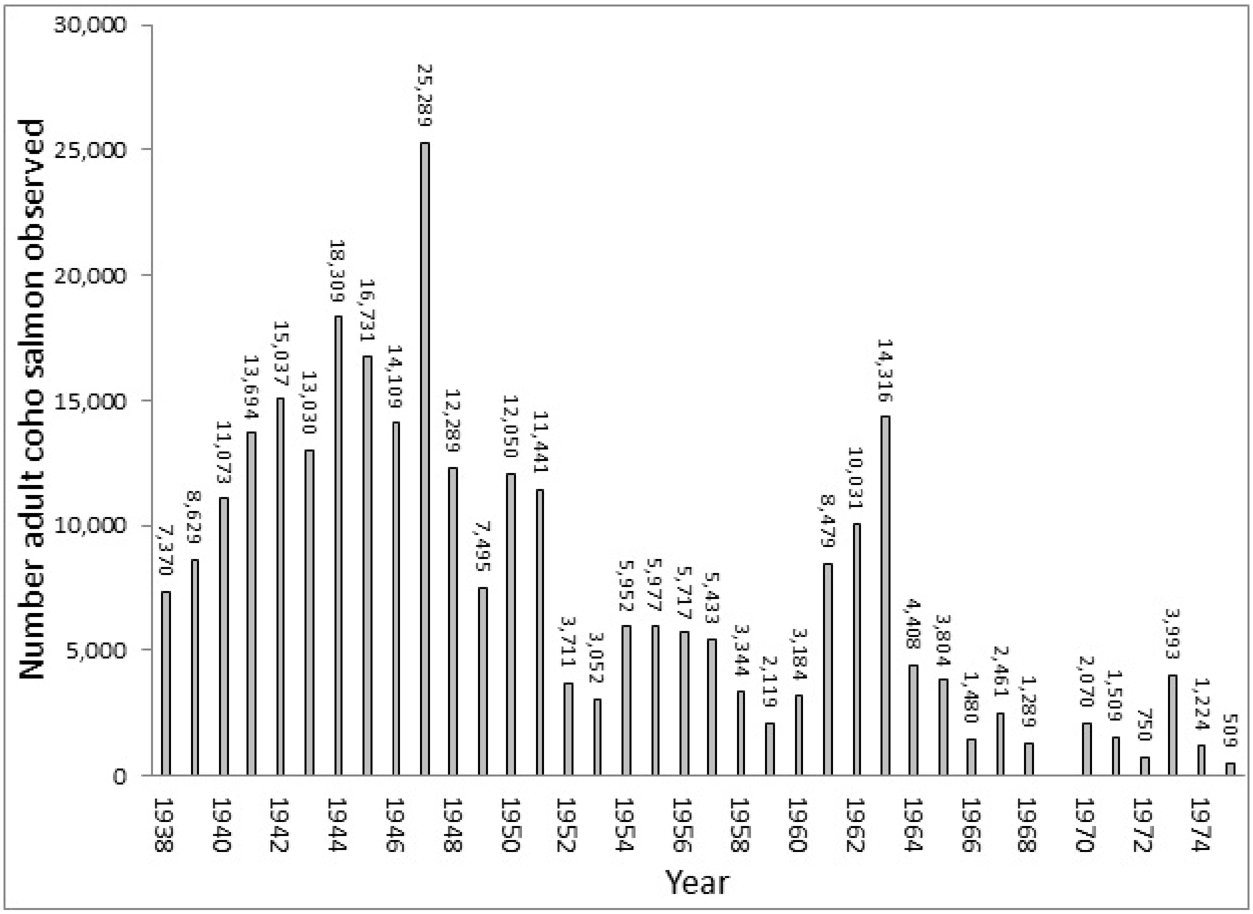


Figure 2-17. Fish counts at Benbow Fish Station, in the South Fork Eel River. Data are from 1938 to 1975 (excluding 1969). Counts may contain hatchery-origin fish. Data source: Taylor 1978.

In addition to the Eel River basin, two other independent populations south of the Eel River basin, the Bear River and Mattole River populations, have similar trajectories. The Bear River population is likely extirpated or severely depressed. Despite multiple surveys over years, no coho salmon have been found in the Bear River watershed (Bliesner et al. 2006, Ricker 2002). In 1996 and 2000, the California Department of Fish and Game (CDFG) surveyed most tributaries of the Bear River, and did not find any coho salmon (CDFG 2004a). In addition, CDFG sampled the mainstem and South Fork Bear River between 2001 and 2003 and found no coho salmon (Jong et al. 2008). In the Mattole River, surveys of live fish and carcasses since 1994 indicate the population is severely depressed and well below the depensation threshold of 250 spawners. Recent spawner surveys in the Mattole River resulted in only three and nine coho salmon for 2009 and 2010, respectively. These low numbers, along with a recent decline since 2005, indicate that the Mattole River population is at a high risk of extinction.

### 2.4.2 Productivity

The productivity of a population (i.e., production over the entire life cycle) can reflect conditions (e.g., environmental conditions) that influence the dynamics of a population and determine abundance. In turn, the productivity of a population allows an understanding of the performance of a population across the landscape, habitats in which it exists, and its response to those habitats (McElhany et al. 2000). In general, declining productivity equates to declining population abundance.

Available data show that the 95% confidence intervals for the slope of the regression line include zero for many populations (Figure 2-7 to Figure 2-16), indicating that whether the slope is negative or positive cannot be determined. However, there is 95% confidence that the slope of the regression line is negative, indicating a decreasing trend, for Mill Creek in the Smith River and Freshwater Creek in Humboldt Bay Tributaries. In contrast, there is 95% confidence that the slope of the regression line is positive, indicating an increasing trend, at Gold Ray Dam in the Upper Rogue River.

### 2.4.3 Spatial Structure

The viability report for the SONCC coho salmon ESU explicitly described spatial structure and concluded data were insufficient to set specific population spatial structure targets (Williams et al. 2008). In the absence of such targets, McElhany et al. (2000) suggested the following: "As a default, historical spatial processes should be preserved because we assume that the historical population structure was sustainable but we do not know whether a novel spatial structure will be", where "historical" means "before the recent or severe declines that have been observed in many populations (McElhany et al. 2000)."

An ESU persists in places where it is able to track environmental changes, and becomes extinct if it fails to keep up with the shifting distribution of suitable habitat (Thomas 1994, Williams et al. 2008). If freshwater habitat shrinks due to climate change (Battin et al. 2007) or habitat degradation, certain areas such as inland rivers and streams could become inhospitable to coho salmon, which would change the spatial structure of the SONCC coho salmon ESU, having implications for the risk of species extinction.

Available data are inadequate to determine whether the spatial distribution of SONCC coho salmon has changed since 2005. In 2005, Good et al. (2005) noted that they had strong indications that breeding groups have been lost from a significant percentage of streams within their historical range. Relatively low levels of observed presence in historically occupied coho salmon streams (32 to 56 percent from 1986 to 2000) indicate continued low abundance in the California portion of the SONCC coho salmon ESU. The relatively high occupancy rate of historical streams observed in brood year 2001 suggests that much habitat remains accessible to coho salmon (70 FR 37160, June 28, 2005). Brown et al. (1994) found survey information on 115 streams within the SONCC coho salmon ESU, of which 73 (64 percent) still supported coho salmon runs while 42 (36 percent) did not. The streams Brown et al. (1994) identified as lacking coho salmon runs were all tributaries of the Klamath River and Eel River basins. CDFG (2002b) reported a decline in SONCC coho salmon occupancy, with the percent reduction dependent on the data sets used. All the assessments based on fish presence described above were affected by the often poor hydrologic conditions present in the survey years.

Although there is considerable year-to-year variation in estimated occupancy rates, it appears that there has been no dramatic change in the percent of coho salmon streams occupied from the late 1980s and early 1990s to 2000 (Good et al. 2005). However, the number of streams and rivers currently supporting coho salmon in this ESU has been greatly reduced from historical levels, and watershed-specific extirpations of coho salmon have been documented (Brown et al. 1994, CDFG 2004a, Good et al. 2005, Moyle et al. 2008, Yoshiyama and Moyle 2010). In summary, recent information for SONCC coho salmon indicates that their distribution within the ESU has been reduced and fragmented, as evidenced by an increasing number of previously occupied streams from which they are now absent (NMFS 2001). However, extant populations can still be found in all major river basins within the ESU (70 FR 37160; June 28, 2005).

The spatial structure of each population was not quantified for this plan because data are insufficient. The current spatial structure of each population is described in Chapters 7 to 46.

### 2.4.4 Diversity

The primary factors affecting the genetic and life-history diversity of SONCC coho salmon appear to be low population abundance and the influence of hatcheries and out-of-basin introductions. Although the operation of a hatchery tends to increase the abundance of returning adults (70 FR 37160; June 28, 2005), the reproductive success of hatchery-born salmonids spawning in the wild can be less than that of naturally produced fish (Araki et al. 2007a). As a result, the higher the proportion of hatchery-born spawners, the lower the overall productivity of the population, as demonstrated by Chilcote (2003). Williams et al. (2008) considered a population to be at least at a moderate risk of extinction if the contribution of hatchery coho salmon spawning in the wild exceeds 5 percent. Populations have a lower risk of extinction if no or negligible ecological or genetic effects resulting from past or current hatchery operations can be demonstrated. Because the main stocks in the SONCC coho salmon ESU (i.e., Rogue River, Klamath River, and Trinity River) remain heavily influenced by hatcheries and have little natural production in mainstem rivers (Weitkamp et al. 1995; Good et al. 2005), some of these populations are at high risk of extinction relative to the genetic diversity parameter. The extent of hatcheries in the ESU, and a discussion of their effects, is described in Chapters 3 and 7 to 46. Table 2-4 shows those populations with hatchery stress and threat ranks of high (greater than 10 percent and less than 30 percent hatchery-origin adults) and very high (greater than 30 percent hatchery-origin adults).

Table 2-4. Populations with hatchery effects rated as a high or very high stress and threat. Table shows % hatchery spawners, and source.

| Population | Stress and Threat Rank | Average Percentage Hatchery Origin Adults |
|---|---|---|
| Upper Klamath River | Very High | 47% at Bogus Creek from 2004 to 2012, excluding 2006 and 2009; Knechtle and Chesney (2013b) |
| Shasta River | High | 16% in 2001, 2003, 2004; Ackerman and Cramer (2006). 23% from 2001 to 2004; Ackerman et al. (2006). 43% from 2007 to 2012; Chesney and Knechtle (2013) |
| Lower Trinity River | Very High | 85-97% from 1997 to 2002; Sinnen et al. 2009. 60-100% from 1998 to 1999; Dutra and Thomas (1999) |
| South Fork Trinity River | Very High | 36% in 1985; Jong and Mills (1992) |
| Upper Trinity River | Very High | 97%, USFWS and HVT (1999) |

Some populations are extirpated or nearly extirpated (i.e., Middle Fork Eel, Bear River, Upper Mainstem Eel) and some brood years have low abundance or may be absent in some areas (e.g., Shasta River, Scott River, Mattole River, Mainstem Eel River), which further restricts the diversity present in the ESU. The ESU's current genetic variability and variation in life-history likely contribute significantly to long-term risk of extinction. Given the recent trends in abundance across the ESU, the genetic and life-history diversity of populations is likely very low and is inadequate to contribute to a viable ESU.

### 2.4.5 Oregon Assessment

The Oregon Department of Fish and Wildlife assessed the status of the Rogue Coho Species Management Unit (SMU), which includes the Upper Rogue, Middle Rogue, and Illinois River populations (ODFW 2005a) using five interim criteria defined in their Native Fish Conservation Policy. These criteria were designed to identify cases of significant near-term conservation risks. The Rogue Coho SMU was found Not At Risk because all three populations met all six criteria (Table 2-5). The criteria used by ODFW and NMFS to assess the status of the ESU were different, leading to different results. In addition, the NMFS assessment included all populations within the ESU, while the ODFW assessment was limited to the three interior Rogue populations within the Rogue Coho SMU.

Table 2-5. Interim criteria and standards. As defined in the Native Fish Conservation Policy risk assessment of Oregon salmon and steelhead SMUs (ODFW 2005a).

| Attribute | Criteria |
|---|---|
| Existing populations | At least 80% of historical populations are still in existence (i.e., not extinct) *and* not at risk of extinction in the near future. |
| Habitat use distribution | Naturally produced members of a population occupy at least 50% of the historically-used (pre-development) habitat in at least three of the last five years for at least 80% of existing populations. |
| Abundance | Number of naturally-produced fish is greater than 25% of average levels in at least three of the last five years for at least 80% of existing populations. |
| Productivity | Population replacement rate for at least 80% of existing populations is at least 1.2 naturally-produced adult offspring per parent in three of the last five years when total abundance was less than average returns of naturally produced fish. |
| Reproductive independence | 90% or more of spawners are naturally produced in at least three of the last five years for at least 80% of existing populations. |
| Hybridization | Hybridization with non-native species is rare or nonexistent in three of the last five years for at least 80% of existing populations. |

### 2.4.6 Summary

Though population-level estimates of abundance for most independent populations are lacking, the best available data indicate that none of the seven diversity strata appears to support a single viable population as defined by the SONCC coho salmon technical recovery team's viability criteria (low extinction risk; Williams et al. 2008). Further, 24 out of 31 independent populations are at high risk of extinction and 6 are at moderate risk of extinction (Table 2-6).

Based on the above discussion of the population viability parameters, and qualitative viability criteria presented in Williams et al. (2008), NMFS concludes that the SONCC coho salmon ESU is currently not viable and is at high risk of extinction.

The decline in abundance from historical levels, and the poor status of population viability metrics in general, are the main factors behind the extinction risk faced by SONCC coho salmon. The primary causes of the decline are likely long-standing human-caused conditions (e.g., harvest and habitat degradation), which exacerbated the impacts of adverse environmental conditions (e.g., drought and poor ocean conditions) (60 FR 38011; July 25, 1995). The demographic response to impaired habitat has been a reduction in the number of fish and their range, which has made them less resilient to environmental stresses such as poor ocean conditions. The stresses and threats that contribute to the current status of SONCC coho salmon are described in Chapter 3.

Table 2-6. SONCC coho salmon ESU core and non-core 1 populations and their current risk of extinction.

| Stratum | Population | Extinction Risk | Depensation Threshold (1*IP-km) | Extinction Risk Criteria Used[1] |
|---|---|---|---|---|
| Northern Coastal Basin | Elk River | High | 63 | Spawner density |
| | Lower Rogue River | High | 81 | Population decline |
| | Chetco River | High | 135 | Spawner density |
| | Winchuck River | High | 57 | Spawner density |
| Interior Rogue River | Illinois River | High | 590 | Population decline |
| | Middle Rogue/Applegate Rivers | High | 603 | Population decline |
| | Upper Rogue River | Moderate | 689 | Spawner density |
| Central Coastal Basin | Smith River | High | 325 | Spawner density |
| | Lower Klamath River | High | 205 | Spawner density |
| | Redwood Creek | High | 151 | Spawner density |
| | Little River | Moderate | 34 | Spawner density |
| | Mad River | High | 136 | Spawner density |
| Interior Klamath | Middle Klamath River | Moderate | 113 | Spawner density |
| | Upper Klamath River | High | 425 | Spawner density |
| | Shasta River | High | 144 | Spawner density |
| | Scott River | Moderate | 250 | Spawner density |
| | Salmon River | High | 114 | Spawner density |
| Interior Trinity | Lower Trinity River | High | 112 | Spawner density |
| | South Fork Trinity River | High | 242 | Spawner density |
| | Upper Trinity River | Moderate | 365 | Spawner density |
| South Coastal Basin | Humboldt Bay tributaries | Moderate | 191 | Spawner density |
| | Lower Eel/Van Duzen Rivers | High | 394 | Spawner density |
| | Mattole River | High | 250 | Spawner density |
| Interior Eel | Mainstem Eel River | High | 68 | Spawner density |
| | Middle Mainstem Eel River | High | 232 | Spawner density |
| | South Fork Eel River | Moderate | 464 | Spawner density |

[1]As described in Williams et al. (2008) and Table 2-3.

This page intentionally left blank.

# 3. Stresses and Threats

Stresses are the physical, biological, or chemical conditions and associated ecological processes that may be impeding SONCC coho salmon recovery. General categories of stresses include water quality, competition, disease, access to habitat, instream flows, insufficient quality and quantity of physical habitat, and predation. Threats are activities or impacts that cause or contribute to the stresses that limit recovery of the species, including: water diversions, hydropower impacts, land management, invasive species, fish harvest management, and hatchery management.

When the SONCC coho salmon ESU was listed under the Endangered Species Act (ESA) in 1997, NMFS identified the factors which led to the decline of the species (62 FR 24588, May 6, 1997), and the stresses and threats associated with those factors. These factors, called "listing factors", are described in Chapter 1. Table 3-1, Table 3-2, and Table 3-3 describe the stresses and threats associated with each listing factor. Each population's stresses and threats are assessed in the population profiles (Chapters 7 to 46). This chapter describes the stresses and threats associated with each listing factor, the causes of those stresses and threats, and what can be done to address them. In addition, this chapter describes the listing factor "Inadequacy of existing regulatory mechanisms", which contributes to all stresses and threats.

NMFS assessed the viability of individual populations within the SONCC coho salmon ESU and the current condition of their habitats using five steps: (1) identify conservation targets; (2) assess population viability; (3) identify potential threats and stresses; (4) compile available literature, data and best professional knowledge on the condition of the landscape; and (5) determine the severity and impact of stresses and threats affecting each population. This methodology is detailed in Appendix B.

The timeframe for assessment of stresses and threats is over the next ten years[5] under current circumstances and management (Appendix B). In addition to those stresses identified at the time of listing, additional stresses currently affecting SONCC coho salmon were identified and ranked using the Conservation Action Planning (CAP) workbook (explained in Appendix B) for each life stage of coho salmon.

[5] The effects of climate change are expected to take at least 50 years to manifest.

Table 3-1. Relationship between listing factors, stresses and threats for SONCC coho salmon.

| **Threat** | **Listing Factor** | | | | |
|---|---|---|---|---|---|
| | Habitat Destruction, Modification or Curtailment | Over-Utilization for Commercial, Recreational, Scientific, or Educational Purposes | Disease and Predation | Inadequate Regulatory Mechanisms | Other Natural and Man-made Factors |
| Roads | X | | | X | |
| Timber Harvest | X | | | X | |
| Channelization/Diking | X | | | X | |
| Agricultural Practices | X | | X | X | |
| Dams/Diversions | X | | X | X | |
| Mining/Gravel Extraction | X | | X | X | |
| Urbanization | X | | X | X | |
| Fishing and Collecting | | X | | X | |
| Climate Change | X | | X | X | X |
| Hatcheries | | | | X | X |
| Fire | X | | | X | |
| Invasive/Non-native Alien Species | X | | X | X | |

Table 3-2. Matrix of interrelated threats and stresses in the SONCC coho salmon ESU.

| **Threats** | **Stresses** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Adverse Hatchery-Related Effects | Impaired Water Quality | Degraded Riparian Forest Conditions | Increased Disease/ Predation/ Competition | Altered Sediment Supply | Lack of Floodplain/ Channel Structure | Altered Hydrologic Function | Barriers | Adverse Fishery and Collecting-Related Effects | Impaired Estuary/ Mainstem function |
| Climate Change | | X | X | X | X | X | X | | | X |
| Roads | | X | X | | X | X | X | X | | X |
| Channelization/Diking | | X | X | | X | X | X | | | X |
| Agricultural Practices | | X | X | | X | X | X | X | | X |
| Timber Harvest | | X | X | | X | X | X | X | | X |
| Urban/Residential/ Industrial Development | | X | X | | X | X | X | X | | X |
| High Severity Fire | | X | X | | X | | X | | | |
| Mining/Gravel Extraction | | X | X | | X | X | X | X | | X |
| Dams/Diversions | | X | X | X | X | X | X | X | | X |
| Fishing and Collecting | | | | | | | | | X | |
| Invasive/Non-Native/Alien Species | | | | X | | | | | | X |
| Hatcheries | X | | | X | | | | | | |

Table 3-3. Comparison of threats at the time of listing to current stresses and threats described in recovery plan.

| Threat or Stress Assessed in Plan | Threats Identified at Time of Listing | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logging | Road Building | Grazing and Mining | Urbanization | Stream Channelization | Dams | Wetland Loss | Beaver Trapping | Water Withdrawals | Unscreened Diversions | Over Fishing (non-tribal) | Natural Factors | Artificial Propagation |
| **Threats** | | | | | | | | | | | | | |
| Roads | X | X | | X | X | | X | | | | | | |
| Timber Harvest | X | X | | | | | X | | | | | | |
| Channelization/Diking | | | X | | X | | | | | | | | |
| Agricultural Practices | | | X | | | X | | X | X | X | | | |
| Dams/Diversions | | | X | | | X | X | X | | | | | |
| Mining/Gravel Extraction | | | X | | X | | | | | | | | |
| Urbanization | | | | X | | | X | X | | | | | |
| Fishing and Collecting | | | | | | | | | | | X | | X |
| Climate Change | | | | | | | | | | | | X | |
| Hatcheries | | | | | | | | | | | X | | X |
| Fire | | | | X | | | | | | | | | |
| Invasive/Non Native Species | | | | X | | X | | | | | | | |
| **Stresses** | | | | | | | | | | | | | |
| Adverse Hatchery Related Effects | | | | | | | | | | | | | X |
| Impaired Water Quality | X | X | X | X | | X | X | X | X | X | | | |
| Degraded Riparian Forest | X | X | X | X | X | | X | X | | | | | |
| Increased Disease/Predation/Competition | | | | X | | X | | | X | | | | X |
| Altered Sediment Supply | X | X | X | X | X | X | X | | | | | X | |
| Lack of Floodplain and Channel Structure | | X | X | X | X | | X | X | | | | | |
| Altered Hydrologic Function | X | X | X | X | X | X | X | X | | | | | |
| Barriers | | | X | X | X | X | | | X | | | | |
| Impaired Estuary/Mainstem Function | X | X | X | X | X | X | X | X | X | | | X | |
| Adverse Fishery and Collecting Related Effects | | | | | | | | | | | X | | X |

In addition to the CAP assessment process, NMFS used the best available science regarding the impacts of predicted shifts in climate, effects from fishing and collecting activities, and estuary and mainstem condition on the ability of the species' to recover. Additional categories (either stresses or threats) were created for Climate Change, Impaired Estuary/Mainstem Function, and Fishing and Collecting.

## 3.1 Stresses

In each population profile we summarize and rank the stresses and threats (Chapters 7 to 46). Each of these population profiles includes a summary table of the stress rankings by coho salmon life stage, the overall stress ranking, and a narrative discussing the effects on the population. In addition to the stresses identified during listing, we performed a stress ranking and assessment for Impaired Estuary/Mainstem Function and Adverse Fishery- and Collection-Related Activities. Whenever available, empirical data were used in the stress assessment. Where empirical information was not available, NMFS staff relied on best professional judgment to assign a severity ranking to each stress by life stage. Refer to Appendix B for more detailed information on the methodologies used to rank stresses. The stresses assessed in this plan are listed in Table 3-4.

In the following subsection we summarize the stresses existing within the SONCC coho salmon ESU, with a brief description of the effects to coho salmon and their habitat associated with each stress. In addition, each population profile (Chapters 7 to 46) provides a detailed description of each stress at the population level, and the recovery strategy and actions recommended to achieve viability by reducing the severity of each stress as needed.

Table 3-4. Summary of stress severity ranking by population. Stress ranking represent CAP results as follows: L = Low, M = Medium, H = High, VH = Very High. See Appendix B for definition of severity rankings. See Chapters 7 to 46 for detail about any particular population's ranking.

| | **Stresses** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Population** | Adverse Hatchery Related Effects | Impaired Water Quality | Degraded Riparian Forest | Increased Disease/ Predation / Competition | Altered Sediment Supply | Lack of Floodplain and Channel Structure | Altered Hydrologic Function | Barriers | Impaired Estuary/ Mainstem Function | Adverse Fishery- and Collection-Related Effects | Total High or Very High |
| Elk River | L | H[1] | H | L | M | VH[1] | H | M | M | L | 4 |
| Lower Rogue River | M | VH[1] | H | L | H | VH[1] | M | M | VH | L | 5 |
| Chetco River | L | H | VH[1] | NA | M | VH[1] | H | L | H | L | 5 |
| Winchuck River | L | VH[1] | H | NA | H | VH[1] | H | M | H | L | 6 |
| Brush Creek | L | L | VH[1] | NA | M | VH[1] | H | L | L | L | 3 |
| Mussel Creek | L | M | VH[1] | NA | H | VH[1] | H | L | H | L | 5 |
| Hunter Creek | L | H | VH[1] | NA | H | VH[1] | M | L | H | L | 5 |
| Pistol River | L | H | VH[1] | NA | VH | VH[1] | H | L | H | L | 6 |
| Smith River | M | H | M | L | M | H[1] | L | H | H[1] | M | 4 |
| Lower Klamath River | M | M | H | M | VH[1] | VH[1] | H | M | H | L | 5 |
| Redwood Creek | L | VH | H | M | H | VH[1] | M | L | VH[1] | L | 5 |
| Maple Creek/Big Lagoon | L | L | M | L | VH[1] | VH[1] | M | L | VH | L | 3 |
| Little River | L | M | H | NA | VH[1] | H[1] | M | M | M | L | 3 |
| Mad River | M | VH | H | M | VH[1] | VH[1] | M | M | VH | L | 5 |
| Elk Creek | L | M | H[1] | NA | M | H[1] | M | L | M | L | 2 |
| Wilson Creek | L | L | H[1] | NA | H | H[1] | M | L | M | L | 3 |
| Strawberry Creek | L | M | M | NA | H | M | M | H[1] | H[1] | L | 3 |
| Norton/Widow White Creek | L | M | VH[1] | NA | M | H[1] | M | M | L | L | 2 |
| Humboldt Bay Tributaries | L | H | H | L | VH | VH[1] | M | H | H[1] | L | 6 |

| Population | Adverse Hatchery Related Effects | Impaired Water Quality | Degraded Riparian Forest | Increased Disease/ Predation / Competition | Altered Sediment Supply | Lack of Floodplain and Channel Structure | Altered Hydrologic Function | Barriers | Impaired Estuary/ Mainstem Function | Adverse Fishery- and Collection-Related Effects | Total High or Very High |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Stresses** | | | | | | | | | | |
| Low. Eel/Van Duzen rivers | L | H | H | H | VH | H[1] | M | L | H[1] | L | 6 |
| Bear River | L | VH | VH[1] | NA | VH | VH[1] | L | L | H | L | 5 |
| Mattole River | L | H | H | NA | H | VH[1] | VH[1] | L | H | L | 6 |
| Guthrie Creek | L | M | M | NA | H[1] | H[1] | L | L | M | L | 2 |
| Illinois River | M | H | VH[1] | M | H | H | VH[1] | H | VH | L | 7 |
| Mid. Rogue/Applegate rivers | M | VH | VH[1] | H | H | VH | VH[1] | H | VH | L | 8 |
| Upper Rogue River | M | VH[1] | VH | H | VH | VH | VH[1] | H | VH | L | 8 |
| Middle Klamath River | M | H[1] | M | H | H | H[1] | H | H | H | L | 7 |
| Upper Klamath River | VH | H | H | H | H | VH | H[1] | VH[1] | H | L | 9 |
| Salmon River | M | M | H[1] | M | M | H[1] | L | L | M | L | 2 |
| Scott River | M | VH | VH[1] | M | VH | H | VH[1] | L | VH | L | 6 |
| Shasta River | H | VH[1] | H | VH | M | H | VH[1] | H | VH | L | 8 |
| South Fork Trinity River | VH | H[1] | H | L | H[1] | H | H | H | M | L | 6 |
| Lower Trinity River | VH | M | M | M | H | VH[1] | H[1] | M | M | L | 4 |
| Upper Trinity River | VH[1] | M | M | H | M | H | VH[1] | VH | M | L | 5 |
| South Fork Eel River | L | H | H | H | VH | VH[1] | H[1] | H | H | L | 8 |
| Mainstem Eel River | L | H[1] | H | H | VH | VH[1] | H | M | H | L | 7 |
| Mid. Fork Eel River | L | H[1] | H | H | H | H[1] | M | M | H | L | 6 |
| Mid. Mainstem Eel River | L | H | H | H | VH[1] | H | VH[1] | M | H | L | 7 |
| Upper Mainstem Eel River | L | VH | H | H | H | H | H[1] | VH[1] | H | L | 5 |
| North Fork Eel River | L | H[1] | H | H | VH[1] | H | H | M | H | L | 7 |

[1]Identified as a key limiting stress.

### 3.1.1 Adverse Hatchery-Related Effects

Three artificial propagation programs are part of the SONCC coho salmon ESU: the Cole Rivers Hatchery (Rogue River), Trinity River Hatchery ,and Iron Gate Hatchery (Klamath River) coho salmon programs (70 FR 37160, June 28, 2005). Annual coho salmon production goals at these hatcheries are 200,000, 500,000, and 75,000 respectively. These hatcheries produce not only coho salmon, but also Chinook salmon and steelhead for release into the wild. Together, these hatcheries release approximately 14,215,000 hatchery salmonids into SONCC coho salmon ESU rivers annually. In addition to the three hatcheries, the Mad River and Rowdy Creek hatcheries in California and the Elk River Hatchery in Oregon are located within the ESU and produce steelhead and Chinook salmon that can prey on or compete with natural SONCC ESU coho salmon.

Table 3-5. Production levels at hatcheries throughout the SONCC coho salmon ESU.

<table>
<tr><th>State</th><th>Hatchery</th><th>Coho Salmon Production</th><th>Chinook Salmon Production</th><th>Steelhead Production</th></tr>
<tr><td rowspan="5">Oregon</td><td rowspan="3">Cole Rivers[1]</td><td rowspan="3">200,000 (released into Rogue River)</td><td rowspan="3">1.6 million (spring-run released into Rogue River)</td><td>220,000 (summer- run released into Rogue River)</td></tr>
<tr><td>132,000 (winter-run released into Rogue River)</td></tr>
<tr><td>132,000 (winter-run released into Applegate River)</td></tr>
<tr><td rowspan="2">Elk River[2]</td><td rowspan="2">Not Applicable</td><td>325,000 fall-run smolts into Elk River</td><td rowspan="2">50,000 (winter-run smolts into Chetco River</td></tr>
<tr><td>200,000 fall-run smolts into Chetco River</td></tr>
<tr><td rowspan="4">California</td><td>Iron Gate[3]</td><td>79,710</td><td>6,280,978</td><td>104,324</td></tr>
<tr><td>Trinity River[3]</td><td>502,617</td><td>4,434,995</td><td>800,000</td></tr>
<tr><td>Mad River[4]</td><td>Not Applicable</td><td>Not Applicable</td><td>172,000</td></tr>
<tr><td>Rowdy Creek</td><td>Not Applicable</td><td>105,000</td><td>100,000</td></tr>
<tr><td colspan="5">[1] Data from ODFW 2014a<br>[2] Data from ODFW 2014b<br>[3] Data from ICF/Jones and Stokes 2010<br>[4] Data from CDFW 2013</td></tr>
</table>

Hatchery fish can affect natural salmon populations through a variety of ecological mechanisms, such as increased competition (Nickelson et al. 1986, NRC 1996, McMichael et al. 1997), predation (Sholes and Hallock 1979, HSRG 2004), genetic dilution (NRC 1996), and disease transmission (Goede 1986, NRC 1996, Coutant 1998, Moffitt et al. 1998). These interactions can occur immediately after release (presmolt or smolt stage) or after most hatchery smolts have emigrated. Effects from these stresses may include, on a population level: decreased spawning and reproductive success, decreased productivity, decreased abundance, changes in diversity and spatial structure, and mortality (Chilcote et al. 1986, Leider et al. 1990, Berejikian 1995, Fleming et al. 1997, McLean et al. 2003, HSRG 2004, Araki et al. 2009, Araki and Schmidt 2010, Williamson et al. 2010, Thériault et al. 2011, Whitcomb et al. 2014). In a recent literature review, 12 studies found negative effects of hatchery rearing on the fitness of hatchery fish, 8 studies found decreased reproductive success of hatchery origin fish, and 4 additional studies reported a decrease in the survival rate of hatchery fish as compared to wild fish (Araki and Schmidt 2010).

### Competition

If hatchery fish are released in large numbers relative to natural-origin juveniles in a limiting environment, natural-origin fish may be affected through competition (Nielsen 1994). Competition occurs when the demand for a resource by two or more organisms exceeds the available supply (McMichael et al. 1999). Adverse competitive effects of hatchery salmonids on natural-origin salmonids may include food resource competition, competition for spawning sites, and redd superimposition (NMFS 2002a). Several studies have shown that wild fish may be displaced from preferred feeding and hiding locations by hatchery fish (Abbott et al. 1985, McMichael et al. 1997), which can lead to increased vulnerability to predation and decreased forage ability (McMichael et al. 1999). Ruggerone and Nielsen (2004) found evidence that intraspecific and interspecific competition with hatchery-origin juveniles and smolts in estuaries decreased the survival and growth rate of wild juveniles.

Adverse effects of competition may result from direct interactions, whereby a hatchery-origin fish interferes with natural-origin fish's access to limited resources, or through indirect means, such as the use of a limited resource by hatchery fish, which reduces the amount of resources available for natural-origin fish (SIWG 1984). Newly released hatchery smolts may compete with natural-origin smolts for food and space in areas where they interact during downstream migration (HSRG 2004). Interactions with juvenile hatchery-origin salmonids may lead to behavioral changes in natural-origin salmonids that are detrimental to productivity and survival (Pearsons et al. 1994). Many studies have suggested that hatchery-origin fish are competitively superior (when they are released at a larger size than the natural fish) and can displace natural-origin fish (Nickelson et al. 1986). Natural-origin fish may be competitively displaced by hatchery fish early in life, especially in cases when hatchery fish are more numerous, are of equal or greater size as wild fish, or are released as non-migrants and have taken up residency before natural-origin fry emerge from redds (Nielsen 1994, Pearsons et al. 1994).

Adverse effects from these interactions are dependent on the exposure time between populations, and the quantity and quality of habitat and resources available. The relative size of affected natural-origin fish when compared to hatchery fish, as well as the abundance of hatchery fish encountered, also will determine the degree to which natural-origin fish are displaced (Steward and Bjornn 1990). Large hatchery releases may cause displacement of rearing natural-origin juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations or premature out-migration (Pearsons et al. 1994). Hatchery origin fish may also alter natural-origin salmonid migratory responses or movement patterns, leading to a decrease in foraging success (Hillman and Mullan 1989, Steward and Bjornn 1990).

In a review of 270 references on ecological effects of hatchery salmonids on natural salmonids, Flagg et al. (2000) found that, except in situations of low wild fish density, increasing release numbers of hatchery fish can negatively impact naturally produced fish. Evident from the review is that competition of hatchery fish with naturally produced fish almost always has the potential to displace wild fish from portions of their habitat (Flagg et al. 2000). Additional data on competition varies, and effects have been shown to be neutral to negative depending on the situation (NMFS 2002a). Any competitive interactions likely diminish as hatchery-produced fish disperse, but resource competition may continue to occur at some unknown, but lower level as natural-origin juvenile salmon and any commingled hatchery juveniles emigrate seaward (USFWS 1994).

**Predation**

Release of large numbers of hatchery salmonids in freshwater and estuarine areas brings risks to wild salmonids attributable to direct predation (direct consumption) or indirect predation (increases in predation by other predator species due to enhanced attraction) (NMFS 2002a). Studies have shown that hatchery fish can prey on smaller wild fish in some situations (Sholes and Hallock 1979, Hawkins and Tipping 1999, Pearsons et al. 2007, Naman and Sharpe 2010). The spatial and temporal overlap of predator and prey is one of the most influential factors in determining the extent of effects from predation (Naman and Sharpe 2010).

Hatchery-origin fish may prey upon wild juvenile salmonids at several stages of their life stage: when the smolts are newly released, when they have residualized prior to smolting (NMFS 2002a), or in estuarine and marine areas HSRG 2004). In general, natural-origin salmonid populations are most vulnerable to predation when natural-origin populations are depressed and predator abundance is high; in small streams, where migration distances are long; and when environmental conditions favor high visibility (SIWG 1984). Predation by hatchery fish on natural-origin smolts or sub-adults is less likely to occur than predation on fry. Naman and Sharpe (2010) found that there is at minimum a low level of predation occurring in all systems where yearling salmonids are released and overlap with smaller fish.

The potential for adverse effects on natural coho salmon populations is highest in late spring when lower flows and higher water temperatures may increase competition for suitable rearing habitat (CDFG and NMFS 2001). In the Trinity River, predation rates as high as 0.53 percent have been documented (Naman 2008). Naman (2008) found that when hatchery steelhead are released in March and April, natural-origin salmonids are very small, increasing the potential for predation. This study also found that hatchery-origin steelhead were able to consume prey that were up to 45 percent of their body length, and that hatchery-origin steelhead did not appear to be gape limited, meaning their prey was not too big to fit into their mouths (Naman 2008). Although the level of predation may not be as high in other SONCC coho salmon ESU basins with hatcheries, predation of natural coho salmon by hatchery steelhead is likely occurring at some level. Given the small number of wild-born juvenile coho salmon, predation at any level may be having an adverse effect on coho salmon.

### Genetic Diversity

Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1993, Quinn 1997). Straying occurs when an adult spawns in a stream other than the one it was born in. Natural straying serves a valuable function in preserving diversity through genetic drift and in re-colonization of vacant habitat. However, straying may be considered a risk when it occurs at unnatural levels or from unnatural sources, such as hatchery fish. Hatchery fish may be a threat to natural population productivity, diversity, and natural gene flow when they interbreed with natural-origin fish. Hatchery fish straying is considered a risk if it results in additional and potentially harmful gene-flow.

Hatchery activities can threaten the natural genetic diversity among salmon populations in several different ways. Many hatcheries have historically bred and released salmon that were not native to the drainage into which they were released. When these fish stray and breed with native salmon, the unique genetic attributes of the local salmon populations can be degraded or lost through dilution by the genetic attributes of the out-of-basin fish (Reisenbichler and Rubin 1999, Ford 2002). In addition, the transferring of genes from hatchery fish to wild fish can be problematic because hatchery programs have the potential to significantly alter phenotypic traits (Hard et al. 2000; Kostow 2004) and behavior (Berejikian et al. 1996) of reared fish. Genetic interactions between hatchery and naturally produced stocks can decrease the amount of genetic and phenotypic diversity of a species by homogenizing once disparate traits of hatchery and natural fish. The result can be progeny with lower survival (McGinnity et al. 2003, Kostow 2004) and ultimately, a reduction in the reproductive success of the natural stock (Reisenbichler and McIntyre 1977, Chilcote 2003, Araki et al. 2007b, Williamson et al. 2010, Chilcote et al. 2011, Thériault et al. 2011, Whitcomb et al. 2014), potentially compromising the viability of natural stocks via out breeding depression (Reisenbichler and Rubin 1999, HSRG 2004). Araki et al. (2009) found wild-born descendants of hatchery fish showed significant decreases in reproductive success, and that reproductive success can decrease as rapidly as 40 percent per captive reared generation. Hatchery fish may exhibit reduced homing fidelity relative to natural-origin fish (Grant 1997, Quinn 1997, Jonsson et al. 2003, Goodman 2005), resulting in unnatural levels of gene flow into recipient populations.

Natural populations in the Klamath and Trinity basins are heavily influenced by hatcheries (Weitkamp et al. 1995; Good et al. 2005) through genetic and ecological interactions. Genetic risks associated with out-of-basin and out-of-ESU stock transfers have largely been eliminated because such transfers rarely occur. However, two significant genetic concerns remain: 1) the potential for domestication selection in hatchery populations such as the Trinity River, where there is little or no infusion of wild genes, and 2) straying by large numbers of hatchery coho salmon either in basin or out-of-basin. Spawning by hatchery salmonids in rivers and streams is often not controlled (Independent Scientific Advisory Board 2002) and hatchery fish stray into rivers and streams, transferring genes from hatchery populations into naturally spawning populations (Pearse et al. 2007).

Because most of the main stocks in the SONCC coho salmon ESU (i.e., Rogue River, Klamath River, and Trinity River) remain heavily influenced by hatcheries and have little natural production in mainstem rivers (Weitkamp et al. 1995; Good et al. 2005), many of these populations have reduced genetic diversity. The genetic and life-history diversity of the Shasta

River population unit has been significantly impaired by the straying of hatchery-born coho salmon from Iron Gate Hatchery. Straying of adult hatchery coho salmon into the Shasta River has been estimated at 2, 73, 20, and 25 percent of the spawning population from 2007-2010, respectively (Chesney and Knechtle 2011b). Hatchery-origin coho salmon make up most of the spawning run to the Trinity River each year. On average, only three percent of in-river spawners in the Upper Trinity River were not reared in a hatchery (USFWS and HVT 1999). Between 1997 and 2002, hatchery coho salmon constituted between 85 percent and 97 percent of the coho salmon (adults plus jacks) returning to the Willow Creek weir in the Lower Trinity River (CDFG 2009). Most of these fish likely migrate upstream and interact with naturally-produced coho salmon in the Upper Trinity River. Spawning surveys in 1998-99 found a high proportion of hatchery strays (60-100 percent) in all Lower Trinity River streams where coho salmon were found (Dutra and Thomas 1999). Jong and Mills (1992) found that 35.8 percent of returning adults to the South Fork Trinity River in 1985 were of hatchery origin. Because adult coho salmon returns to Trinity Hatchery have been in excess of 25,000 fish during some years, it is likely that the stray rate of hatchery coho salmon to the South Fork Trinity River has continued to be high (>35 percent). Although the actual proportion of hatchery fish in the river changes from year to year and depends largely on natural returns, these data indicate that straying of hatchery coho salmon does occur in important tributaries of the Klamath River basin.

Not all effects of hatchery fish on natural origin fish are negative. In populations experiencing very low abundance, such as the Shasta River population, the presence of hatchery fish can help maintain a population until abundance increases or habitat improves. The addition of hatchery-origin fish to a population that is experiencing reduced abundance can assist in continuing the retention of a full set of genes and genetic characteristics that may only exist in the hatchery-origin population (Brannon et al. 2004). Using hatchery fish to improve genetic diversity may assist the population in the long run when abundance and productivity increase, allowing the complete life-history diversity and genetic traits of the population to exist for future generations (Brannon et al. 2004). Since hatchery fish retain genes from their originating population, increasing the breeding population size of an extant population by adding hatchery fish can provide a benefit by contributing genetic variation to the existing wild population, variation that is necessary to adapt to changing conditions over time (Brannon et al. 2004).

### Disease

Natural-origin coho salmon may be exposed to diseases from hatchery-born coho salmon through hatchery effluent, which can contain fish pathogens. Interactions between hatchery fish and natural fish in the environment may also result in the transmission of pathogens if either the hatchery or natural fish are harboring fish disease and the two types of fish interact (NMFS 2002a). Under natural, low-density conditions, most pathogens do not lead to a disease outbreak. When fish disease outbreaks do occur, they are often triggered by stressful hatchery rearing conditions, or by a deleterious change in the environment (Saunders 1991). Hatchery-origin fish may have an increased risk of carrying fish disease pathogens because of relatively high rearing densities that increase stress and can lead to greater manifestation and spread of disease within the hatchery population.

### 3.1.2 Impaired Water Quality

One of the most important ecological requirements of coho salmon is cold, clean, well-oxygenated water. Impaired water quality parameters in the SONCC coho salmon ESU include increased water temperature, changes in pH above or below optimum levels, reduced dissolved oxygen, increased nutrient loading, and increased extent or duration of turbidity. Human activities that impair water quality include water diversions, in-channel construction, riparian vegetation reduction, agriculture, alteration of the streambed and banks, components of timber management, and the introduction of point- and non-point source pollution from urbanization and industrialization. NMFS concluded that impaired water quality is either a high or very high stress in 27 out of 40 populations in the SONCC coho salmon ESU, primarily due to increased water temperature, decreased dissolved oxygen, and increased turbidity (Table 3-4; Chapters 7 to 46).

Increased water temperature is one of the most widespread (and greatest) stresses in the SONCC coho salmon ESU. Water temperature influences coho salmon growth and feeding rates (partly through increased metabolism) and development of embryos and alevins (McCullough 1999), as well as timing of life-history events such as freshwater rearing, seaward migration (Holtby and Scrivener 1989), upstream migration and spawning (Spence et al. 1996). Increased water temperature can be detrimental to the survival of most life stages of coho salmon, but in the SONCC coho salmon ESU summer-rearing juveniles are the most likely to be affected by elevated water temperatures. Elevated water temperature can result in increased levels of stress hormones in coho salmon, often resulting in mortality (Ligon et al. 1999). Increased water temperature, even at sub-lethal levels can inhibit migration, reduce growth, stress fish, reduce reproductive success, inhibit smoltification, contribute to outbreaks of disease, and alter competitive dominance (Elliott 1981). Increases in water temperature may result from changes in the quantity and quality of riparian vegetation, the presence of dams, water diversions, other anthropogenic activities, and have also been correlated to large-scale (or localized) climate change and precipitation. Additionally, threats including timber harvest, urbanization, roads, and other land use activities affect water temperatures within the SONCC coho ESU.

In addition to appropriate water temperatures, salmonids need adequate concentrations of dissolved oxygen for the survival of all life stages (Spence et al. 1996). Reduced levels of dissolved oxygen can impair the growth (Herrmann et al. 1962) and developmental (Silver et al. 1963) processes of various life stages of salmon, including eggs and fry. Low dissolved oxygen can also decrease the swimming (Davis et al. 1963), feeding and reproductive ability of juveniles and adults (Bjornn and Reiser 1991). Such impacts can affect fitness and survival by altering embryo incubation periods, decreasing the size of fry, increasing the likelihood of predation, and decreasing feeding activity (Carter 2005). Under extreme conditions, low dissolved oxygen concentrations can be lethal to salmonids (Bjornn and Reiser 1991).

Nutrient contributions from sources such as fertilizer run-off, livestock, and septic systems may foster algae blooms that can contribute to elevated pH levels, increased ammonia toxicity, and depressed dissolved oxygen levels. Algae and other aquatic plants create diel 24 hour cycles in which photosynthesis causes high pH during daylight hours and respiration causes low dissolved oxygen at night (Nimick et al. 2011), both of which may be stressful or lethal to salmonids. Additional water quality impairments may be caused when large algae blooms begin to decay and increase the biological oxygen demand (Lathrop et al. 1998, Landsberg 2002). These water quality problems may be exacerbated by reduced flows.

Both acidic (pH <6.5) or alkaline conditions (pH >8.5) can cause salmonid stress (Spence et al. 1996). Adverse effects from low pH can occur at levels that are not lethal to adult fish, but which can impair reproduction and other processes. Reproductive impairments include altered spawning behavior, reduced egg viability, decreased emergence success and reduced survival of the early life stages which are known to be the most vulnerable to low pH (Jordahl and Benson 1987). Conversely, chronic high pH levels in freshwater streams can also decrease activity levels of juvenile salmonids, induce stress responses, decrease or stop feeding, and induce a loss of equilibrium (Murray and Ziebell 1984). Prolonged exposure to pH levels of 8.5 or greater may exhaust the ion exchange capacity at gill membranes and lead to increased alkalinity in the bloodstream of salmonids (Wilkie and Wood 1995). If water temperatures are high (e.g. 25 °C), high pH may also cause conversion of ammonium ions to highly toxic dissolved ammonia (Goldman and Horne 1983).

Historically, populations of adult Pacific salmon and steelhead released mass quantities of nutrients, energy, and other essential biomolecules into their natal watersheds through the process of reproduction. These salmon-derived materials (marine-derived nutrients) support the productivity of freshwater and riparian food webs through release of eggs and carcass decomposition. The salmon-nutrients promote both primary and secondary productivity and ultimately juvenile salmonid growth (Bilby et al. 1996, Schindler et al. 2003, Kiffney et al. 2014). However, salmon spawning populations are severely reduced across much of their native range (CA, OR, WA, ID); population reductions of over 90% in some rivers are likely contributing to widespread resource limitation for salmonid-rearing food webs (Gresh et al. 2000). For example, a recent study in the Cedar River, Washington documented that observed food limitation in juvenile coho salmon can be remedied by providing access to salmon analogs (pasteurized pellets formed from adult Chinook salmon); specifically coho body size was 50% greater at the end of a 45-d experiment in which salmon analogs were added at a biomass density of 0.6 $kg/m^2$ (Kiffney et al. 2014). Similar juvenile salmonid growth responses have been observed in a variety of field and experimental studies (Bilby et al. 1996, Wipfli et al. 2004, Guyette et al. 2013).

A number of studies have suggested that restoration of food web processes, including restoring the resources provided from spawning salmon, may serve as an effective strategy in addressing food-limitation in salmonid-rearing food webs thereby contributing to population recovery of listed salmon populations (Wipfli and Baxter 2010). There are four possible approaches to addressing resource limitation of salmonid-rearing food webs, including additions of inorganic nutrients, salmon carcass analogs, natural salmon carcasses and increased adult escapement. Resource additions of salmon carcass tissue have promoted food web productivity, including juvenile salmonid growth, across a range of loading rates (~0.1 – 1.0 $kg/m^2$ wet mass of salmon tissue or analogs; Claeson et al. 2006, Janetski et al. 2009, Kohler et al. 2012, Kiffney et al. 2014).

The four approaches to restoring inputs of marine-derived nutrients have a number of advantages and disadvantages; which method is most effective and practical depends on a variety of conditions including time of year, ambient nutrient levels, spawning biomass densities, and logistical constraints (e.g., remoteness, costs, access to disease-free carcasses, staff, see Kiffney et al. 2005 and Compton et al. 2006). For example, the ecological effects of live adult salmon exceed those of carcasses (Tiegs et al. 2011) and resource additions in summer likely exceed those in late fall or winter (Kiffney et al. 2014). All nutrient addition projects, regardless of the method of enhancement, should be coupled with monitoring programs to ensure objectives and targets are met and that unintended consequences are avoided. What to monitor depends on technical and logistical constraints but could include nutrient concentrations in water (total and dissolved nitrogen and phosphorus); periphyton and invertebrate productivity; salmonid growth, biomass and smolt production; and the stable isotopes of carbon and nitrogen, which provide a tracer for salmon-derived nutrients (Bilby et al. 2001, Kiffney et al. 2005, Compton et al. 2006).

**Water Quality Programs**

Federal and state programs exist to maintain and improve water quality conditions throughout the SONCC coho salmon ESU. Both California and Oregon have statewide water quality programs aimed at improving current water quality conditions, and the U.S. Environmental Protection Agency (USEPA) works closely with both states to identify and improve conditions in impaired watersheds.

In 1969, the California Legislature enacted the Porter-Cologne Water Quality Control Act (the Act) to preserve, enhance and restore the quality of the State's water resources. The Porter-Cologne Act is the principal law governing water quality in California. Unlike the Clean Water Act, Porter-Cologne applies to both surface water and ground water. Beyond establishment of the state framework, this act has been revised to comply with the federal Clean Water Act.

The Act established the State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards (RWQCBs) as the principal state agencies with the responsibility for controlling water quality in California. Under the Act, water quality policy is established, water quality standards are enforced for both surface and ground water, and discharges of pollutants from point and non-point sources are regulated. The Act authorizes the SWRCB to establish water quality principles and guidelines for long range resource planning including ground water and surface water management programs and control and use of recycled water. The California Coastal Act of 1976 extended the California Coastal Commission’s authority indefinitely. The California Coastal Commission was established by a voter initiative in 1972, and provides oversight for projects that impact water resources along the California coast. The California Coastal Commission has joint responsibility with the State Board and Regional Boards for implementation of the state’s Nonpoint Source Program (see section 319 of the Clean Water Act, section 309 of the Coastal Zone Management Act of 1972, and section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990).

The Oregon Department of Environmental Quality (ODEQ) is the state agency responsible for protecting Oregon’s surface waters and groundwater. ODEQ’s Water Quality Program develops water quality standards for Oregon’s waters, monitors water quality in designated river basins, regulates point source discharges, regulates injection systems by issuing permits to protect groundwater, and controls nonpoint sources of pollution through statewide management plans. Oregon has established both numeric and narrative water quality criteria, but does not have streamflow criteria to protect streamflow. Anti-degradation rules exist in areas around the state and help to maintain water beneficial uses of water. ODEQ is the state agency tasked with developing and implementing TMDLs.

Using the Oregon Water Quality Index to monitor trends in water quality, ODEQ regularly collects water samples at over 150 sites on more than 50 rivers and streams across the state. ODEQ visits most sites six times annually and tests a number of water quality variables at each visit. The state has monitored some sites routinely since the late 1940s (available at http://www.deq.state.or.us/lab/wqm/docs/09-LAB-004.pdf). The data are used to determine whether there is too much pollution in a water body, and to set limits on how much pollution a water body can receive. The ODEQ also maintains a volunteer water quality monitoring program around the state, providing equipment and assistance to volunteers and groups wanting to assist in water quality data collection (available at: http://www.deq.state.or.us/lab/wqm/docs/08-LAB-015.pdf). Oregon's Water Quality Nonpoint Source Control Program Plan (ODEQ 2000) identified the pollution management programs, strategies, and resources that were currently in place or that were needed to minimize nonpoint source pollution effects. The plan integrates a variety of other state and federal initiatives, and the state is currently completed the process of re-evaluating the program.

The Clean Water Act (CWA; 33 USC § 1251 et seq.) is a federal law aimed at improving and protecting water resources around the United States. The CWA was adopted "to restore and maintain the chemical, physical and biological integrity of the Nation's waters" (33 U.S.C. § 1251(a)). Under section 303(d) of the CWA (33 USC 1313(d)), States are required to identify those waters that are not meeting water quality standards. These waters are placed on the State's list of impaired waters, which is submitted to the U.S. Environmental Protection Agency (USEPA) for review and approval. States must develop total maximum daily loads (TMDLs) for these impaired waters. TMDLs are a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards. If the USEPA disapproves of the State's list of impaired waters and TMDLs, then the USEPA establishes the list and TMDLs.

Since the initial listing of SONCC coho salmon many TMDLs have been completed (Table 3-6), and California and Oregon are working to manage excessive pollutants and other water quality impediments. TMDLs in California are developed by RWQCBs. These TMDLs are designed as Basin Plan amendments and include implementation provisions. The beneficial use of salmonid fishes is most often affected by non-point source sediment and temperature impairments, so development of non-point source TMDLs is important. The ability of these TMDLs to protect coho salmon in Oregon and California is expected to be significant in the long term. Ultimately their efficacy in protecting coho salmon habitat will depend on how well the protective measures are implemented, monitored, and enforced.

Table 3-6. List of total maximum daily loads (TMDLs) and their status. Data from the North Coast Regional Water Control Board and the Oregon Department of Environmental Quality websites.

| Watershed | Pollutant(s) | TMDL Status | Watershed | Pollutant(s) | TMDL Status |
|---|---|---|---|---|---|
| Mattole River | Sediment and Temperature | Completed - 2004 | Klamath River | Sediment | In Progress |
| Lower Eel River | Sediment and Temperature | Completed - 2007 | Salmon River | Temperature | Completed - 2006 |
| Lower Eel River | Low Dissolved Oxygen | In Progress | Scott River | Sediment and Temperature | Completed - 2006 |
| Van Duzen River | Sediment | Completed - 1999 | Shasta River | Organic enrichment, Low DO, Temperature | Completed - 2007 |
| Middle Fork Eel River | Sediment and Temperature | Completed - 2003 | Upper Trinity River | Sediment | Completed - 2001 |
| Middle Mainstem Eel River | Sediment and Temperature | Completed - 2004 | Upper Trinity River | Mercury | In Progress |
| North Fork Eel River | Sediment and Temperature | Completed - 2002 | South Fork Trinity River | Sediment | Completed - 2001 |
| South Fork Eel River | Sediment and Temperature | Completed - 1999 | South Fork Trinity River | Temperature | In Progress |
| Upper Mainstem Eel River | Sediment and Temperature | Completed - 2004 | Upper Rogue River | Bacteria, DO, pH, Sediment, Temperature | Completed - 2008 |
| Elk River | Sediment | Completed-2011 | Middle Rogue River | Bacteria, Sediment, Temperature | Completed - 2008 |
| Freshwater Creek | Sediment | Completed-2011 | Lower Rogue River | Bacteria, Temperature | Completed - 2008 |
| Humboldt Bay | PCBs | In Progress | Lobster Creek (Rogue River) | Temperature | Completed - 2002 |
| Jacoby Creek | Sediment | In Progress | Bear Creek (Rogue River) | Temperature, Bacteria | Completed - 2008 |
| Mad River | Sediment, Turbidity, Temperature | Completed - 2007 | Lower Sucker Cr (Illinois River) | Temperature | Completed - 2002 |
| Redwood Creek | Sediment | Completed - 1998 | Illinois River | Temperature | Completed - 2008 |
| Redwood Creek | Temperature | In Progress | Chetco River | Bacteria, DO, pH, Temperature | Initiated |
| Klamath River | Nutrients, Bacteria, Temperature, Low DO | Completed - 2010 | Applegate River | Temperature, DO | Completed - 2004 |

Under CWA section 518(e) (33 U.S.C. § 1377(e)), tribes may apply to the USEPA to be treated as a State for purposes of various listed sections of the CWA, and USEPA-approved tribal water quality standards apply to surface waters within tribal lands. The Hoopa Valley, Yurok, and Karuk tribes have all developed water quality control plans (Hoopa Valley Tribe Environmental Protection Agency 2008, Yurok Tribal Environmental Program 2004, Karuk Tribe of California 2002) and the Quartz Valley and Resighini Rancherias have developed water quality programs (Quartz Valley Indian Reservation 2009, Resighini Rancheria Environmental Department 2006).

### 3.1.3 Degraded Riparian Forest Conditions

Riparian forests provide significant benefits to freshwater aquatic systems and the biota that live within and around them (Welsch 1991). Riparian forests influence the water table, moderate discharge during high flow events, regulate microclimates, provide shade to control temperature, protect stream banks from erosion (Bisson and Wondzell 2009), intercept sediment (Mellina and Hinch 2009), and help maintain instream water quality by filtering nutrient runoff (Welsch 1991). In addition, riparian forests are the source of instream large wood, which is important in creating and maintaining the habitat complexity necessary for high quality coho salmon rearing habitat (Crispin et al. 1993, Gallagher et al. 2012) and providing breeding sites for some amphibians and invertebrates (Moseley et al. 1998). Though all riparian forests supply wood to streams, old growth and late seral forests tend to be dominated by large conifers, which are uniquely capable of shaping instream and floodplain conditions as dead wood (Naiman et al. 2010).

Riparian dead wood provides numerous ecological functions, which vary somewhat depending on whether they remain standing or fall onto the forest floor or into water bodies such as streams, wetlands or ponds (Pollock and Beechie 2014). Thinning riparian conifer forests generally reduces the production of ecologically functional riparian dead wood (e.g., >30 cm or > 50 cm diameter) in both the short and long term, in correlation with the intensity of the thin (Pollock et al. 2012, Pollock and Beechie 2014). Optimal thinning conditions in moist Douglas-fir forests are in young (<40 years), densely planted (>300 trees per acre) stands where the primary management goal is to produce very large diameter live trees or very large diameter dead wood (Beechie et al. 2000, Pollock and Beechie 2014). For example, in Beechie et al. (2000), moderate thinning adjacent to large (15 m wide) streams increased "pool forming" wood production, whereas such thinning next to smaller streams reduced pool-forming wood production (See table 2 and figure 6 of Beechie et al. 2000). Riparian area structure and composition throughout the ESU has changed due to irrigation diversions, timber harvest, farming, grazing, wildfire, and urbanization, which all contribute to a high or very high ranking of degraded riparian forest conditions in 33 populations in the ESU (Table 3-4; Chapters 7 to 46). Of these, timber harvest has been the primary source of human disturbance in riparian areas (Villarin et al. 2009). In California, harvest of riparian redwood forests began in the middle of the 19th century but was then reduced after 1973 when the California Forest Practices Act set limits to harvest in riparian zones (Russell 2009). Historically, riparian forests were frequently harvested to the edge of the water and logs were dragged through the water to splash dams and haul roads (Richardson et al. 2012). Historic timber practices often significantly altered riparian forest composition to favor early successional stages dominated by deciduous species such as red alder and willow (Sedell et al. 1988, Russell 2009, Villarin et al. 2009). As a consequence, many stream banks have smaller trees of fewer species resulting in smaller, shorter-lived instream large wood (Sedell et al. 1988), even 100 years after harvest (Russell 2009).

Agriculture and livestock grazing have also degraded riparian forests. Geographic Information System (GIS) analyses of land use and ownership in coastal Oregon indicate that much of the larger low gradient, low elevation river valleys that historically supported coho salmon are privately owned and their riparian forests have been cleared for agricultural and developed uses (Burnett et al. 2007, Firman et al. 2011), a condition that also exists within coastal California. The conversion of forest to agriculture is associated with many negative effects on stream ecosystems, including lower densities of coho salmon, a lack of conifers, and a scarcity of large wood (Burnett et al. 2007, Firman et al. 2011). Livestock grazing affects riparian zones by compacting soil, removing vegetation, preventing woody seedling growth, and physically impacting stream morphology by breaking down banks, often resulting in wide, shallow channels (Belsky et al. 1999, Poff et al. 2011). Major bank erosion and mass wasting is much more prevalent on non-vegetated stream banks, resulting in increased sediment loads and channel widening (Naiman and Decamps 1997).

Riparian ecosystems are complex and the various threats to them should be viewed collectively (Poff et al. 2011). For example, episodic flooding plays a major role in structuring riparian vegetation in a natural ecosystem (Hawkins et al. 1997, Villarin et al. 2009), but after human alterations to riparian areas, the overall effects of floods are exaggerated (Hawkins et al. 1997). Disruption to natural landscapes, such as timber harvest (and associated road building), livestock grazing, and urbanization can promote rapid runoff (Hawkins et al. 1997, Beechie et al. 2012) and magnify the destructive power of peak flows to stream banks left unprotected by overgrazing or over-harvesting (Hawkins et al. 1997). Major floods occurring in the years 1955, 1964, 1974, 1986, 1997, and 2006 likely caused significant damage to riparian areas throughout the ESU. In general, eliminating or decreasing riparian areas may result in stream channelizing and straightening, channel widening, channel aggradation, and lowering of the water table (Belsky et al. 1999). The effects of degraded riparian conditions on fish habitat include reduction of streamside shade and cover, decreased large wood recruitment, increases in stream temperature, changes in water quality and stream morphology, and the addition of sediment through bank degradation and off-site soil erosion (Forest Ecosystem Management Team [FEMAT] 1993, Spence et al. 1996, Cohen 1997, Mellina and Hinch 2009).

### 3.1.4 Increased Disease/Predation/Competition

Disease and predation are locally significant throughout the ESU, and are likely limiting the recovery of some SONCC coho salmon populations. Currently, disease and predation are listed as a high or very high stress to 13 populations in the ESU (Table 3-4). Impacts from diseases are likely exacerbated by human-induced environmental impacts and activities, such as alteration of hydrologic function through dams and diversions, impaired water quality conditions, hatchery practices, habitat alterations, and changing climatic conditions. Coho salmon are exposed to numerous bacterial, protozoan, and parasitic pathogens throughout their lives, and have evolved with exposure to these and other organisms (Stocking and Bartholomew 2004). Susceptibility of fish to disease changes according to environmental condition and overall health. When water quality deteriorates, diminished flows cause crowding and stress, or when parasite spore loads are extremely high, then lethal disease outbreaks can occur (Foott 1995, Spence et al. 1996, Guillen 2003, CDFG 2004b, Yurok Tribal Environmental Program 2004, Nichols and Foott 2005). Disease issues arise when the interaction between host and pathogen is altered and when natural resistance levels become impaired by stressful environmental conditions or decreased fitness levels. Within the last few decades, the prevalence of diseases in wild stocks has been an increasing concern, and has become a factor in the continuing survival and viability of wild stocks of coho salmon (CDFG 2002a).

Diseases can affect coho salmon in almost any life stage where exposure occurs. Some diseases infect returning adults as they enter bays and estuaries, while other diseases attack or kill juveniles rearing upstream. Many pathogens may remain dormant in juveniles or when conditions are not stressful, and then appear symptomatically when fish return to freshwater and conditions become stressful. Different life stages have different susceptibilities, making it difficult to discern time of infection or disease infection rates and causes. Known diseases and disease agents that can cause significant losses to adults include: bacterial kidney disease (*Renibacterium salmoninarum*), furunculosis (*Aeromonas salmonicida*), columnaris (*Flexibacter columnaris*), *pseudomonas/aeromonas*, and *ichthyopthirius* or “Ich” (*Ichthyopthirius multifilis*). Juvenile salmonids are primarily affected by furunculosis, columnaris (*Flavobacterium columnare*), coldwater disease (*Flexibacter psychrophilis*), *Nanophyetus salmonicola*, Aeromonid bacteria, pseudomonas/aeromonas, ichthyopthirius, the kidney myxosporean *Parvicapsula minibicornis*, and ceratomyxosis (*Ceratonova shasta*) (CDFG 2002a, Federal Energy Regulatory Commission [FERC] 2007).

Diseases proliferate when fish are stressed by high water temperatures, crowding, environmental contaminants, or decreased oxygen (Warren 1991). In addition, adequate water quantity and quality during the late summer months are critical in controlling or triggering disease epidemics, and degraded condition of these variables may trigger the onset of epidemics in fish that are carrying the infectious agents (Holt et al. 1975, Wood 1979, Matthews et al. 1986, Maule et al. 1988). Problems remain in identifying the proximate and ultimate causes of death due to epidemic disease outbreaks, and the subsequent effect that these are having on population survival numbers. The lack of data continues to hamper the efforts of managers to understand the full effect that disease is having on coho salmon populations.

Although not emphasized in the original listing document, ceratomyxosis, which is caused by *C. shasta*, is one of the most significant diseases affecting juvenile coho salmon due to its prevalence and impacts in the Klamath Basin (Nichols et al. 2003). Bartholomew et al. (2006) believes that the recent increases in air temperature may be compounding the disease potential in the Klamath Basin. High water temperature, low dissolved oxygen, high pH (alkalinity) and possibly unionized ammonia in the mainstem Klamath River create stressful conditions for all ages and types of salmonids. These conditions can then increase disease transmission to coho salmon. Severe infection of juvenile coho salmon by *C. shasta* may be contributing to declining adult coho salmon returns in the Klamath basin (Foott et al. 2010). *C. shasta* has been responsible for most of the mortality of Klamath River juvenile salmonids in recent years. Mortality rates from temporary and longer term exposures at various locations in the Klamath River vary based on location, time of year, year, and water temperature, but are consistently high (10 to 90 percent) (Bartholomew 2008).

In addition, parasitic infections by *P. minibicornis* were detected in 65 percent of young of the year and 71 percent of yearling coho salmon in the mainstem Klamath River in 2007 (Nichols et al. 2008). Additionally, the Klamath River below Iron Gate Dam supports large populations of the intermediate host (a polychaete worm) of *C. shasta* due to an abundant food supply (particulate organic matter) and ample amounts of its two favored substrates (fine particulate organic matter that settles on the bottom of the river bed and mats of the attached algal species *Cladophora* that are stimulated by high nutrient levels).

Adults in the Klamath basin are also impacted by other diseases, primarily from the common pathogens *Ichthyopthirius multifilis* (Ich) and *Flavobacterium columnare* (columnaris) (NRC 2004). These pathogens were partially responsible for the 2002 adult fish kill on the Klamath River (USFWS 2003, Lynch and Risely 2003, Belchik et al. 2004, CDFG 2004b). During this event, over 300 coho salmon and 34,000 Chinook salmon were killed by a disease epizootic from Ich and columnaris, which was exacerbated by stressful conditions in the Klamath River (USFWS 2003, Belchik et al. 2004, CDFG 2004b). Conditions favoring massive growth of Ich and columnaris were created that year due to high densities of returning Chinook salmon, low September flows and warm water temperatures (USFWS 2003, Belchik et al. 2004, CDFG 2004b) that likely delayed and inhibited migration of adult fish further upstream (USFWS 2003). Adult mortality from Ich and columnaris are not as common as juvenile mortality from *C. shasta* or *P. minibicornis* (Bartholomew et al. 2003). In summary, disease effects are likely to negatively impact all of the VSP parameters for the SONCC coho salmon ESU, especially in the Klamath River Basin, because both adults and juveniles can experience high mortality in some years.

At the time of listing, predation was listed as a factor contributing to the decline and listing of coho salmon in the SONCC ESU, but more recent data suggests that it is a bigger problem than originally thought. Notable predators include non-native Sacramento Pikeminnow (*Ptychocheilus grandis*) and hatchery fish, as well as predation by other non-native species in some areas. These impacts are exacerbated by habitat modification, impaired water quality, hatchery practices, and other anthropogenic activities (Marine and Cech 2004).

In some watersheds, the rapid expansion of invasive predator populations was facilitated by alterations in habitat conditions (particularly increased water temperatures) that favor these species (Brown et al. 1994). Non-native fishes such as Sacramento pikeminnow, smallmouth bass (*Micropterus dolomieu*), brown trout (*Salmo trutta morpha fario*) and channel catfish (*Ictalurus punctatus*) can consume significant numbers of juvenile salmon (NMFS 1998). Sacramento pikeminnow have been observed throughout the Eel River basin and are a predator likely limiting juvenile coho salmon survival (CDFG 1994, 2004; NMFS 1996). In the Trinity River, brown trout are abundant enough to make up a substantial proportion of observations by biologists collecting juvenile salmonid habitat utilization data (Martin, A., pers. comm. 2009) and they likely consume naturally produced fry and juvenile coho salmon. Without adequate avoidance habitat (deep pools and undercut banks), and adequate flows for migration and rearing, predation can have a significant negative effect on juvenile salmonid growth (Quinn and Peterson 1996, Schlosser 1987, Bugert and Bjornn 1991, Bjornn and Reiser 1991, Brown 1999).

In addition to non-native species, hatchery fish can exert predation pressure on juvenile coho salmon. Native fishes in coastal streams and rivers have generally coevolved with native salmon and steelhead, which are also used for hatchery stocks. Under natural conditions native fishes may subsist with minimal, if any, negative interactions with salmon and steelhead in rivers and streams. The addition of large numbers of hatchery fish at one time and location, such as that occurring under salmon and steelhead stocking programs, may potentially result in locally elevated rates of predation and competition (ICF/Jones & Stokes 2010). The potential for predation and competition between hatchery‒reared and naturally produced salmonids depends on the degree of spatial and temporal overlap, differences in size and feeding habitats, migration rate and duration of freshwater residence, and the distribution, habitat use, and densities of hatchery and natural juveniles (Mobrand et al. 2005). Recently, concern has been expressed about the potential for hatchery‒reared salmon and steelhead to prey on or compete with wild juvenile Pacific salmonids (*Oncorhynchus* spp.) and the impact this may have on threatened or endangered salmonid populations (Naman 2008, Kostow 2009). Released at larger sizes and in great quantity, hatchery-reared salmonids prey on naturally-produced juvenile coho salmon (Kostow 2009). For example, predation by hatchery fish may result in the loss of tens of thousands of naturally produced coho salmon fry annually in some areas of the Trinity River (Naman 2008). Nickelson (2003) demonstrated that the productivity of wild coho salmon in 14 Oregon coastal basins was negatively correlated to the average number of hatchery smolts released into these basins, suggesting strong ecological interactions between hatchery and wild fish. Nickelson (2003) also reviewed evidence for the role of behavior and concluded that large numbers of hatchery fish likely increase mortality of wild fish by attracting predators and/or increasing their exposure to predators.

Predation by marine mammals (principally seals and sea lions) is a concern in areas experiencing dwindling run sizes of salmon (69 FR 33102, June 14, 2004). However, salmonids appear to be a minor component of the diet of marine mammals and therefore this type of predation is likely not contributing significantly to further decreases in run sizes (Scheffer and Sperry 1931, Jameson and Kenyon 1977, Graybill 1981, Brown and Mate 1983, Roffe and Mate 1984, Hanson 1993, Goley and Gemmer 2000, Williamson and Hillemeier 2001). Among other mammalian predators that can impact salmonid populations in freshwater areas, mink (*Mustela vison*) and otter (*Lutra canadensis*) can take significant numbers of overwintering coho salmon juveniles and migrating smolts, although this is dependent upon conditions favorable to predators and the availability of other prey (Sandercock 1991).

### 3.1.5 Altered Sediment Supply

The complex riverine habitat that coho salmon thrive in depends upon a balance of instream structure, transport capacity, and sediment supply (Yarnell et al. 2006). The alteration in the quantity and composition of the sediment supply into streams and rivers is a stress created through a variety of human induced threats. Increases in turbidity, changes in the quantity and quality of suspended sediment, and associated decreases in water quality can be caused by a variety of activities including timber harvest, grazing, agriculture, mining, road building, urbanization, and construction (Bash et al. 2001). These activities, when performed in excess or without proper management, have been shown to have the ability to contribute to periodic pulses or chronic levels of suspended sediment in streams (Bash et al. 2001) and likely have a wide range of effects on all life stages of salmonids. Impacts caused by these activities include changes to the size and composition of sediment entering the stream (Opperman et al. 2005, Kaufmann et al. 2009), changes to the quantity of sediment (Reid et al. 2010), and alterations in the timing of sediment entering stream channels (Cordone and Kelley 1961). Altered sediment supply is a high or very high stress in 31 populations in the SONCC coho salmon ESU (Table 3-4).

Many of the historical and ongoing anthropogenic activities in the ESU have caused changes to the amount and timing of sediment delivery to streams, most often evident as an increased amount of fine sediment. Increased sedimentation has been shown to have direct negative effects on coho salmon by interfering with their physiological and biological processes, and indirect effects through degradation of their habitat (Cordone and Kelley 1961, Koski 1966, Kondolf 2000). Accelerated rates of erosion and increased sediment delivery to streams after timber harvest and road construction are common occurrences in the mountainous, forested watersheds that are common in the ESU (Sidle et al. 1985, Montgomery et al. 2000). Impacts may result directly from increased sediment in suspension or through the deposition of fine sediment on or within the stream bed (Collins et al. 2011). High concentrations of suspended sediment can increase turbidity, decrease water clarity, and impair foraging efficiency thereby reducing growth and feeding rates of fish (Newcombe and McDonald 1991, Arauho 2011, Collins et al. 2011). Turbidity can reduce the amount of light available for photosynthesis and hence decrease primary production by algae and plants (Ryan 1991); however, there is also some evidence that these biota can adapt to maintain productivity at elevated sediment levels (Parkhill and Gulliver 2002, Izagirre et al. 2009). High suspended sediment loads can also clog or abrade sensitive fish gills and other soft tissues (Newcombe and Jensen 1996). The most common behavioral alteration associated with increased turbidity is reduced juvenile salmonid feeding behavior. There is an inverse relationship between turbidity and feeding efficiency or prey ingestion (Berg 1982, Berg and Northcote 1985, Sweka and Hartman 2001). Salmonids are visual predators that feed largely on drifting invertebrates, and changes in efficiency can be correlated to a decrease in their reactive distance to prey as turbidity increases. Feeding efficiency of juvenile coho salmon may drop by 45 percent at a turbidity level of 100 Nephelometric Turbidity Units (NTU) (Berg 1982), and turbidity as low as 70 NTU reduced salmonid foraging effectiveness and delayed their response to food (Bisson and Bilby 1982).

Increased sediment load can dramatically alter channel morphology. Pools may be filled, channels widened (Lisle 1982), riparian vegetation buried, streambank heights raised, and floodplain and flood prone areas disconnected (Kelsey 1980, Lisle 1982, Roberts and Church 1986, Knighton 1991). These alterations in geomorphology (i.e. excess sediment buildup, changes in proportion of fines) can increases the frequency and magnitude of localized flood events, which has occurred in Elk River, an important coho-bearing tributary to Humboldt Bay (Patenaude 2004). It may take decades before channels impacted by large aggradation events can fully recover (Madej et al. 2009). Lowland river systems are particularly susceptible to adverse effects of excess sedimentation owing to their low energy and limited ability to recover to their natural form (Kemp et al. 2011).

In spawning gravels, deposited fine sediment fills interstitial spaces between particles, reducing intergravel flow and inhibiting alevin movement, thereby decreasing survival rates (Kondolf 2000, Sparkman 2003, Greig et al. 2005). Excess fine sediment smothers habitat used by benthic organisms, decreasing the production of algae and macroinvertebrates that are an important food source for fry, juveniles, and smolts (Suttle et al. 2004, Cover et al. 2008). It can also decrease habitat availability and cover thereby increasing predation risks.

The quantity and timing of coarse sediment delivery to streams has also been altered by human activities throughout the SONCC ESU. Coarse sediment is an essential component of geo-fluvial mechanisms, such as gravel bar development (Ock and Kondolf 2012), and of spawning and rearing habitat for coho salmon (Lorenz and Eiler 1989). Reduced sediment supply can limit the availability of spawning substrate, alter availability of velocity refugia and macroinvertebrate habitat, and cause large scale changes in the morphology of downstream reaches (Cordone and Kelley 1961). Dams and other man-made barriers trap coarse sediment (Kondolf 1997) as well as decrease the frequency and magnitude of flows that mobilize these large particles thereby altering channel bed morphology, and impacting instream habitat (Ock and Kondolf 2012). Within the SONCC ESU, major dams on the Eel, Klamath, Applegate, Rogue, Shasta and Trinity rivers are of particular concern because they impede coarse sediment transport downstream into areas inhabited by coho salmon. Gravel mining also results in the removal of coarse sediment, which can significantly alter physical habitat characteristics and fluvial mechanisms, such as causing increased river depth, bank erosion, and head-cutting (Freedman et al. 2013). When upstream sediment sources are disturbed by dams or mining, high flows tend to transport only the finer fraction of the stream bed, leaving the coarser particles behind, causing channel incision and eventually an immobile channel (Kondolf 1997). These changes can create a significant stress on coho salmon, which rely on the natural dynamic structure of a river for instream cover, deep pools, appropriately sized spawning substrate and off-channel habitats, all of which cease to be created when the channel bed becomes immobile. These changes can last long after the dam or other structures are removed, and work to restore these areas may take years and even decades.

### 3.1.6 Lack of Floodplain and Channel Structure

Unconstrained reaches of low gradient rivers provide complex slow water habitats, including side-channels, lakes, backwaters, alcoves, sloughs, and beaver ponds (Independent Multidisciplinary Science Team [IMST] 2002, Branton 2011), that are essential for juvenile salmonid survival and rearing success. However, these reaches are highly susceptible to anthropogenic land use changes and alterations in channel morphology. Activities such as agriculture, timber harvest, mining and gravel extraction, flood control, road building, and urbanization and development of riparian areas can result in changes to floodplain and channel structure including channel straightening and reduced hydrological connectivity to off-channel and side channel habitat (Burnett et al. 2007 (timber harvest), Brown et al 1998 (mining and gravel extraction), Branton 2011 (flood control)). The lack of floodplain and channel structure is ranked as a high or very high stress in 39 of 40 populations of SONCC coho salmon (Table 3-4).

When stream channels are straightened, diked, and leveed, coho salmon suffer harmful effects through decreases of natural pool, winter rearing, and spawning habitats. Channel simplification also causes indirect changes in the timing of peak flows, increases in the frequency of scour events, and changes in the movement of sediment through the system (IMST 2002). Reduced hydrological connectivity may render these areas disproportionately susceptible to inter-annual variations in winter and summer stream flows (Sommer et al. 2005). When floodplains and off-channel habitats become disconnected from the main channel, juvenile fish can be displaced downstream during high flow events, encounter mortality from physical damage caused during high flows, and experience a decrease in the ability to survive through the winter from decreases in prey resources and slow water rearing and holding areas (Pess et al. 2002, Kock et al. 2012).

A lack of slow water, over-winter habitat has been shown to be a limiting factor to coho salmon populations. Solazzi et al (2000) showed that adding wood, alcoves, and dammed pools to a stream can significantly increase the over-winter survival of juvenile coho salmon.

A significant contributor to lack of floodplain and channel structure in the SONCC coho salmon ESU is a paucity of instream large wood. Coho salmon juveniles favor pools that contain shelter provided by large wood (Reeves et al. 1989). Research from across the Pacific Northwest has shown that streams with more large wood have more pools because large wood provides scour-forcing obstructions that create pools (Buffington et al. 2002, Montgomery et al. 2003, Rosenfeld and Huato 2003). Larger pieces of wood are more stable than smaller pieces of wood, and ratio of log length to channel width can be used as a gauge of stability (Montgomery et al. 2003). Past and current timber harvest practices have degraded riparian forests across the SONCC coho salmon ESU, decreasing the number of large conifers in riparian zones and reducing the potential for recruitment of long-lasting large wood (Sedell et al. 1988, Benda and Bigelow 2014). Hardwood trees like alder and willow are now the most abundant species in many riparian zones (Roni et al. 2002). These hardwood species do not provide long lasting large wood for channel forming processes (Cederholm et al. 1997) and their maximum potential size, and therefore stability, is much smaller than conifers. Early accounts of Pacific Northwest streams described prolific accumulations of wood in rivers and streams that settlers then cleared to facilitate movement of boats and logs during the late 1800s and early 1900s (Collins and Montgomery 2002). Then, during the 1950s, 1960s, and into the 1970s, fishery managers and biologists further removed large wood from streams, fearing it restricted fish passage and led to log jams and bank erosion (Sedell et al. 1988, Gallagher et al. 2012). As a result, the amount of large wood in streams is currently far lower than historical levels, resulting in a reduced capacity of stream habitats to support coho salmon.

The historical decline in beaver (*Castor canadensis*) populations has also contributed to lack of floodplain and channel structure. Beaver ponds provide high quality winter and summer rearing habitat for coho salmon (Reeves et al. 1989, Pollock et al. 2004). Beavers were highly valued for their fur pelts, and from the 1780s to 1840s, trappers swept through the Pacific Northwest, reducing the formerly robust beaver population to remnant levels (ODFW 2005b). The effect of decreased beaver abundance on coho salmon populations was likely very significant. For example, a study of the Stillaguamish River Basin in Washington compared current conditions with estimated historical conditions and concluded that the loss of beaver ponds accounted for most of the estimated 86 percent reduction in smolt production potential (SPP) of winter habitat and most of the 61 percent reduction of SPP for summer habitat (Pollock et al. 2004). Although still much reduced from pre-trapping levels, beaver populations have rebounded somewhat since the end of the era of intensive trapping. Recent studies in the Lower Klamath, Middle Klamath and Shasta sub-basins confirm that beaver ponds provide high quality summer and winter rearing habitat for coho salmon (Chesney et al. 2009, Silloway 2010). Information regarding the distribution and abundance of beavers within the SONCC coho salmon ESU is relatively limited (Lanman et al. 2013). In Oregon, ODFW fish habitat surveys detected beaver dams in the Rogue River basin but not in the Brush Creek, Mussel Creek, Hunter Creek, Pistol River, or Chetco River basins (although only a small portion of the Chetco basin was surveyed); there are no survey data available for the Elk River or Winchuck River. In California, beavers are present in the Smith River, Klamath River, Redwood Creek, Little River, Widow White Creek, Strawberry Creek, and Mad River basins. Beavers are absent in Humboldt Bay, Bear River, Mattole River, and most of the Eel River basin with the exception of Outlet Creek, mainstem Eel River in the vicinity of Cape Horn Dam, and a single sighting on Ten Mile Creek in the upper South Fork Eel sub-basin (Lanman et al. 2013, Riverbend Sciences 2014).

Using beaver as a salmon habitat restoration tool has proven to be effective and cost efficient (Pollock et al. 2007; DeVries 2012, Andonaegui 2000). In addition to creating off channel habitat for juvenile coho, beaver ponds can raise the water table, store spring runoff for late season release into streams (Parker 1986) and cool the water downstream of the beaver dams (Pollock et al 2003). Beaver ponds have been shown to expand riparian forests (Pollock et al 2007) and decrease erosive perturbation (Parker 1986). Beaver ponds slow high velocity stream flows and trap sediment behind their dams, which speeds up the recovery rate of down-cut stream channels and reduces turbidity downstream (Naiman et al 1988). Beavers are classified as a predatory species in Oregon and current regulations allow private landowners to destroy beavers and their habitat without notification to state agencies. In California, CDFW issues depredation permits to private landowners to destroy problematic beavers, and allows recreational trapping of beavers (no bag or possession limit) in Del Norte, Humboldt, Siskiyou, and Trinity counties. The coast of California south of Little River had previously been considered outside the historical range of beavers (Tappe 1942), but a recent review of historical evidence indicates that beavers were in fact native to the entire California coast (Lanman et al. 2013).

### 3.1.7 Altered Hydrologic Function

Water is the most essential component of fish habitat. The alteration of hydrology can create both environmental and physical changes that affect coho salmon. Environmental changes include altered timing and magnitude of high and low flows, alteration of temperature and dissolved oxygen levels, and changed cues for seasonal migration. Physical changes include aggradation or incision of the stream channel, scouring of the stream bed, disconnection of channel and floodplains, and damage to riparian vegetation from flooding events. Altered hydrologic function is ranked as a high or very high stress in 21 of the 40 populations in the ESU (Table 3-1, Chapters 7 to 46).

While every life stage of coho salmon requires adequate stream flow, summer rearing juveniles are most vulnerable because stream flows within the SONCC coho salmon ESU typically reach annual lows during the late summer or early fall due to lack of precipitation. Human water withdrawals for irrigation of agricultural crops and landscapes are highest during this period of lowest stream flow, resulting in the potential for significant flow reductions. Reduced summer flows can reduce growth and survival of coho salmon juveniles through several pathways, including: stream dewatering, increased water temperature, reduced habitat volume and quality, reduced food availability, and increased vulnerability to predation.

The most extreme case of reduced flow is stream dewatering, causing immediate mortality of any coho salmon rearing in the dry reach. While loss of surface flow can occur for prolonged durations, such as months, loss of surface flow can also occur on much shorter time scales such as hours or minutes. Small streams with multiple adjacent water diversions that operate simultaneously are particularly susceptible to running dry (Lancaster 2013) or experiencing rapid flow decreases (Deitch et al. 2009).

An additional stress to low-flow conditions is the emergence of marijuana cultivation in many areas of the SONCC coho salmon recovery domain. Although the number of plants grown each year is unknown, the water diversion required to support these plants is placing a high demand on a limited supply of water (Bauer, S., pers. comm. 2013a). Most diversions for marijuana cultivation occur at headwater springs and streams, thereby removing the coldest, cleanest water at the most stressful time of the year for coho salmon (Bauer, S., pers. comm. 2013b). Based on an estimate from the medical marijuana industry, each marijuana plant may consume 900 gallons of water per growing season (Humboldt Growers Association [HGA] 2010).

Juvenile coho salmon spend summer in freshwater and are sensitive to high summer water temperatures. Water temperatures can be strongly affected by the quantity of water in a stream, with effects varying by location and season according to site-specific factors. For example, computer simulations predict that a 50% reduction in flow would cause peak summer water temperature to increase as much as 2-3˚C in Bull Creek, a tributary to the South Fork Eel River, while a 50% increase in flow would decrease temperatures by a slightly lesser amount (Allen 2008). Similarly, another model predicts that a 50% decrease in groundwater accretions would increase peak summer water temperatures in mainstem Scott River by 2-3˚C, whereas a 50% increase would reduce water temperatures by as much as 2˚C (NCRWQCB 2005).

As flow decreases, so do the depth, volume, and complexity of pools where coho salmon juveniles over-summer (May and Lee 2004). Another potential result of low summer flow is loss of hydraulic connectivity in riffles (Magoulick and Kobza 2003). In such cases, pools become isolated from each other and drift of aquatic macroinvertebrates from riffles into pools is eliminated, reducing food availability for juvenile salmonids and hence reducing growth rates (Stillwater Sciences and Dietrich 2002, McBain and Trush 2012). Field experiments in a small Humboldt Bay stream found that even when hydraulic connectivity was maintained, reduced flow resulted in less invertebrate drift that reduced growth of rainbow trout (Harvey et al. 2006). With loss of connectivity, fish movement is restricted to single habitat units and they become more vulnerable to predation (Magoulick and Kobza 2003). Studies in a Washington stream found that juvenile coho that moved between habitat units grew faster than those who did not move (Kahler et al. 2001).

Increased flow (either total annual, spring or summer) results in increased smolt migration (Berggren and Filardo 1993, McCormick et al. 1998) and survival (Mathews and Olson 1980, Scarnecchia 1981, Giorgi 1993, Čada et al. 1994, Lawson et al. 2004). Berggren and Filardo (1993) found a significant correlation between average flow and smolt migration time in the Columbia River. Scarnecchia (1981) found a highly significant positive relationship between total stream flows and the rate of survival to the adult life stage for coho salmon in five Oregon rivers. Mathews and Olson (1980) documented a positive correlation between summer stream flow and adult coho salmon abundance. Coho salmon smolt production was positively correlated with summer flows in a coastal Washington stream (Beecher et al. 2010) and spring flows on the Oregon Coast (Lawson et al. 2004). Summer flow is an important explanatory variable of juvenile steelhead survival in tributaries of the Russian River (Grantham et al. 2012).

In addition to the relationship between flows and juvenile salmonid survival, flows can also affect juvenile salmonid growth. In studies on brook trout and juvenile Atlantic salmon, Davidson et al. (2010) and Xu et al. (2010) found that increased flow was generally associated with higher growth rates. Juvenile salmonids had 24 to 50 percent size reductions under low flow conditions (Davidson et al. 2010, Xu et al. 2010, Nislow and Armstrong 2012).

NMFS analyzed stream flow, precipitation, reservoir storage, and Geographic Information Systems (GIS) data to calculate a series of quantitative indicators, which were then used in conjunction with other information to inform NMFS' professional judgments, of the magnitude of the stress of altered hydrologic function for each coho salmon population and life stage (Asarian 2014). Altered hydrologic function is a high or very high stress in 18 of 39 populations throughout the ESU (Table 3-4).

As discussed in the following paragraphs, hydrologic function has been altered throughout the ESU by several mechanisms, including: 1) alteration of vegetation, which affects evapotranspiration and interception of precipitation; 2) landscape, channel, and floodplain alterations that increase storm flow, reduce infiltration, and reduce exchange between surface water and groundwater; and 3) water withdrawals reduce stream flow while dams impound water and shift the timing of stream flow.

The structure and species composition of vegetation in a watershed has a large effect on interception (i.e., precipitation that is caught by vegetation before it reaches the ground) and evapotranspiration. Timber harvest reduces the amount of precipitation intercepted by vegetation, resulting in increased peak flows during storm events (Reid and Lewis 2009), although this effect dissipates over time as vegetation re-grows (Grant et al. 2008). Reduced interception also elevates summer base flows for an initial number of years following harvest; as trees grow back, this effect diminishes with time and then reverses (Cafferata and Reid 2013, Surfleet and Skaugset 2013). Long-term studies in Oregon experimental forests showed that clearcut or thinning treatments, which replaced mature or old (100 to 250-yr-old) forest with young (i.e., 30 to 50-yr-old) forest reduced summer stream flow by 20-80% (Perry 2007), consistent with other studies showing higher evapotranspiration by young compared to old tree stands (Moore et al. 2004, Jassal et al. 2009, Wharton el al. 2009). In the Andrews Experimental Forest in Oregon, water use by riparian trees in a 40-year old stand was estimated to be 3.27 times greater than in a 450-year old stand, due to a combination of greater sapwood area, species composition (more alder and less Douglas fir and western hemlock), and younger trees in the 40-year old stand (Moore et al. 2004). Scaling sap flow measurements to the stand scale and using a forest growth model to predict future conditions, Stubblefield et al. (2011) concluded that stand-level water use by trees in the Mattole River watershed is likely to decline in future decades as the number of young (< 5 cm diameter at breast height) trees decreases due to canopy closure and stem suppression. A century of fire suppression has also altered vegetation communities, including the conversion of vast acreages of meadows (Mattole River and Range Partnership 2009) and oak woodlands (Engber et al. 2011) into dense stands of Douglas fir, which likely have higher evapotranspiration than the communities they replaced.

A variety of human activities reduce infiltration and groundwater recharge, resulting in increased storm flow and reduced base flow. By compacting soil and short-circuiting shallow subsurface flow paths, roads affect the timing and magnitude of peak flows (Grant et al. 2008). Other impervious surfaces such as parking lots and roofs have a similar effect (Spence et al. 1996, Booth and Jackson 1997). Filling of wetlands, channelization, and diking reduces floodplain connectivity and results in decreased groundwater recharge. In addition, trapping has greatly reduced the distribution and abundance of beavers (ODFW 2005b), resulting in fewer beaver dams available to recharge groundwater and promote floodplain connectivity (Pollack et al. 2007). The resulting channel incision can disconnect stream channels from their floodplains, causing a loss of riparian vegetation due to reduced groundwater levels and floodplain desiccation (Beechie et al. 2010). Salmon habitat can be severely altered by floods, sometimes requiring decades to recover. During flood events, land disturbances resulting from timber harvest, road construction, mining, urbanization, livestock grazing, agriculture, fire, and other uses may contribute sediment directly to streams or exacerbate sedimentation from natural erosive processes (California Advisory Committee on Salmon and Steelhead Trout 1988; California State Lands Commission 1993; FEMAT 1993). In some California streams, the pool-riffle sequence and pool quality still have not fully recovered from the 1964 regional flood. In fact, Lisle (1982) and Weaver and Hagans (1996) found that many Pacific coast streams continue to show signs of harboring debris flows from the 1964 flood, remaining shallow, wide, warm, and unstable.

By changing the flow of water, sediment, nutrients, energy, and biota, dams and water diversions interrupt and alter most of a river's important ecological processes, and therefore most aquatic organisms living in the river. There are numerous dams and diversions that occur throughout the SONCC coho salmon ESU, causing stress to coho salmon through a multitude of direct and indirect effects. More information on the effects of altered hydrologic function is included where applicable in other parts of Chapter 3, including section 3.2.9 (Dams and Diversions).

### 3.1.8 Barriers

Fish passage barriers in some way restrict the amount of available stream habitat on virtually all SONCC coho salmon rivers and are listed as a high or very high threat in 13 out of 41 populations (Table 3-4). The most common types of barriers include road-stream crossings (e.g., culverts), dams, tidegates, and agricultural diversions (Chapters 7 to 46). Unscreened diversions in particular were mentioned at the time of listing as a threat to SONCC coho salmon and are still a concern today (CDFG 2004a). Barriers can be inhibit salmonids through the physical blocking of stream reaches (e.g., dams, sediment buildup, changes in gradient at tributary mouths, etc.) or through water temperatures that increase to such an extent that salmonids cannot pass through the area during a portion of the year (Richter and Kolmes 2003, McElhany et al. 2000). These thermal barriers can be created by the removal of riparian vegetation, the simplification of stream channels, or from climate change, while physical alterations are mostly created by anthropogenic changes in land use.

While many road-stream crossing structures and diversions have been upgraded with structures that are designed to accommodate fish passage, several hundred road-related barriers and unscreened diversions still exist throughout the ESU, blocking access to hundreds of miles of freshwater habitat (CalFish 2009, ODFW 2008a). Efforts are currently underway to improve or remove fish passage barriers in as many places as feasible. Large dams used for water storage or hydroelectric purposes (such as the Trinity Dam, the Potter Valley Project dams in the Eel River basin, William L. Jess Dam on the Rogue River, and Matthews Dam on the Mad River) have blocked access to high quality habitat that was once accessible to coho salmon, in addition to changing the hydrologic function of their respective rivers. Efforts are being made around the ESU to remove or retrofit these structures, and return accessibility to previously blocked historical salmonid habitat. Dry stream reaches resulting from changes in stream flow, diversions, or channel aggradation can also present seasonal barriers to migration. The current lack of high quality habitat available within many populations has made the issue of barriers even more significant, because many barriers block some of the highest quality habitat and remaining refugia within key watersheds.

Approximately 450 manmade barriers remain throughout the California portion of the ESU (Koller 2010), which block access to historical spawning and rearing areas. Several significant fish passage improvements have occurred throughout the ESU. In the Rogue River, three dams were recently removed (Savage Rapids Dam in 2009, Gold Hill Dam in 2008, and Gold Ray Dam in 2010) and one was notched (Elk Creek Dam in 2008) to restore natural flow and fish passage. William L. Jess dam, the current upstream extent of the Rogue River, impounds Lost Creek Lake and is used for hydropower and flood control. Since 2005, in California 661 miles of stream have been opened to fish passage by removing 440 barriers (available at: http://www.dfg.ca.gov/fish/Administration/Grants/FRGP/index.asp). Overall, coho salmon passage has improved over the last five years, but barriers remain a major threat because many are still unaddressed and continue to block passage. More information regarding the direct and indirect effects of barriers can be found in the description of the effects of dams and diversions (Section3.2.9) and the description of altered hydrologic function (3.1.7). Geographically-specific information about barriers in need of remediation can be found in each population profile (Chapters 7 to 46) where applicable.

### 3.1.9 Impaired Estuary/Mainstem Function

Estuaries are semi-enclosed coastal water bodies where ocean and freshwater streams mix and include marshes, forested swamps, eelgrass beds, mudflats, tidal channels and backwater sloughs (Bottom et al. 2005, Gleason et al. 2011). Juvenile salmon use estuaries to acclimate to saltwater and to gather olfactory information for successful homing (Dittman et al. 1996, Bottom et al. 2005). During their freshwater to saltwater transition, juvenile coho salmon also depend on slow, backwater estuarine habitat, such as forested wetlands (Eaton 2010), to provide protection from predators and increased growth rates due to a highly productive macrodetrital food web based on accumulated organic matter (Sibert et al. 1977, Bottom et al. 2005). Examples within the SONCC coho salmon ESU include the Lower Klamath River, where coho salmon juveniles thrive in mainstem side channels, off-channel ponds, and backwaters where tributaries join the mainstem (Soto et al. 2008, Hillemeier et al. 2009). The typical coho salmon life cycle comprises one or more years of juvenile rearing in freshwater and then a relatively short but critical migration through the estuary on their way to the ocean (Shapovalov and Taft 1954, Thorpe 1994). However, coho salmon juveniles can rear extensively in estuaries (Miller and Sadro 2003, Lestelle 2007, Koski 2009, Craig 2010, Gleason et al. 2011, Jones et al. 2014), or move to the estuary for a season and then return to freshwater (Weybright 2011). For example, coho salmon smolts in Humboldt Bay, California spent an average of 9 to 12 days in tidal main channel floodplain and off-channel habitat and 15 to 21 days in the Humboldt Bay and the lower estuary (Pinnix et al. 2013). These diverse life-history strategies likely provide the species with resilience to detrimental conditions (Koski 2009, Bottom et al. 2009, Craig 2010).

Estuaries are found along the coastal shoreline, which is also home to a majority of the human population of the Pacific Northwest (Koski 2009, Gleason et al. 2011). In order to accommodate human development, many estuaries and associated low gradient stream reaches have been physically altered and degraded by diking, draining, and filling (Koski 2009). Anthropogenic activities have caused decreases in the quantity and quality of estuary habitat, decreases in water quality from timber harvest, road construction, riparian vegetation removal, and non-point source pollution (Gleason et al. 2011), as well as changes in estuary productivity from alterations in nutrient levels. In many watersheds, hydrologic connectivity and habitat have been reduced in estuaries and low gradient reaches by dikes, levees, tidegates, and culverts, which constrain and alter the natural hydrology, change instream channel morphology, and disconnect the channel from the surrounding floodplain (Koski 2009, Gleason et al. 2011). Estuarine habitat can be improved and expanded by removing or modifying tidegates (Roegner et al. 2010) or excavating new channels and ponds, as occurred recently in Salmon Creek (Love 2012) and Wood Creek (Anderson 2008, Hauer 2013) along Humboldt Bay.

More than half of Pacific Northwest wetlands have been lost due to anthropogenic activities, much of it in the stream-estuary zone commonly used by rearing coho salmon (Miller and Sadro 2003, Pinnix et al. 2013, Jones et al. 2014). For example, Redwood Creek is flanked for the first 3.4 miles by flood control levees that confine the channel to a 250-foot-wide channel migration zone, which bisects the estuary and has resulted in extensive loss of estuarine area and decreased habitat value (Cannata et al. 2006). Tideland reclamation and the construction of dikes and levees for agricultural purposes have considerably altered the natural function of the Eel River estuary, reducing estuarine habitat by 60% (Yoshiyama and Moyle 2010). Slough and creek channels that once meandered throughout the Eel River delta are now confined by levees that slow flow to a point that many have become filled with sediment (Yoshiyama and Moyle 2010). Levees occur in many populations within the ESU. Impaired estuary/mainstem function results in a high to very high impact in 28 out of 40 SONCC coho salmon populations (Table 3-4).

Estuaries and the salmonids that depend on them will be impacted by global warming in numerous ways (Katz et al. 2012). An acceleration of current rates of sea level rise will cause a shift in the extent and diversity of the coastal marshes, swamps, beaches, and other estuarine habitats in many areas of the Pacific Northwest (Galbraith 2005). Many low lying coastal and intertidal areas are expected to be inundated causing loss of freshwater marshes, swamps, and tidal flats and conversions to salt marshes and transitional marshes (National Wildlife Federation (NWF) 2007). Estuarine beaches will likely suffer losses due to inundation and significant erosion (NWF 2007). Under a conservative scenario of 2ºC warming within the next century, the Humboldt Bay estuary could lose 29% of its tidal flats, although salt marshes would expand (Galbraith 2005). Since marshes play a critical role in the regulation of nutrients and filtering of pollutants, net losses to coastal marsh habitat will likely cause declining water quality (NWF 2007). Habitat changes that result from sea level rise will be determined by local topography and estuaries in some populations, such as Elk River, are predicted to expand significantly with sea level rise (Flitcroft et al. 2013b). Climate change will alter precipitation and runoff patterns, which could increase estuarine salinity and in turn magnify the toxicity to fish of several pesticides often found in estuaries draining agricultural watersheds (Schlenk and Lavado 2011).

## 3.1.10 Adverse Fishery and Collection-Related Effects

### Historical Fishing Impacts

In the final rule to list SONCC coho salmon (62 FR 24588, May 6, 1997) overfishing was recognized as a contributing factor in the compromised escapement levels seen between 1950 and 1990. Fishing regulations were changed to be more protective of coho salmon beginning in 1994, when the retention of coho salmon in ocean commercial and recreational fisheries was prohibited from Cape Falcon, Oregon (south of the Columbia River) to the U.S./Mexico border. In recent years, there has been some limited commercial fishing for coho salmon in the area from Cape Falcon, Oregon to Humbug Mountain, Oregon, but these fisheries have operated within the ESA-related limits for the Lower Columbia River, Oregon Coast, and SONCC coho salmon ESUs. California waters were open to coho salmon retention prior to 1998. Currently, coho salmon retention is limited to the mark-selective recreational hatchery coho salmon fishery in Oregon waters, and tribal harvest under federal reserved fishing rights in the Klamath River basin.

On average, only two percent of coho salmon eggs survive to the smolt stage, and only 10% of those smolts survive to adulthood (Quinn 2005). Fishing affects SONCC coho salmon recovery because it targets these adult fish. Adult fish have demonstrated the ability to survive the stresses and threats affecting egg, fry, juvenile, and smolt life stage and will soon reproduce, and their capture before reproduction prevents successful reproduction.

### Federally Managed Fisheries

***Salmonid fisheries***

SONCC coho salmon are managed as part of the Oregon Coast Natural (OCN) stock aggregate, which includes coho salmon produced from all Oregon river and lake systems south of the Columbia River and contributes primarily to ocean fisheries off Oregon and California (Pacific Fishery Management Council [PFMC] 1999). OCN coho salmon are part of a larger aggregate of natural and hatchery production south of Leadbetter Point, Washington known as the Oregon Production Index (OPI) (Sharr et al. 2000). SONCC coho salmon are vulnerable to incidental mortality due to hooking and handling in the commercial and recreational ocean fisheries that primarily target Chinook salmon.

Amendment 13 to the PFMC Pacific Coast Salmon Plan, which was adopted in 1997, was designed to ensure that fishery-related impacts do not act as a significant impediment to the recovery of depressed OCN coho salmon stocks (Sharr et al. 2000). In contrast to previous management approaches, fishery management under Amendment 13 is based upon exploitation (i.e., mortality) rates, not escapement targets. These exploitation rates are based upon estimates of habitat production potential that incorporate effects of both freshwater and marine environments and are derived from habitat-based assessment and modeling of OCN coho salmon production (Sharr et al. 2000). Amendment 13 considers recovery of OCN stocks by ensuring sufficient spawner escapement to seed spawning habitat. A review of the effectiveness of Amendment 13 proposed more conservative allowable exploitation rates at very low levels of spawner abundance and marine survival, and slightly higher rates when conditions of spawner abundance and marine survival are favorable (Sharr et al. 2000). This proposal was adopted by the PFMC (L. Kruzic, NMFS, pers. comm. 2011). Two recent amendments to the Pacific Coast Salmon Plan are relevant to SONCC coho salmon. Amendment 14 (PFMC 2000b) redefines optimal yield, and both Amendment 14 and Amendment 16 (PFMC 2011a and NMFS 2011) provide new criteria to prevent or end overfishing of non-ESA listed species.

Ocean exploitation rates for SONCC coho salmon are based on the exploitation rate on Rogue/Klamath (R/K) hatchery stocks (NMFS 1999a). NMFS issued a biological opinion requiring that the overall annual ocean exploitation rate for R/K hatchery coho salmon remain less than 13% (NMFS 1999a). In 2001, the PFMC adopted management measures for Federal ocean waters under which all key coho salmon management objectives, based on the 1999 NMFS biological opinion, the Pacific Coast Salmon Plan, and the OCN Coho Salmon Work Group recommendations, were met. The major salmonid fishery affecting SONCC coho salmon is for Chinook salmon. Current regulations on Chinook salmon fisheries include time and area closures, seasonal quotas, minimum sizes, gear restrictions, and allowable take. Since 1999 the estimated exploitation rates on R/K hatchery coho salmon have been considerably lower than 13 percent (Figure 3-1). Due to a lack of life cycle monitoring stations and fishery monitoring effort, the effect of the fishery on particular populations within the SONCC coho salmon ESU is unknown. The viability criteria presented in this recovery plan were not considered in the biological opinion (NMFS 1999a), as they were not yet available when that opinion was prepared.

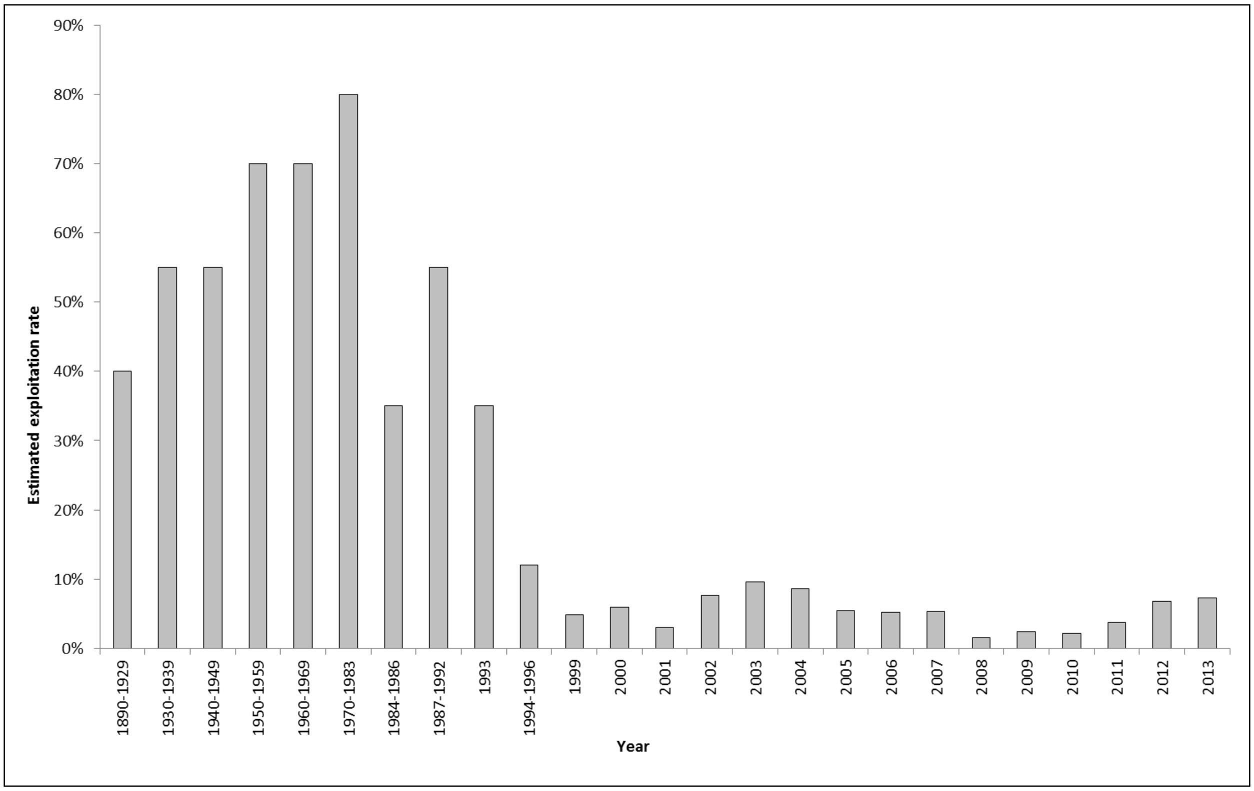



Figure 3-1. Estimated exploitation rate of coho salmon in southern Oregon and northern California. 1890 to 1996 rates are Oregon coast natural (OCN) stock aggregate estimates from ODFW (1997); 1998 rate is a preseason estimate for the OCN stock aggregate (PFMC 1999); 1999 to 2012 rates are post-season estimates for Rogue/Klamath (R/K) coho salmon (PFMC 2000 to 2004, 2005a, and 2006 to 2013, respectively); and the 2013 rate is a preliminary post-season estimate for R/K coho salmon (PFMC 2013a).

***Non-salmonid fisheries***

*Groundfish*

The groundfish fishery management plan includes 82 species, nearly all of which live on or near the ocean floor. Major types of fishes included in this group include rockfishes, flatfishes, roundfishes, sharks, and skates (NMFS 2003a). Most groundfish are harvested using trawls, pots, and hook-and-line gear. Mid-water and bottom trawls have been known to catch salmon (NMFS 1999b). NMFS has evaluated the impact of this fishery on listed salmon and steelhead and concluded it is not likely to adversely affect salmon or adversely modify critical habitat (NMFS 1999b and NMFS 2006). The Biological Opinion limits allowable bycatch of Chinook salmon in the trawl fisheries, but does not limit bycatch of other salmon or steelhead. The rationale is as follows: "Coho, chum, sockeye are caught in relatively low numbers in both the midwater trawl whiting fishery and the bottom trawl fishery with average catch per year coastwide in the tens to a few hundred of fish, and in the bottom trawl fishery in the tens of fish. Therefore, it is unlikely that listed ESUs of coho, chum, or sockeye will be significantly affected by the groundfish fishery" (NMFS 1999b)". Al-Humaidhi et al. (2012) summarized the observed and estimated total bycatch of salmon in West Coast fisheries, including groundfish, between 2002 and 2010. It is unknown what proportion of coho salmon observed in these fisheries originated in the SONCC coho salmon range. Bycatch of coho salmon in the coastwide non-hake groundfish sectors varied, but remained below 100 fish (Al-Humaidhi et al. 2012). In the Pacific hake sectors, coastwide bycatch peaked in 2007 at 475 coho salmon, and the bycatch in each of the next three years was below 100 (Al-Humaidhi et al. 2012). Based on the NMFS (1999b) and NMFS (2006) consultations, the threat posed by the groundfish fishery to SONCC coho salmon is low.

*Coastal Pelagics*

Coastal pelagic species (CPS) include northern anchovy, market squid, Pacific sardine, Pacific (chub or blue) mackerel, and jack (Spanish) mackerel. Anchovy and sardine are known as important forage species for all predators including salmon and steelhead. All the species in this group are extremely important to the ecosystem used by SONCC coho salmon. As explained in the 2003 regulatory amendment to the CPS fisheries management plan (PFMC 2005b):

> Anchovy, sardine, hake, jack mackerel, and Pacific mackerel achieve the largest populations in the California Current region as well as in other major eastern boundary currents. These populations are key to the trophic dynamics of the entire California Current ecosystem. Anchovies and sardines are the only fish in the ecosystem that consume large quantities of primary production (phytoplankton), all five of the species are significant consumers of zooplankton. All five species of fish, particularly mackerels and hake, and also squid are important predators of the early life stages of fish. The juvenile stages of squid and all five species of finfish, and in many cases the adults, are important as forage for seabirds, pinnipeds, cetaceans, and other fish.

As coho salmon grow, fish make up a greater proportion of their diet (Shapovalov and Taft 1954). The diet of ocean-caught coho salmon is dominated by fishes such as herring, sand lance, sardines, and smelts (Sandercock 1991). Targeted CPS fisheries could reduce the amount of prey available to SONCC coho salmon. Such deficits could negatively impact salmon, marine mammals, and top predators. In addition, harvest of prey species could increase the predation pressure on juvenile salmon. Prey species provide alternate food sources for predators of juvenile salmonids such as hake, and the presence of prey species can reduce predation pressure on juvenile salmonids (Emmett and Sampson 2007). There is an ongoing debate over how to account for the needs of all predators in the ecosystem when developing models to determine acceptable harvest levels of prey species (e.g., Marine Fish Conservation Network 2007). The National Research Council concluded there was a need for an ecosystem-based assessment of fishery impacts, rather than management of a single fish species in isolation (NRC 2006). NMFS has recognized the need for ecosystem-based management on the west coast, most recently through formulation of the NOAA Ecosystem Approach to Management and establishment of the California Current Regional Ecosystem as a management area (NOAA 2004).

The PFMC has adopted a conservative, risk-averse approach to management of CPS, which reduces the likelihood of such negative effects on salmon and their ecosystem. The need to "provide adequate forage for dependent species" is recognized as a goal and objective of the CPS fisheries management plan (PFMC 2011b). A control rule is a simple formula used by the PFMC in evaluating allowable harvest levels for each of the CPS. The CPS control rules contain measures to prevent excessive harvest, including a continual reduction in the fishing rate as the biomass declines. In addition, the control rule adopted for species with significant catch levels explicitly leaves thousands of tons of CPS biomass unharvested and available to predators. No ecosystem model currently exists that could calculate the caloric needs of all predators in the ecosystem, so the amount of this set aside is necessarily an estimate that may be modified if new information becomes available. Ocean temperature is a factor in the control rule for Pacific sardine, in recognition of the effects of varying ocean conditions on fish production rates. Allowable harvest rates are automatically reduced in years of poor production. The PFMC developed the Fishery Ecosystem Plan (FEP) to enhance the PFMC's species-specific management programs with more ecosystem science, broader ecosystem considerations, and management policies that coordinate Council management across its Fishery Management Plans and the California Current Ecosystem (PFMC 2013b). The FEP includes an initiative to protect unfished lower trophic level (forage) fish species (PFMC 2013b). NMFS has determined CPS fisheries are not likely to adversely affect ESA-listed species, including the SONCC coho salmon ESU (PFMC 2014). Due to the conservative control rules used to manage CPS fisheries, and the preservation of a portion of CPS biomass for predator consumption, the CPS fishery poses a low threat to SONCC coho salmon recovery.

*Pacific Halibut*

Pacific halibut (*Hippoglossus stenolepis*) occur on the continental shelf from California to the Bering Sea. Harvest of this species (not to be confused with the California halibut, *Paralichthys californicus*) is managed by the International Pacific Halibut Commission (IPHC), which determines allowable catch. The Pacific Fishery Management Council then allocates portions of the catch to commercial, recreational, and tribal fisheries in California, Oregon, and Washington. Although fishing for this species is allowed in California, in the past ten years only one Pacific halibut was commercially landed in waters off California (Bruce Leaman, Executive Director, IPHC, personal communication 12/18/07). Even in areas where commercial fishing for this species is more prevalent, bycatch of salmonids is rare. Perhaps this is because the favored commercial halibut gear, demersal longlines, are set near the ocean floor at depths where salmonids rarely occur. The IPHC conducts an annual survey of the species caught on commercial Pacific halibut longlines. The survey includes 1,200 stations off of Washington and Oregon, with one station on the Oregon/California boarder. Less than one salmon is captured per year survey wide, on average (Claude Dykstra, Survey Manager, IPHC, personal communication 12/18/07).

The recreational fishery for Pacific halibut extends into California. A very small portion of the allowable catch (8,308 lbs. in 2007) was allocated to the U.S. recreational fisheries south of Humbug Mountain, Oregon. The number of salmon caught in the recreational halibut fishery off California appears to be very small. In 2007, there were only five reported cases when recreational fishermen caught salmon and Pacific halibut on the same trip (Melody Palmer-Zwahlen, CDFG, 12/19/07, personal communication).

Based on the low incidence of bycatch of Pacific salmon in commercial or recreational Pacific halibut fisheries, and the fact that relatively little Pacific halibut fishing occurs in California, effects from this fishery pose a low stress to SONCC coho salmon recovery.

### State-Managed Fisheries

In Oregon, adipose-fin-clipped coho salmon (hatchery coho salmon) can be retained when caught recreationally in state-managed waters (streams, rivers, tidewaters and bays), subject to area-specific season and bag restrictions (ODFW 2011a). NMFS (2007a) estimated that 3.3 percent of Rogue/Klamath (R/K) hatchery coho salmon caught in this mark-selective fishery would die post-release. Retention of coho salmon caught in any California-managed fisheries in the range of the SONCC coho salmon ESU is prohibited (CDFG 2011). Some incidental coho salmon mortality likely occurs in association with the release of coho salmon in Chinook- and steelhead-directed freshwater fisheries, but is likely low (NMFS 1999a). The impact of California-managed inland fisheries on SONCC coho salmon has not been formally evaluated by NMFS. Formally evaluated means an ESA Section 7 consultation has been completed or a determination has been completed under any applicable limit in NMFS' protective regulations promulgated under ESA Section 4(d) (50 CFR 223.203).

### Tribal-Managed Fisheries

The Yurok and Hoopa tribes have federally recognized fishing rights and pursue subsistence, ceremonial, and commercial fisheries for Chinook salmon and steelhead in the Klamath River basin (CDFG 2002a). The number of coho salmon harvested by these tribes is less than the number of Chinook salmon taken in subsistence fisheries in the Klamath River and the Trinity River. The Karuk tribe uses dip nets to catch salmonids at Ishi Pishi Falls on the Klamath River. The Round Valley tribe holds a federally recognized right to pursue fisheries for salmon in the Eel River (Langridge 2002). The impact of in-river tribal fishing on the SONCC coho salmon ESU has not been formally evaluated by NMFS. Formally evaluated means an ESA Section 7 consultation has been completed or a determination has been completed under any applicable limit in NMFS' protective regulations promulgated under ESA Section 4(d) (50 CFR 223.203 or 223.204).

Fishing for coho salmon within the Yurok tribe's reservation on the lower Klamath River, which extends from about 2 miles upstream of Weitchpec, California, to the Pacific Ocean, has been monitored since 1992. During the period of monitoring, the Yurok Tribe has harvested approximately 70% of their catch below the Highway 101 bridge. The median Yurok harvest from the entire area from 1994 to 2012 was 345 coho salmon (YTFP 2014), which approximates an average annual maximum[6] harvest of 3.1 percent of the total run. The total run size for the Klamath basin was determined by combining wild and hatchery adult counts at the Trinity River, Iron Gate Hatchery, and Shasta and Scott river weirs (YTFP 2014). On average, about 42 percent of the coho salmon harvested by the Yurok Tribe were progeny of coho salmon that spawned in the wild (Williams 2010). The effect of the Yurok fishery on particular populations

[6]Denominator for calculation only includes coho salmon counts at Trinity River Weir, Scott and Shasta river, and Iron Gate Hatchery, and therefore does not include all Klamath and Trinity basin coho salmon escapement. Therefore, it is a maximum estimated harvest rate.

within the SONCC coho salmon ESU is unknown, because all nine of the Klamath River basin coho salmon populations migrate through the lower Klamath River.

Trinity River coho salmon are harvested by the Yurok and Hoopa tribes Table 3-7 describes the estimated percentage of the total Trinity coho salmon run harvested by each tribe.

Table 3-7. Estimated number of Trinity River coho salmon harvested by the Yurok and Hoopa tribes. Includes percentage of total adult run size harvested by Yurok and Hoopa tribes, from 1997 to 2008. M= Marked (hatchery), U = Unmarked (natural origin).

| Year | Estimated Yurok harvest | | Estimated Hoopa harvest[2] | | Estimated total Trinity River adult escapement[3] | | Percentage harvested by Yurok tribe | | Percentage harvested by Hoopa tribe | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | U[1] | M | U | M | U | M | U | M | U |
| 1997 | 22 | 2 | 39 | 3 | 1,885 | 271 | 1.2% | 0.7% | 2.1% | 1.1% |
| 1998 | 117 | 6 | 88 | 54 | 10,285 | 1,297 | 1.1% | 0.5% | 0.9% | 4.2% |
| 1999 | 120 | 9 | 65 | 36 | 4,785 | 630 | 2.5% | 1.4% | 1.4% | 5.7% |
| 2000 | 70 | 1 | 211 | 22 | 10,586 | 386 | 0.7% | 0.3% | 2.0% | 5.7% |
| 2001 | 1214 | 111 | 506 | 100 | 28,139 | 3,389 | 4.3% | 3.3% | 1.8% | 3.0% |
| 2002 | 327 | 4 | 327 | 20 | 15,653 | 526 | 2.1% | 0.8% | 2.1% | 3.8% |
| 2003 | 121 | 23 | 85 | 17 | 22,963 | 4,352 | 0.5% | 0.5% | 0.4% | 0.4% |
| 2004 | 553 | 302 | 312 | 80 | 27,167 | 10,092 | 2.0% | 3.0% | 1.1% | 0.8% |
| 2005 | 640 | 24 | 153 | 21 | 27,947 | 2,856 | 2.3% | 0.8% | 0.5% | 0.7% |
| 2006 | 241 | 24 | 442 | 38 | 18,774 | 1,734 | 1.3% | 1.4% | 2.4% | 2.2% |
| 2007 | 61 | 17 | 68 | 14 | 4,436 | 1,257 | 1.7% | 1.4% | 1.5% | 1.1% |
| 2008 | 147 | 13 | 262 | 53 | 6,864 | 1,302 | 2.1% | 1.0% | 3.8% | 4.1% |
| **Median 1997-2008** | **134** | **15** | **182** | **29** | **13120** | **1300** | **1.9%** | **0.9%** | **1.7%** | **2.6%** |

[1] Calculated as follows: (Estimated harvest of marked Trinity River Hatchery (TRH) fish, provided by Yurok Tribal Fisheries Program / estimated proportion of marked Trinity River Hatchery coho salmon that migrated upstream of the Willow Creek weir) - estimated harvest of marked Trinity River Hatchery fish. Jacks were excluded.
[2] Source: Hoopa Tribal Fisheries Program, unpublished data.
[3] Calculated as follows: Est. adult escapement above WC weir + Est. ocean incidental mortality[4] + Est. Yurok marked harvest + Est. Hoopa marked harvest + Est. recreational harvest upstream of WC weir (source: CDFG, unpublished data) + Est. recreational harvest downstream of WC weir (source: Hoopa Tribal Fisheries Program, unpublished data).
[4] Calculated as follows: (Est. Yurok marked harvest + Est. Hoopa marked harvest + Est. recreational harvest upstream of WC weir + Est. recreational harvest downstream of WC weir)* pre-season projected ocean incidental mortality rate (source: Pacific Fishery Management Council [PFMC] 2011).

Karuk fishermen are allowed by CDFW to catch salmon using dip nets at Ishi Pishi Falls on the Klamath River if they adhere to the same limits as Chinook salmon sport fishermen (CDFG 2002a). A Karuk tribe representative stated "its members rarely harvest more than 200 salmon and steelhead per year, that protected species such as coho salmon are never kept, and that these protected species are released alive" (Driscoll 2009).

### Collection for Research Purposes

When NMFS re-affirmed the listing of SONCC coho salmon in 2005 (70 FR 37160, 37196; June 28, 2005), NMFS identified collection or handling of fish among activities that may harm certain listed salmon ESUs and thus result in violation of the ESA Section 9 take prohibition. Information on SONCC coho salmon populations is needed for the NMFS 5-year status reviews, as well as to determine the effectiveness of habitat restoration actions, and ultimately for de-listing. This information is derived from research studies of life-history strategies, abundance, distribution, and genetics, and involves take of individuals.

Within the ESA, there are two mechanisms to enable listed fish to be taken for research purposes, and exempt the permit holder from the prohibitions of the ESA. Under Section 10(a)(1)(A) and NMFS implementing regulations at 50 CFR § 222.308, NMFS may issue permits for scientific research purposes or to enhance the propagation or survival of species listed as threatened or endangered under the ESA. The permitted activities must not operate to the disadvantage of the listed species and must provide a bona fide and necessary or desirable scientific purpose or enhance the propagation or survival of the listed species. NMFS generally issues permits for up to five years, although permits for longer periods have been issued.

NMFS regulations under ESA Section 4(d) (50 CFR § 223.203(b)(7)), provide that take prohibitions for certain listed threatened species of anadromous salmonids, including SONCC coho salmon, do not apply to scientific research activities conducted by employees or contractors of certain tribes and state fish and wildlife agencies, including the California Department of Fish and Wildlife and the Oregon Department of Fish and Wildlife, or as a part of a monitoring and research program overseen by or coordinated with that agency, if the agency meets specific requirements listed in these regulations.

Specific activities authorized for research purposes by either a permit issued under ESA section 10(a)(1)(A) or the ESA section 4(d) regulations described above may include: direct observation, capture (electrofisher, nets, trawls, and traps), handling, anesthetizing, marking, tagging, tissue sampling, and other activities necessary to conduct various studies to promote the conservation of the species, enhance the species' survival, or add significantly to the body of knowledge of SONCC coho salmon. The primary effects of these activities are in the form of harassment associated with intentional take. Harassment generally leads to stress and other sub-lethal effects and is caused by observing, capturing, and handling fish. Unintentional mortality may occur during handling or after the fish has been released. Depending on the activities and life stage, NMFS anticipates from one to five percent of handled fish may die. Permits may include any conditions deemed necessary by NMFS, including reporting or inspection requirements for monitoring the impacts of permitted activities.

Prior to issuance of either a permit under ESA section 10(a)(1)(A) or approval of a research program under the ESA section 4(d) regulations described above, NMFS must determine whether the action is likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat.

## 3.2 Threats

Threats are the activities or processes that have caused, are causing, or may cause the stresses and thus the destruction, degradation and/or impairment of SONCC coho salmon and their habitat. The major factors listed in 1997 as responsible for the decline of SONCC coho salmon were timber harvest, road building, grazing and mining activities, urbanization, stream channelization, dams, wetland loss, beaver trapping, water withdrawals and unscreened diversions for irrigation (62 FR 24588, May 6, 1997). Many of these activities continue to threaten coho salmon populations in this ESU, while additional threats have emerged as significant factors that should be addressed in order for recovery to occur. NMFS' an analysis of current threats in this recovery plan has identified the following as currently contributing to the destruction, modification, or curtailment of habitat or range: dams and diversions, channelization and diking, agricultural operations, timber harvest, climate change, roads, urban/industrial/residential development, high severity fire, mining and gravel extraction, invasive species, hatcheries, and fishing and collecting (See Chapters 7 to 46).

These threats have led to significant stresses on coho salmon populations throughout the ESU (Chapters 7 to 46) and have contributed to the decline of the species. The following threats (Table 3-8) occur throughout the ESU and are believed to be the main causes of the previously described stresses (Table 3-4). Table 3-8 lists the ranking assigned to each threat in each population of the SONCC coho salmon ESU. Population-specific ratings are discussed in Chapters 7 to 46.

Table 3-8. Threat severity ranking by population.

| Population | Threats | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate change | Roads | Channelization/ Diking | Agricultural Practices | Timber Harvest | Urban / Residential Industrial Development | High Severity Fire | Mining/Gravel Extraction | Dams/Diversions | Invasive/Non Native Alien Species | Hatcheries | Road Stream Crossing Barriers | Fishing and Collecting | Total High or Very High |
| Elk River | M | M | H[1] | VH[1] | M | L | L | L | H | M | L | H | L | 4 |
| Lower Rogue River | M | VH[1] | H | M | H | H[1] | L | M | M | M | M | L | L | 4 |
| Chetco River | M | H | H[1] | M | H | VH[1] | M | H | M | M | L | M | L | 5 |
| Winchuck River | L | H | VH[1] | H | M | VH[1] | M | M | M | H | L | M | L | 5 |
| Brush Creek | M | VH[1] | H | NA | H[1] | L | L | NA | M | NA | L | L | L | 3 |
| Mussel Creek | L | VH | VH[1] | M | VH[1] | H | L | NA | L | NA | L | L | L | 4 |
| Hunter Creek | M | VH[1] | VH | H | VH[1] | H | M | L | M | L | L | M | L | 5 |
| Pistol River | M | VH[1] | VH | H | VH[1] | M | M | L | M | NA | L | L | L | 4 |
| Smith River | M | H | H[1] | H[1] | L | M | M | M | L | M | M | H | M | 4 |
| Lower Klamath River | H | H | VH[1] | VH[1] | H | M | L | M | H | M | M | M | L | 6 |
| Redwood Creek | M | VH[1] | VH[1] | M | M | M | M | H | M | M | L | L | L | 3 |
| Maple Creek/Big Lagoon | L | VH[1] | M | L | H[1] | L | M | NA | M | M | L | L | L | 1 |
| Little River | L | H[1] | M | H[1] | M | M | M | NA | M | NA | L | L | L | 2 |
| Mad River | M | VH[1] | H | M | M | M | M | H[1] | M | NA | M | L | L | 3 |
| Elk Creek | L | M | H[1] | M | L | H[1] | L | NA | L | NA | L | L | L | 2 |
| Wilson Creek | L | VH[1] | L | L | M[1] | L | L | NA | L | NA | L | L | L | 1 |
| Strawberry Creek | L | M | H[1] | M | H | M | NA | NA | L | NA | L | H[1] | L | 2 |
| Norton/Widow White Creek | L | VH[1] | VH[1] | M | M | VH | M | NA | M | L | L | H | L | 4 |
| Humboldt Bay Tributaries | M | VH[1] | VH[1] | H | H | H | L | NA | M | M | L | L | L | 5 |
| Low Eel/Van Duzen Rivers | M | VH | H[1] | H | H | H | M | M | H[1] | H | L | L | L | 8 |

| Population | Threats | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate change | Roads | Channelization/ Diking | Agricultural Practices | Timber Harvest | Urban / Residential Industrial Development | High Severity Fire | Mining/Gravel Extraction | Dams/Diversions | Invasive/Non Native Alien Species | Hatcheries | Road Stream Crossing Barriers | Fishing and Collecting | Total High or Very High |
| Bear River | M | VH[1] | L | H | H[1] | NA | M | L | L | NA | L | L | L | 2 |
| Mattole River | M | H | M | M | H | H[1] | H | L | VH[1] | NA | NA | L | L | 5 |
| Guthrie Creek | L | H | L | H[1] | H[1] | L | L | NA | L | NA | L | L | L | 2 |
| Illinois River | H | VH[1] | H | H | H | M | M | VH | VH[1] | M | M | H | L | 8 |
| Mid. Rogue/Applegate Rivers | L | VH | VH | VH | H | VH[1] | M | H | VH[1] | M | M | H | L | 8 |
| Upper Rogue River | H | VH | H | VH[1] | VH | VH[1] | M | M | H | M | M | M | L | 7 |
| Middle Klamath River | H | M | L | L | L | NA | H[1] | M | H[1] | L | M | M | L | 3 |
| Upper Klamath River | HV | VH[1] | VH | H | M | L | M | L | VH[1] | L | VH | M | L | 7 |
| Salmon River | VH[1] | M | NA | L | L | L | M[1] | M | L | L | M | L | L | 1 |
| Scott River | VH | H | VH | VH[1] | M | M | H | M | VH[1] | NA | M | L | L | 7 |
| Shasta River | H | H | H | VH[1] | L | M | M | M | VH[1] | NA | H | L | L | 6 |
| South Fork Trinity River | H | VH[1] | L | M | L | L | M | L | H[1] | L | VH | L | L | 4 |
| Lower Trinity River | H | H | VH[1] | M | M | M | M | L | H | L | VH[1] | L | L | 5 |
| Upper Trinity River | H | H | M | M | M | M | M | L | VH[1] | H | VH[1] | H | L | 5 |
| South Fork Eel River | M | VH[1] | M | M | H | H | H | M | H[1] | H | L | H | L | 7 |
| Mainstem Eel River | H | VH | M | M | H | M | H | M | H[1] | H[1] | L | M | L | 6 |
| Mid. Fork Eel River | H | H[1] | H[1] | M | M | M | H | NA | M | H | L | L | L | 5 |
| Mid. Mainstem Eel River | H | H[1] | H | H | H | M | H | M | VH[1] | H | L | L | L | 8 |
| Upper Mainstem Eel River | VH | VH[1] | NA | M | L | L | H | NA | VH[1] | VH | L | L | L | 5 |
| North Fork Eel River | H | VH[1] | L | M | M | L | H[1] | NA | M | H | L | L | L | 4 |

[1] Identified as a key limiting threat.

### 3.2.1 Climate Change

Climate change impacts salmonids throughout the Pacific Northwest and California (Battin et al. 2007, Moyle et al. 2013). The overwhelming majority of climate models predict a warming trend resulting from rising levels of greenhouse gases in the atmosphere, although the magnitude varies among models (Barnett et al. 2005, Daniels et al. 2012). Climate change is expected to detrimentally affect SONCC coho salmon in freshwater, estuarine, and ocean habitats. Climate change will likely alter runoff patterns by causing a precipitation shift from snow to rain (Kiparsky and Gleick 2003), earlier snowmelt (Knowles et al. 2006), lower summer flows (Barr et al. 2010), and more intense storms that will increase peak flows (Doppelt et al. 2008, Bates et al. 2008). In addition, ocean acidification is expected to reduce ocean productivity (Feely et al. 2008) and sea level rise will alter estuarine habitat (Galbraith et al. 2005).

Coho salmon are particularly vulnerable to climate change due to their need for year-round cool water temperatures (Welsh et al. 2001). SONCC coho salmon spend an extended period rearing in freshwater and, being near the southern end of their distribution, often reside in streams already near the upper limits of their thermal tolerance. Through effects on air temperatures and stream flows, climate change is expected to increase water temperatures to the detriment of coho salmon. Climate change effects on stream temperature within the SONCC coho salmon ESU are already apparent (Isaak et al. 2012). For example, in the Klamath River, Bartholow (2005) observed a 0.5 ºC per decade increase in water temperature since the early 1960s, and model simulations predict a further increase of 1-2 ºC over the next 50 years (Perry et al. 2011).

Models of future climate change project that the western United States will have reduced volumes and persistence of snowpacks across the region (Gleick 1987, Lettenmaier and Gan 1990), reduction in the fraction of precipitation that falls as snow rather than rain (Kiparsky and Gleick 2003), and hastening of the onset of snowmelt once snowpacks have been formed (Knowles et al. 2006), resulting in earlier runoff relative to current conditions (Kiparsky and Gleick 2003). Warmer winter air temperatures will decrease the snowpack in northern California and southern Oregon by up to 75% by 2040 and nearly 100% by 2080 (Doppelt et al. 2008). Snow acts as a natural reservoir by delaying runoff from winter months when precipitation is high, and climate change is projected to shift the timing and duration of releases from these natural reservoirs, altering instream conditions that salmon have evolved with (Kiparsky and Gleick 2003). Overall this would result in earlier and higher high flows, and earlier and lower low flows (Doppelt et al. 2008, NMFS and USFWS 2013). An analysis of the past 50 years in California has already revealed trends toward warmer winter and spring temperatures, a smaller fraction of precipitation falling as snow, a decrease in the amount of spring snow accumulation in lower and middle elevation mountain zones, and an advance in snowmelt of 5 to 30 days earlier in the spring (Knowles et al. 2006).

High flows and associated flooding are a natural process and can be beneficial to salmon and salmon habitat as a disturbance mechanism for scouring fine sediment from gravel, distributing large wood, recharging aquifers, allowing fish passage, transporting sediment and organic matter, and maintaining channel features (Lisle 1989). However, the potential increased rain and earlier snowmelt resulting from climate change could also detrimentally impact SONCC coho salmon populations by altering the timing of spring freshets, potentially increasing severity and quantity of flood events, increasing water temperatures, and altering the intensity of winter storms, thereby changing habitat accessibility, run timing, and egg development (Roos 2003). Eggs will likely develop faster in the higher winter and spring water temperatures, leading to earlier emergence. The early coho salmon fry could then be displaced downstream during high spring flows (Doppelt et al. 2008) thereby increasing exposure to predation. Even though higher spring temperatures would increase the growth rate of fry, the higher summer temperatures would decrease the amount of cold water refugia, which could lead to thermal stress and juvenile mortality (NMFS and USFWS 2013).

A potential shift to earlier and higher flows caused by climate change could have other effects on coho salmon and their habitat. Higher frequency and magnitude of winter flood events could affect coho salmon by increasing the risk of redd scouring, displacing eggs and alevins from the gravel before they emerge (Goode et al. 2013, NMFS and USFWS 2013). The timing of downstream migration by coho salmon smolts could be altered in relation to upwelling and ocean conditions and would likely influence smolt survival (NMFS and USFWS 2013). Increased erosion of hill slopes, roads, and streambanks could cause sedimentation of stream beds, which has been implicated as a principal cause of declining salmonid populations (Frissell 1992). Juveniles and smolts can be stranded by flood events, washed downstream out of rearing habitat, or washed out to sea prematurely.

Climate change may also decrease the frequency of fog on the California coast, which would increase air temperature and decrease humidity, leading to increased evapotranspiration by riparian vegetation, decreased stream flow, and increased water temperature. Data from 1901 to 2008 indicate that coastal temperatures have increased more than inland temperatures, accompanied by a reduced number of hours of coastal fog (Johnstone and Dawson 2010). If coastal fog continues to diminish, there will be increased drought stress and potentially a reduction in the range of coast redwoods and associated fish and wildlife communities.

Less snowpack, increased summer temperatures, and drought conditions lead to greater risk of wildfire. The summer of 2012 displayed the sorts of weather and climate extremes that climate change is bringing. Average temperatures for June through August were the third warmest on record, with July the hottest month ever recorded for the nation. Nearly two-thirds of the contiguous U.S. experienced drought conditions. Wildfires spanned more than 3.6 million acres across the western and central U.S. during August, a record for the month (NOAA 2012). An increased frequency of high severity wildfires not only can create lethal water temperatures for coho salmon, but also contributes to multiple stresses such as altered sediment supply and degraded riparian conditions, which are described below in Section 3.2.7 (High Severity Fire).

The impacts of climate change on coho salmon are not restricted to fresh water habitats. Survival of coho and other salmon species in the ocean is dependent on ocean food webs, which are strongly influenced by climate (Peterson et al. 2012, Rupp et al. 2012, Ruzicka et al. 2011, Sharma et al. 2013). Ocean acidification is increasing in surface waters off northern California more rapidly than previously estimated (Feely et al. 2008) and is likely to affect plankton and marine food webs, resulting in decreased coho salmon growth rates (Crozier et al. 2008). Global sea level has risen over the last several decades at a rate of about 20 cm per century and with climate change that rate is increasing (Cayan et al. 2009), causing a mean sea level rise expected to reach almost a meter by 2100 (Cayan et al. 2009, Laird et al. 2013). Sea level rise is projected to affect estuaries, coastal wetlands, and other low-lying lands, change the amount and location of critical estuarine and brackish habitats for salmon, and increase the salinity of rivers, bays, and groundwater tables (Intergovernmental Panel on Climate Change [IPCC] 2007). The IPCC (2007) suggests that by 2080, sea level rise could convert as much as 33 percent of the world's coastal wetlands to open water. Sea-level rise will also extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for fish and wildlife that inhabit these coastal areas (Kundzewicz et al. 2007). New brackish and freshwater wetland areas will be created as seawater inundates low-lying inland areas or as the freshwater table is pushed upward by the higher stand of seawater (Pfeffer et al. 2008).

The threat and stress assessment for this recovery plan included consideration of climate change and resultant environmental conditions. Climate change poses a serious threat to the viability of SONCC coho salmon populations (NRC 2004, Moyle et al. 2013, NMFS and USFWS 2013). Although SONCC coho salmon are diverse and resilient and have persisted through many climatic changes over the millennia, the modern climate change is happening at a rapid pace during an already warm period in which populations are already depressed and fragmented from intense human development (Battin et al. 2007, Isaak et al. 2012). The reduced genetic diversity resulting from depressed population size may limit the ability of individuals to adapt to changing climatic conditions. In addition, as climate change reduces the carrying capacity of the habitat within the range of SONCC coho salmon, species viability may be more difficult to achieve. Even if greenhouse gas emissions that cause climate change were stabilized, warming and sea level rise would continue for centuries because greenhouse gas emissions remain in the atmosphere for decades and there are time lags in climate system feedbacks (Solomon et al. 2009).

Beechie et al. (2012) recommended restoring stream flow, re-connecting floodplains, and re-aggrading incised channels as the best strategies to mitigate the anticipated effects of climate change on salmonids. Protecting beaver populations in watersheds vulnerable to climate change may help buffer some of the effects of climate change by reconnecting the floodplain, slowing and storing water in the basin, extending summer flows and restoring perennial flows to some streams. Beaver ponds help recharge groundwater tables and increase interaction between surface and groundwater flows, often cooling the water downstream of beaver dams. Beaver restoration can be an effective solution for many types of climate related issues in aquatic and riparian ecosystems, and it is generally far less expensive than alternatives (Scheffer 1938, Fouty 2003, Müller Schwarze and Sun 2003).

Furniss et al. (2010) describe the most effective response to a changing climate as a renewed commitment to the principles and practices of sound watershed management, with the objective of maintaining or improving watershed resilience. Watershed vulnerability assessments can evaluate relative resilience to changing climate and help set management priorities. Vital signs of a resilient watershed include capture and storage of rainfall, recharge of groundwater reservoirs, minimization of erosion, regulation of stream flows, storage and recycling of nutrients, and provision of habitat for native aquatic and riparian species.

### 3.2.2 Roads

Roads are a pervasive feature throughout the ESU and reflect a legacy of land use activities. Nearly all populations that comprise the SONCC coho salmon ESU are affected by high road density, with some populations having greater than 10 miles of road per square mile. Roads are ranked as a high or very high threat in 35 of 40 populations in the ESU (Table 3-8, Chapters 7 to 46). Roads can affect salmon populations by blocking migration, through interrupting and disrupting natural drainage patterns, increasing peak flow (Ziemer 1998), and increasing stream bed and bank instability (Chamberlin et al. 1991, McIntosh et al. 1994). Roads have been shown to impact spawning habitat, channel form, sediment inputs, and prey production. Additionally, roads placed immediately adjacent to watercourses can affect coho salmon through the removal of riparian vegetation, floodplain disconnection, and non-point source pollution inputs. Armentrout et al. (1998) used a reference of 2.5 mi/mi$^2$ of roads as a watershed management objective to maintain hydrologic integrity in Lassen National Forest watersheds harboring anadromous fish. Cederholm et al. (1981) found that fine sediment in salmon spawning gravels increased between 260 to 430 percent over background levels in watersheds with more than 4.1 mi/mi$^2$. Although some roads have been decommissioned, there are still many miles of existing roads and maintenance is often lacking, leading to chronic impacts on habitat. Road building for access to marijuana cultivation sites is common on many areas of the SONCC coho salmon recovery domain. Many of these roads are likely unpermitted and contribute excessive amounts of fine sediment to coho salmon streams. Across the ESU, sediment from roads has contributed to decreased emergence survival, and reduced carrying capacity for juvenile salmonids due to the filling of pools, channel simplification, and reduced feeding and growth due to high turbidity levels. Landslides triggered from road building-related activities are large sources of sediment (Spence et al. 1996) and may create large scale episodic mass wasting events that can severely impact a year class. Cederholm et al. (1981) reported that the percentage of fine sediments in spawning gravels increased above natural levels when more than two and a half percent of a basin area was covered by roads.

In addition to contributing fine sediment, roads can also affect water quality through the addition of heavy metal, gas, oil and other pollutants deposited on roads and subsequently washed into streams (Sandahl et al. 2007). These pollution inputs are difficult to remedy since they come from a variety of sources and can be spread out along the entire road length. Many pollution inputs occur during the winter months, which may have an effect on embryo and alevin salmon life stages, further decreasing survival and altering reproductive success.

Despite recent efforts to address impacts associated with roads, there still remains inadequate funding for road maintenance and rehabilitation projects, inadequate regulations for maintenance and building on private roads, and a large number of existing problems associated with private and public roads throughout the ESU.

#### Plans Addressing Road Sediment

While management programs and plans that help alleviate effects from road development are lacking in many areas of the ESU, several counties within northern California have worked collaboratively to develop a comprehensive manual to guide road installation, maintenance, and remediation. To qualify their road programs under the applicable limit in NMFS' protective regulations promulgated under ESA Section 4(d) [4(d) rule; 50 CFR 223.203(b)(10)], Humboldt, Del Norte, Trinity, Siskiyou and Mendocino counties (Five Counties) collaboratively developed the "Water Quality and Stream Habitat Protection Manual for County Road Maintenance in Northwestern California Watersheds" (Five Counties Salmon Conservation Program 2002; hereafter referred to as "Manual"), which is based largely on the Oregon Department of Transportation (ODOT) Road Maintenance Handbook (ODOT 1999). The Manual includes design and construction guidelines and best management practices that minimize erosion and maintain or improve fish passage. This manual is the first to be developed in California and represents a collaborative effort in addressing road maintenance impacts on coho salmon. Since 1998, the Five Counties effort has assessed and prioritized 245 road crossings for repair or replacement, using the biological needs of salmonids as their main driving factor. This program has repaired or replaced 56 road culverts, improved or enabled access to 137 miles of fish habitat, and completed Road Erosion Inventories on over 2,000 miles of road (Five Counties Salmonid Conservation Program 2010). In 2007, NMFS approved the Five Counties' Manual under the 4(d) rule.

Similarly, ODOT's "Routine Road Maintenance Water Quality and Habitat Guide Best Management Practices" (ODOT 1999) is utilized across the state of Oregon to identify and implement measures, or best management practices, that minimize potential environmental impacts associated with ODOT activities. In California, the state transportation agency (Caltrans) utilizes the "Caltrans Storm Water Quality Handbook, and Construction Site Best Management Practices Manual" to provide contractors and Caltrans staff with detailed information of construction site best management practices (BMPs) to be used on state-managed roads.

Other important programs to address road-related sediment issues include the Northwest Forest Plan for land administered by U.S. Forest Service and Bureau of Land Management, the North Coast Regional Water Quality Control Board's regulation of private and state timber lands, and the Habitat Conservation Plans (HCPs) for lands managed by Humboldt Redwood Company, Green Diamond Resource Company, and Fruit Growers Supply Company. Information about these programs is included in Section 3.2.5 (Timber Harvest).

### 3.2.3 Channelization and Diking

NMFS identified stream channelization and diking as a threat to SONCC coho salmon at the time of listing and it remains a threat today in 26 of 40 populations in the ESU (Table 3-8, Chapters 7 to 46). Diking and channelization are especially prominent in the low-lying areas of most watersheds (Ricks 1995). Stream reaches have been channelized and diked to aid in the conversion of land from forest and riparian to agricultural, industrial, and urban land use. In nearly all the lowlands and estuaries within the ESU, the majority of historical floodplain and off-channel habitat have been diked for agriculture purposes and flood protection (Chapman and Knudsen 1980).

Diking leads to the direct loss of habitat through disconnection of channel, floodplain, and wetland habitat. The simplified channel disrupts normal hydrologic function, often increasing the velocity of the water and in turn displacing complex woody structures that provide important rearing habitat for juvenile coho salmon. Channelization and diking will often transition a complex channel containing pools, riffles, and side channels, into a single thread channel primarily dominated by riffle habitat. In the fall, juvenile coho salmon typically move from summer nursery areas to off-channel habitat such as side channels, ponds, and sloughs to rear in the winter (Brown and Hartman 1988; Nickelson et al. 1992). During the winter coho salmon also selectively inhabit deep pools with substantial accumulations of LWD (Bustard and Narver 1975; Murphy et al. 1984). Juvenile coho salmon seek these slow water habitats associated with complex channels to avoid being displaced by the high velocity flows in the mainstem channel during the winter. Quinn and Peterson (1996) found a positive correlation between reach scale complexity and the overall survival and body size of juvenile coho salmon. More recently, Sommer et al. (2005) found that salmonids that were able to access floodplain habitat in the winter increased in size substantially faster due to higher prey consumption, and that survival of fish released into floodplain habitat was higher than of those released into the main channel.

Channelization and diking disrupts natural hydrologic processes, leading to long term geomorphic changes to the stream channel. Levees and dikes reduce bank overflow and access to the floodplain. Because levees are designed to decrease the width of the flow, rivers respond by cutting deeper channels and reaching higher velocities (Poff et al. 1997). Natural erosion and floodplain deposition processes are prevented when the channel banks are hardened and restricted from overflow. Additionally, channel migration and formation of secondary channels is prevented in the channelized stream setting (Shankman and Drake 1990). Because channelization disconnects the channel from sloughs, wetlands, and the floodplain which could hold water that breaches the banks, the magnitude of floods can often be increased. The reduction in upstream water storage will result in accelerated water delivery downstream. Much of damage caused by flooding is a result of levee failures as rivers try to reestablish historical connections to the floodplain (Poff et al. 1997).

Water quality is often degraded due to the disconnection of stream channels from floodplain and wetland features. Channelized coastal plain streams were found to have higher nutrient concentrations than unchannelized streams due at least in part to loss of contact between flowing water and the riparian forests (Kuenzler et al. 1977). Wetlands can be characterized as nutrient sinks and, because most are hydrologically connected to other waters and wetlands, the loss of those wetlands has potentially negative impacts on the water quality of downstream systems. Richardson et al. (2007) found that a multi-phased restoration of a stream and its adjacent wetlands resulted in a significant reduction of downstream nutrients, coliform bacteria, and sediment. In addition, storm water nutrient budgets indicated a substantial attenuation of nitrogen and phosphorus after passing through the wetlands.

Many California and Oregon estuaries have been significantly reduced in size due to the construction of levees and irrigation canals. Estuaries constitute important rearing habitats and migration corridors for juvenile coho salmon, as described in Section 3.1.9 (Impaired Estuarine Function).

### 3.2.4 Agricultural Practices

Conversion of many lowland areas to agricultural use has greatly altered the form and function of streams and their riparian corridors. Irrigated agriculture and livestock grazing can negatively impact coho salmon habitat (Nehlsen et al. 1991) and can directly impact juvenile coho survival and fitness. Agricultural operations located immediately adjacent to watercourses and stream channels have degraded habitat and limited both water quality and quantity through the filling and diking of wetlands, installation of irrigation diversions, channelization, grazing in riparian areas, compaction of soils in upland areas, and indirectly through the use of pesticides and fertilizers (Botkin et al. 1995, Spence et al. 1996). A large proportion of estuaries and floodplains have been converted to agricultural land through the diking and filling of floodplain habitat (see section 3.2.3). The loss of these areas has had major impacts on the form and function of watersheds and their ability to support salmon, especially juvenile coho salmon, which require diverse, complex rearing habitats and floodplain connectivity. In the SONCC coho salmon ESU, Agricultural Practices ranks as a high or very high threat in 18 of 40 populations (Table 3-8, Chapters 7 to 46).

One of the major stresses associated with agricultural practices has been the removal of water from many streams for irrigation or stock watering, which has led to reduced stream flows in the summer and fall, including seasonal loss of surface flow in some streams. Water is the most essential component of fish habitat; without adequate water, coho salmon cannot survive. Water diversions can cause fragmented habitats and increase stream temperatures while impeding the geomorphological processes that maintain stream health (Cone and Ridlington 1996). Decreased water availability can create stressful situations for salmonids, and can decrease fitness and survival of juveniles rearing in areas with degraded water quality (Bjornn and Reiser 1991). For instance, water use in the Scott River Valley, California, has been associated with reductions in summer and fall base flows (Van Kirk and Naman 2008), which has been cited as a limiting factor in coho salmon production in this system (NRC 2004). Consumptive water use has also lowered the water table near affected streams, which has limited the ability of riparian plant species to proliferate and contributes to low flow barriers. In some areas, seasonal and permanent dams are constructed to provide water for agricultural operations and have resulted in altered stream function, migration barriers, changes in stream temperature, and temporary increases in sedimentation.

Agricultural practices can result in the degradation or elimination of riparian areas. Within many riparian areas, the vigor, composition, and diversity of natural vegetation are altered by livestock grazing and agriculture. This alteration has affected the ability of riparian areas to control erosion, provide stability to stream banks, and provide shade, cover, and nutrients to the stream (Mundy 1997). Soil compaction in riparian and upland areas has appreciably reduced soil productivity and caused bank and slough erosion (Bellows 2003). Bank damage can lead to channel widening, lateral stream migration, increased water temperature, and sedimentation (Scholz et al. 2000).

Agriculture is a key producer of non-point-source pollution in the form of nutrients and sediments, which can enter streams with runoff from livestock areas or cultivated fields, and agricultural chemicals. Marijuana cultivation has become abundant in many areas of the SONCC coho salmon recovery domain. Although the number of plants grown each year is unknown, the herbicides, pesticides, and fertilizers used to support these plants are likely impairing water quality in coho salmon streams.

Impacts of agricultural chemical use on coho salmon has been identified as a concern throughout the Pacific Northwest (Laetz et al. 2009); pesticides known to harm salmonids (NMFS 2008) are used within the SONCC coho ESU. For example, herbicide use has resulted in fish kills in the Rogue River basin, including juvenile coho salmon in Bear Creek in 1996 (Ewing 1999). The USEPA is currently consulting with NMFS Office of Protected Resources for the re-registration of 37 pesticide active ingredients that are commonly used in agricultural practices, urban landscaping, and forestry practices. To date, NMFS has completed six opinions addressing 27 active ingredient including organophosphate and carbamate insecticides, thiobencarb, and various herbicides and fungicides. Of these 27 pesticide ingredients with completed consultations, NMFS determined that the continued use of a third of those would jeopardize the continued existence of SONCC coho salmon. Reasonable and Prudent Alternatives (RPAs) were developed for the registration of the following chemicals: Naled, Phosmet, 2, 4-D, Carbaryl, Carbofuran, Methomyl, Chloropyrifos, Diazinon, and Malathion. RPAs include elements such as relabeling, application restrictions in windy conditions or prior to a precipitation event, necessary buffer zones around water bodies, reduced concentrations, reporting requirements for fish mortality, and the implementation of a monitoring program. In April 2013, the National Academy of Sciences' National Research Council released their recommendations for assessing risks from pesticides to listed species under the ESA and the Federal Insecticide, Fungicide, and Rodenticide Act. The USEPA, U.S. Department of Agriculture (USDA), USFWS, and NMFS are working collaboratively to review the report and identify improvements in the current scientific procedures used in evaluating the potential impacts of pesticides to endangered and threatened species. The Federal agencies will develop an implementation plan to provide a timeline and approach for responding to the panel's recommendations and implementing the appropriate revisions to these procedures and approaches. The plan is expected to be available to the public soon.

### Agricultural Regulations

Historically, the impacts to fish habitat from agricultural practices have not been closely regulated. Oregon's Agricultural Water Quality Management Act, also known as Senate Bill 1010, was enacted in 1993 (requirements are currently codified at Oregon Revised Statutes 568.900 to 568.933), and is the basis for the Oregon Department of Agriculture's Agricultural Water Quality Program, which includes Agricultural Water Quality Management Area Plans (see Oregon Administrative Rules Chapter 603, Divisions 90 and 95). Although these plans are intended to reduce the impacts of agricultural practices on water quality, state water quality standards are still not met. The state of California does not have regulations that directly manage agricultural practices, but relies on the TMDL process to improve water quality from all applicable parties. See Section 3.1.2 for more information on the TMDL process. The TMDL process is one way that the federal government, through state agencies, is able to regulate the amount of pollutants and other contaminants that enter a watercourse.

Another more direct federal regulation is the registration of fertilizers and pesticides by the Environmental Protection Agency (USEPA). USEPA has established a program to monitor and regulate pesticides and other chemicals that may harm listed species (Washington State Department of Agriculture (WSDA) 2010). USEPA has accomplished this through the implementation of a pesticide registration and registration review program for a suite of chemical fertilizers used across the United States. USEPA's strategy is to address listed species concerns within the context of the pesticide Registration and Registration Review process. The intent of this program is to provide appropriate protection to listed species and their critical habitat from pesticides while avoiding unnecessary burden on pesticide users and agriculture (WSDA 2010). In order to address the ESA during the pesticide Registration and Registration Review process, USEPA developed the Endangered Species Protection Program (ESPP). The ESPP requires refinements to geographic and biological components of the ecological risk assessment as they apply to listed species. The USEPA may use Bulletins (described below) to mitigate risk to listed species either prior to initiation of consultation or as a mechanism to implement Reasonable and Prudent Alternatives (RPAs) and Reasonable and Prudent Measures (RPMs) identified through consultation with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (WSDA 2010).

Once risks to listed species are identified through either the USEPA registration process or consultation with the NMFS and U.S. Fish and Wildlife Service, USEPA issues Endangered Species Protection Bulletins (Bulletins) that specify mitigation or protective measures. Bulletins describe specific geographic areas within individual U.S. counties where use limitations exist. When needed, Bulletins are referenced in pesticide label statements that inform users the product may harm a threatened or endangered species or their critical habitat (WSDA 2010). The use limitations specified in Bulletins are supplemental label language enforceable for the county specified.

### 3.2.5 Timber Harvest

Substantial timber harvest has occurred throughout the SONCC coho salmon ESU. Timber harvest is ranked as a high or very high threat in 20 of 39 populations in the ESU (Table 3-8, Chapters 7 to 46). In many of these populations, while timber harvest activity has decreased since the peak over 50 years ago, and practices and management have improved, the effects of future timber harvest continues to be a potential threat to coho salmon. In many streams, timber harvest in the riparian areas has resulted in reduced inputs of leaf litter, terrestrial insects, and large wood (Reeves et al. 1993, Nakamoto 1998). Reduction of large wood from the harvest of streamside timber has resulted in the reduction of cover and shelter from turbulent high flows (Cederholm et al. 1997). Numerous studies have identified impacts including reduced large woody debris, increased water temperature, and increased erosion and sedimentation. These impacts have been shown to impair the reproductive success of salmon due to increased turbidity, loss of interstitial spaces for use by juveniles, the smothering of eggs by fine sediments, loss of deep pools, and blockage of spawning habitat by landslides (Beschta and Taylor 1988, Beschta 1978, Brown and Krygier 1971).

The threat from future timber harvest lies in the inability of already degraded landscapes to rebound from continued impacts. If detrimental timber harvest (i.e., clear cutting, decreased age of trees removed) continues, cumulative effects and large scale, landscape-size issues may be perpetuated. In many populations of the SONCC coho salmon recovery domain, forest lands are likely being cleared and graded to create new marijuana cultivation sites. In most cases the land disturbance is not regulated, and likely contributes to excessive amounts of fine sediment in coho salmon streams. The continuation of these harmful timber harvest practices will result in decreased cover and reduced storage of gravel and organic debris, and will likely result in continued loss of pool habitat and a reduction in overall hydraulic complexity (CDFG 2002a).

By altering hydrology and slope stability, timber harvest can increase the amount of fine sediment delivered to streams and impair water quality. There is a strong relationship between the percent of a watershed harvested in the past 15 years and the duration of stream turbidity that exceeds thresholds of salmonid feeding impairment (Klein 2012). Timber harvest reduces the amount of precipitation intercepted by vegetation, resulting in increased peak flows during storm events (Grant 2008). Increased peak flows have only been detected during storms with a return period of 6 years or less (Grant 2008), and the effect diminishes over time as vegetation recovers (Keppeler et al. 2003). Long-term paired watershed studies in Caspar Creek on the Mendocino Coast, where road-related erosion is only a minor contributor to sediment, found that despite robust riparian buffer strips, increased peak flows induced by timber harvest increased gully erosion in small stream channels, expanding drainage networks and contributing significantly to suspended sediment yields (Reid et al. 2010). Timber harvest can also affect slope stability and increase the frequency of shallow landslides. Studies on the Oregon Coast found reduced root strength in clear cuts and industrial forests relative to old-growth conifer forests (Schmidt et al. 2001), and that shallow landslides tended to occur in localized areas with reduced root strength such as gaps in the root network between large trees or in areas lacking large trees (Roering et al. 2003).

One of the greatest continuing stresses from timber harvest is the residual effects of increased input of fine sediment into streams. This impact does not cease when timber harvest activities are complete, but instead continues a legacy of negative effects that begin anew during each winter storm event or high flow. Road building and other timber harvest activities have resulted in mass wasting and surface erosion that will continue to elevate the level of fine sediments in spawning gravels and fill the substrate interstices inhabited by invertebrates (Platts et al. 1989, Suttle et al. 2004). Changes in channel morphology will continue to alter the hydrology and timing of flows in areas affected by these chronic events. Bisson et al. (1997) estimated that, due to anthropogenic activities such as timber harvest, the frequency of major floods was 2 to10 times greater, debris flows and dam-break floods were 5 to 10 times more frequent, and slumps and earth flows were 2 to 10 times more frequent, compared to natural, background conditions. This increase in catastrophic events will likely continue to dramatically alter the conditions in which coho salmon spawn and rear and cause a reduction in food supply, reduced quality of spawning gravels, and an increased severity of peak flows during heavy precipitation. Additionally, the continued removal of riparian canopy cover from these events will result in increased solar radiation, which will create further increase in water temperature (Spence et al. 1996).

While harmful timber harvest practices have been shown to be detrimental to salmon populations, new timber harvest methods that promote stand diversity, thin overcrowded plantations, and help restore fire-damaged lands should be implemented to provide an active recovery for degraded systems throughout the ESU. Appropriate timber harvest will aid in the re-establishment of riparian vegetation, sediment storage, and stand diversity, all ecosystem characteristics that are beneficial to salmonid populations. When thinning, stands should be thinned from below (i.e., the largest trees should be left standing), and post-thinning densities of canopy conifers should generally not be less than 200 trees per acre, unless it can be demonstrated, using properly calibrated forest growth models (e.g., Forest Vegetation Simulator) that more intensive thinning is likely to increase long-term production rates of large dead wood. Trees > 50 cm diameter should not be cut for thinning purposes. Thinned trees should be felledon site and placed in streams and other water bodies, if possible, unless they would greatly increase fire hazard (dry forests only),

### USFS Land Resource Management Plans and BLM Resource Management Plans

The Northwest Forest Plan (NWFP) is a comprehensive ecosystem management strategy for federally managed lands administered by the U. S. Forest Service (USFS) and Bureau of Land Management (BLM) within the range of the northern spotted owl (USFS and BLM 1994). Approximately 53 percent of the land area within the SONCC coho salmon ESU is managed under the NWFP. Over 70 percent of the land in the Trinity River basin is managed by the USFS, and within that area, about 85 percent is designated as critical habitat for SONCC coho salmon. Additionally, within the Six Rivers National Forest which is within the NWFP jurisdiction, there are four independent SONCC coho salmon populations, and public lands account for 75 percent of the population areas.

The Aquatic Conservation Strategy (ACS), a primary component of the NWFP, was designed to protect salmon and steelhead habitat on federal lands managed by the USFS and BLM by maintaining and restoring ecosystem health at watershed and landscape scales (NMFS 1997). Aquatic ecosystem elements embedded in the ACS include: maintenance of hydrologic function, high water quality, adequate amounts of coarse woody debris, complex stream channels that provide a diversity of aquatic habitat types, and riparian areas with suitable microclimate and vegetation. There are four primary components of the ACS: 1) Riparian Reserves, 2) Key Watersheds, 3) Watershed Analysis, and 4) Watershed Restoration. The ACS contains nine objectives that describe general characteristics of functional aquatic and riparian ecosystems, and these objectives are intended to maintain and restore good habitat in the context of ecological disturbance.

Some types of USFS and BLM Land Management Plans contain protective management direction, in some cases more protective than the ACS. With the intention of maintaining connected late-successional and old-growth ecosystems, a system of late-successional reserves and riparian reserves was delineated across federal lands and represents one of these more protective types of Land Management Plans. Late-successional reserves are large blocks of lands designed to maintain well-distributed habitat for the late-successional-dependent species. The riparian reserve network was intended to reverse habitat degradation for at-risk fish species or stocks, including coho salmon, and to serve a terrestrial function by providing a system of old forest structural elements to connect the late-successional reserves. Late-successional reserves provide increased protection for all stream types. Late-successional reserves and riparian reserves serve as core areas of high quality stream habitat, fish refugia, and centers from which degraded aquatic systems can be recolonized once they are restored.

The ACS, late-successional reserves, and riparian reserves are intended to prevent further degradation of aquatic ecosystems and restore habitat over broad landscapes (Lanigan et al. 2012). While the NWFP covers a very large area, the overall effectiveness of the NWFP in conserving Oregon and California coho salmon is limited by the extent of USFS and BLM federal land ownership, which is not uniformly distributed in watersheds within the ESU. However, where administered, the NWFP has made improvements on the landscape through better management of both timber harvesting and road maintenance and construction. A report by Lanigan et al. (2012) documented trends in watershed, riparian and upslope condition throughout the area of the NWFP. Ten percent of watersheds displayed a positive change in indicator categories, with these changes attributed to the combined effects of natural vegetation growth and road decommissioning. A greater proportion of positive changes in watershed condition occurred on late-successional reserve and matrix lands than on congressionally reserved lands (e.g., wilderness areas and national parks), which were already in good condition (Lanigan et al. 2012). Declines in watershed condition were seen in some areas, with declines attributed to the Biscuit Fire of 2002, and other fire complexes that occurred during the 15 years of the study. Overall road density changed only slightly across the area of the NWFP; however, dramatic changes were accomplished in targeted watersheds. For example, road density in Lower Fish Creek in the western cascades declined from 3.3 mi/mi$^2$ in 1994 to 0.8 mi/mi2 in 2008 through the decommissioning of 118 miles of roads (Lanigan et al. 2012). Overall, Lanigan et al. (2012) stated that road decommissioning in landslide prone areas provided the most benefits.

Although public lands tend to be located in the upper reaches of watersheds or river basins, upstream of the highest quality coho salmon habitat, Lanigan et al. (2012) documents that efforts made by both the USFS and BLM through the NWFP have begun to improve coho salmon habitat, and provided improved water quality conditions starting in headwater areas. In other areas, public lands are distributed in a checkerboard fashion, resulting in fragmented landscapes that are more difficult to improve.

### State Forest Practices Acts

State forest practices acts in both Oregon (1971) and California (1973), along with their associated forest practice rules, were designed to promote the continuous economic activity of growing and harvesting forest trees while meeting federal and state environmental standards, rules, and regulations (e.g., CWA, ESA). The state forest practices acts and forest practice rules apply to all non-federal forestland, including private, state-owned and local government-owned forestlands. Because of the preponderance of private timberland and timber harvest activity in the range of this ESU, and potential adverse effects, careful consideration of state forest practices rules and regulations is prudent. At the time of listing, most reviews of the forest practice rules indicated that implementation and enforcement of these rules did not adequately protect coho salmon or their habitats (CDFG 1994, Murphy 1995, Ligon et al. 1999, IMST 1999). The state forest practices acts and forest practice rules in both Oregon and California are continually reviewed, and state regulatory agencies in Oregon and California receive recommendations for improved aquatic habitat protection. Neither has fully adopted recent recommendations, and both Oregon and California Forest Practices Acts are inadequate for the complete protection of salmon in the SONCC coho salmon ESU (NMFS 2009, Ligon et al. 1999). Although the California forest practice rules have a requirement for disapproval of timber harvest plans that would result in a ‘taking’ or finding of jeopardy for listed species (14 CCR § 898.2(d)), the rules do not explicitly describe the method for effectively implementing this requirement.

### California Forest Practices

In 1997, at the time of the original listing of the SONCC coho salmon ESU (62 FR 24588, May 6, 1997), timber harvest was identified as a significant threat to the species and their habitat.

Specifically, NMFS identified inadequacies of the forest practice rules to address large wood recruitment, streamside tree retention, canopy retention standards, monitoring of timber harvest operations, and salvage harvesting. A scientific review panel was formed in November 1998 to evaluate the effectiveness of the California forest practice rules in protecting salmonid species and their habitat. The scientific review panel concluded that the forest practice rules, including their implementation process, do not ensure protection of anadromous salmonid populations (Ligon et al. 1999). One of the primary finding was that cumulative effects were not properly accounted for, suggesting the need for a watershed analysis approach.

In July 2000, The California State Board of Forestry and Fire Protection (BOF) adopted interim Threatened or Impaired Watershed Rules (T&I rules) to protect and restore watersheds with threatened or impaired values. The T&I rules were intended to minimize impacts to salmonid habitat resulting from timber harvest by requiring special management actions in watersheds where either state or federally listed threatened, endangered or candidate populations of anadromous salmonids are present or where they can be restored. Examples of special management actions required by the T&I rules include constructing watercourse crossings that allow for unrestricted fish passage, increasing large wood recruitment, and increasing soil stabilization measures. The T&I rules also require coordination between the California Department of Forestry and Fire Protection (CalFire) and the State and Regional Water Quality Control boards to minimize sediment discharge. The BOF never permanently adopted the T&I rules. Rather, the BOF readopted the T&I rules six times subsequent to 2000.

The T&I rules expired in December 2009, and the Anadromous Salmonid Protection (ASP) rules replaced them in 2010. The BOF's primary objectives in adopting the ASP rules were to: (1) ensure rule adequacy in protecting listed anadromous salmonid species and their habitat, (2) further opportunities for restoring the species' habitat, (3) ensure the rules are based on credible science, and (4) meet Public Resources Code (PRC) § 4553 for review and periodic revisions to the forest practice rules. NMFS staff have actively engaged and participated in BOF meetings and expressed concern to the BOF that the ASP rules, while resulting in some improvements to riparian protections, would not adequately protect anadromous salmonids until several inadequacies in the forest practice rules are addressed (NMFS 2009). Specifically, take of listed salmonids resulting from timber harvest operations in California could be minimized (but not entirely avoided) if the following protections were added to the existing ASP rules: (1) provide Class II-S (standard) streams with the same protections afforded Class II-L (large) streams, (2) include provisions to ensure hydrologic disconnection between timber management roads and streams, and (3) include provisions to avoid hauling logs on hydrologically connected roads during winter periods (NMFS 2009). In addition, NMFS believes the use of scientific guidance will provide additional limitations on the rate of timber harvest in watersheds to avoid cumulative impacts of multiple harvests, and provide greater protections to ensure the integrity of high gradient slopes and unstable areas. This may include limiting the areal extent of harvest in such areas.

ASP rules do not apply where the following plans, permits, or measures apply: an approved Habitat Conservation Plan (HCP) that addresses anadromous salmonid protection; a valid Incidental Take Permit (ITP) issued by CDFG; a valid Natural Community Conservation Planning (NCCP) permit approved by CDFG; or project revisions, guidelines, or take avoidance measures pursuant to a Memorandum of Understanding (MOU) or a planning agreement between the plan submitter and CDFG in preparation of obtaining a NCCP that addresses anadromous salmonid protection. ASP rules also do not apply to upstream watersheds where permanent dams block anadromy and reduce the transport of fine sediment downstream, or watersheds that do not support anadromy and feed directly into the ocean.

The California Forest Practice Rules (CalFire 2013) include an Article 6 on Watercourse and Lake Protection under the Coast, Northern, and Southern Forest District Rules subchapters. The section on Intent of Watercourse and Lake Protection (14 CCR §§ 916, 936, and 956) under this Article and each of these subchapters provides, in relevant part:

> The purpose of this article [6] is to ensure that timber operations do not potentially cause significant adverse site-specific and cumulative impacts to beneficial uses of water, native aquatic and riparian-associated species, and the beneficial functions of riparian zones; or result in an unauthorized take of listed aquatic species; or threaten to cause violation of any applicable legal requirements. This article also provides protective measures for application in watersheds with listed anadromous salmonids and watersheds listed as water quality limited under Section 303(d) of the Federal Clean Water Act.
>
> It is the intent of the BOF to restore, enhance and maintain the productivity of timberlands while providing appropriate levels of consideration for the quality and beneficial uses of water relative to that productivity. Protections include: guidelines for the removal of debris and soil, prohibition of road construction, prohibition of use of tractor roads, requirements to comply with TMDLs, objectives for streamside bank protection, riparian buffers, and providing appropriate shading.

NMFS is working collaboratively with the BOF to limit the effects of forestry operations on threatened and endangered salmonid populations in California, including the SONCC coho salmon ESU. At this time, however, the effects of present timber harvest activities in California continue to pose an ongoing threat to the ESU.

### Oregon Forest Practices

At the time of listing, the Oregon Forest Practices Act (OFPA), modified in 1995 and improved over the previous OFPA, did not have implementing rules that adequately protected coho salmon habitat. In particular, the OFPA did not provide adequate protection for the production and introduction of large wood to medium, small and non-fish-bearing streams. Since the listing of SONCC coho, the Oregon Plan for Salmon and Watersheds (Oregon Executive Order 99-01; 1999) directed the creation of the Forest Practices Advisory Committee to help the Oregon Board of Forestry assess forest practices changes that may be needed to meet state water quality standards and protect and restore salmonids. As of 2003, draft water protection rules and non-regulatory recommendations based on the recommendations of Forest Practices Advisory Committee had been developed, but had not been adopted by the Board of Forestry. A review of OFPA and forest practice rules (IMST 1999) showed the regulations in place may be ineffective at protecting water quality and promoting riparian function and structure, especially in small- and medium-sized streams. In their review of the forest practice rules, the Oregon IMST found that one of the greatest shortcomings of the current rules is that they are dominated by site- and action-specific strategies which, taken together are insufficient for recovering habitat of listed stocks of salmonids (Everest and Reeves 2007). Everest and Reeves (2007) report that current forest practice rules in the Pacific Northwest represent improvements over their preceding rules, but continued change and evolution of the forest practices rules is of vital interest.

Though significant improvements have been made to the current rule package, the Oregon Forest Practice Rules represent the least conservative forest practice regulations administered by the state governments within the SONCC coho salmon ESU. Some riparian areas may be protected by narrow, no-harvest zones; however, the stands located upslope of the no-harvest zones could be subject to intense harvest, leading to diminished riparian function and cumulative effects to anadromous salmonid habitat. In a 2010 status review of Oregon Coast (OC) coho salmon, NMFS concluded that the Oregon Forest Practices Act does not adequately protect OC coho habitat in all circumstances. In particular, disagreements persist regarding: (1) whether the widths of riparian management areas (RMAs) are sufficient to fully protect riparian functions and stream habitats; (2) whether operations allowed within RMAs will degrade stream habitats; (3) operations on high-risk landslide sites; and (4) watershed-scale effects. On some streams, forestry operations conducted in compliance with this act are likely to reduce stream shade, slow the recruitment of large woody debris, and add fine sediments. Since there are no limitations on cumulative watershed effects, road density on private forest lands, which is high throughout the range of this ESU, is unlikely to decrease under the Oregon Forest Practices Act (NMFS 2009).

### Other State Regulatory Mechanisms

Additional mechanisms designed to protect aquatic habitat and species have been put in place to provide further review prior to timber harvest. For example, all Timber Harvest Plans (THPs) on private land must be submitted to CalFire. CalFire distributes the THPs to state and federal reviewing agencies including CalFire, CDFW, the California Regional Water Quality Control Board, NMFS, and the California Geological Survey. Filed THPs are open to public comment. Pre-harvest inspections occur at the proposed harvest site, and recommendations and changes are made to the THP prior to approval by the CalFire director, who takes into account BOF rules, the review teams recommendation, and public comment. Finally, CalFire Unit Forest Practice Inspectors periodically inspect the timber harvest operation to ensure compliance with the approved THP and all laws and regulations.

In addition to their role as a reviewer of THPs, CDFW permits certain activities associated with timber harvest such as road building, which may require Lake and Stream Bed Alteration Agreements when stream crossings are present. CDFW ensures that all activities comply with the California Endangered Species Act and California Environmental Quality Act. The Regional Water Quality Control Boards (Regional Water Boards) are active in regulating discharges from timber harvest and associated activities. The Regional Water Boards are responsible for enforcing the Porter-Cologne Water Quality Act that restricts the discharge of materials that adversely affect the beneficial uses of the waters of the State. The Regional Water Board issues permits, referred to as Waste Discharge Requirements (WDRs) and Waivers of WDRs, which establish conditions or requirements to control discharges of waste to waters of the State. Discharges associated with timber harvesting activities typically include sediment from erosion and/or increased water temperature from loss of riparian canopy.

### Habitat Conservation Plans

Habitat conservation plans (HCPs), Natural Community Conservation Plans (NCCP), and other landscape scale plans, which contain robust monitoring programs and adaptive management elements, have enhanced management of private timberlands in northern California. The monitoring conducted by those engaged in such landscape plans is essential to evaluate whether populations of SONCC coho salmon and their habitat remain viable as management occurs over time. These plans allow for meaningful adjustments in the event that the goals or objectives of the plans are not being achieved. NMFS has approved three private timberlands HCPs within the range of SONCC coho salmon.

The Humboldt Redwood Company (HRC) HCP (formerly Pacific Lumber Company [PALCO] HCP) covers approximately 210,000 acres of industrial timberlands in northern California and includes activities related to timber management, forest road construction and maintenance, and rock quarrying (PALCO 1999). The HCP was finalized in 1999 and is valid through 2049. The major watersheds covered by the HRC HCP include portions of Freshwater Creek, Elk River (in Humboldt Bay Tributaries population), Eel River, Van Duzen River, and the Mattole River. The HRC HCP is habitat-based, having a defined goal of achieving or trending towards properly functioning aquatic conditions. An Aquatics Conservation Plan (ACP) was developed within the HCP with a defined goal to maintain or achieve, over time, properly functioning aquatic habitat conditions. The key variables in the ACP are water temperature, canopy cover, sediment, instream large wood, large wood recruitment, pool frequency, and pool quality. The HRC HCP relies heavily on watershed analysis, monitoring, and adaptive management tools to ensure achievement of habitat goals. HRC has agreed to assess all roads and associated sediment sources on its lands and stormproof all high- and medium-priority sites at a rate of 75 miles per year. As part of the HCP, HRC conducts monitoring for the Best Management Practices Evaluation Program, compliance monitoring, and effectiveness monitoring. Specifically, parameters such as large wood debris levels, water temperature, and in-stream sediment levels are monitored. This type of monitoring is the basis for evaluating the results of carrying out prescriptions on the features or processes that occur on the hill slope and the in-stream environment. The monitoring and effectiveness studies provide for the adaptive management component of the HCP.

Finalized in 2006 and valid through 2056, the Green Diamond Resource Company Aquatic Habitat Conservation Plan (AHCP) applies to approximately 410,000 acres in coastal northern California. This AHCP includes portions of all coastal coho salmon population areas from the Oregon border south to, and including, the Eel and Van Duzen rivers (GDRC 2006). The Yurok Tribe assumed responsibility for and holds an AHCP and ITP for 22,000 acres of the original 410,000 AHCP (Yurok Tribe and GDRC 2011).

The biological goals and objectives of the GDRC AHCP reflect in biological terms the intended result of the operating conservation program (GDRC 2006). The five goals of the AHCP are to: 1) maintain cool water temperature temperatures for aquatic species covered by the AHCP, 2) minimize and mitigate human-caused sediment inputs, 3) provide for the recruitment of large woody debris for instream habitat, 4) maintain or increase amphibian species across the landscape, and 5) monitor and adapt the plan as new information becomes available to provide those habitat conditions as needed to optimize conservation measures that benefit the covered species. Objectives that identify measurable parameters for each goal have also been set and are described in the plan.

Green Diamond describes the conservation benefits of the AHCP as follows (GDRC 2006):

> In addition to the measures to avoid or address specific impacts, the plan includes measures to improve conditions for the covered species and/or their habitats. These additional measures provide a level of mitigation that exceeds the anticipated impacts of taking. Examples include the road decommissioning and upgrading measures (and the accelerated implementation of the measures) and the LWD recruitment measures. Green Diamond also believes that the plan as designed provides for a significant improvement in the habitat conditions for all covered species within the plan area in all HPAs [Hydrographic Planning Areas]. In particular, the Road Management Measures will significantly accelerate the recovery of stream conditions negatively impacted by sediment, and other measures will provide similar improvements of habitat conditions.
>
> The extra measures supply added assurance that a sufficient level of conservation is being provided to address any concern about the sufficiency of any particular measure to address the extent of a particular type of impact. Furthermore, the improvement in conditions that will result from these measures exceeds that needed to meet the ITP [Incidental Take Permit] "minimize and mitigate" standard and will contribute both to the recovery of the ITP species and to efforts to preclude the need to list the ESP [Enhancement of Survival Permit] species.

As part of a conservation program within the AHCP, Green Diamond will remove 50 percent of the high and moderate priority road sites within the first 15 years of plan implementation. These measures, coupled with provisions for riparian protection, mass wasting avoidance, and adaptive management, ensure that adverse impacts to coho salmon rearing, migration, and spawning habitats are minimized, avoided or mitigated. Effectiveness monitoring will track the success of the Conservation Program in relation to the AHCP's biological goals and objectives and provide the basis for the AHCP's Adaptive Management Measures. Four categories of monitoring will be implemented: 1) rapid response monitoring, 2) response monitoring, 3) long-term trend monitoring/research, and 4) experimental watersheds program. Monitoring thresholds will trigger management responses when exceeded.

The Fruit Growers Supply Company (FGSC) HCP covers over 150,000 acres of industrial timberlands in Siskiyou County and includes activities related to timber management and forest road construction and maintenance (FGSC 2012). The plan was finalized in 2012 and is valid through 2062. The timberland covered under the HCP exists primarily in the Upper Klamath watershed, including Scott Valley and portions of Cottonwood Creek. It is the intent of the FGSC HCP to promote hydrologic and forest conditions that contribute to a larger regional recovery strategy for covered species. The four biological objectives of the Aquatic Species Conservation Program included in the HCP are: (1) Protect hydrologic and riparian processes that influence water quality, aquatic habitat, and riparian functions; (2) Maintain a high level of stream shading that contributes to cool water temperature regimes that are consistent with the requirements of the individual Covered Species; (3) Provide for the recruitment of LWD into streams so as to maintain and allow the development of functional stream habitat conditions; (4) Minimize and mitigate human-caused sediment inputs; and (5) Monitor to ensure compliance and effectiveness of the aquatic protection measures for providing those habitat conditions needed to meet the general goals that benefit the Covered Species (FGSC 2012). Specific targets for sediment control include a 50 percent reduction of road-related erosion delivery potential within the first 10 years of the Permits (FGSC 2012)

### 3.2.6 Urban/Residential/Industrial Development

Substantial development and urbanization has contributed to habitat impairment throughout the ESU. Development ranks as a high or very high threat in 13 of the 40 populations of the SONCC coho salmon ESU (Table 3-8, Chapters 7 to 46). Although most of the range of the SONCC coho salmon ESU is considered to be rural, there are three highly urbanized population centers. The Humboldt Bay and Yreka areas in California and the Medford/Grants Pass area in Oregon all have urban centers with high percentages of impervious surfaces that contribute to the degradation of habitat and coho salmon viability. Development and urbanization often leads to degraded habitat through stream channelization, floodplain disconnection, damage or loss of riparian and wetland areas, point and non-point source pollution, bank hardening, and consumptive water use (Botkin et al. 1995). When watersheds are developed, natural vegetative ground cover is removed and/or replaced by impervious surfaces or structures, water infiltration is reduced, and runoff from the watershed is flashier, with increased flood hazard (Leopold 1968). Flood control and unnatural drainage patterns may concentrate runoff, resulting in increased bank erosion, which causes an additional loss of riparian vegetation and undercut banks, and eventually causes widening and down cutting of the stream channel. Streams that are channelized and/or diked frequently lack native riparian vegetation and provide little coho salmon habitat value.

In developed areas, point-source and nonpoint-source pollution are common. Sediments washed from urban and industrial areas often contain trace metals such as copper, cadmium, zinc, and lead (California State Lands Commission 1993, Sandahl et al. 2007). An acute example of this phenomenon is when toxic storm water runoff from urban and industrial sources led to high pre-spawn mortality of adult coho salmon in tributaries to Washington's Puget Sound (Booth et al. 2006). Improperly maintained underground septic systems in residential areas can leach bacteria and nutrients into the water table. One significant emerging issue is the input of pharmaceuticals, endocrine disruptors, and personal care products to the watershed, products that are not effectively removed in standard treatment processes (Sumpter and Johnson 2005). These products, together with pesticides, herbicides, fertilizers, gasoline, and other petroleum products, contaminate drainage waters and harm juvenile coho salmon and their aquatic invertebrate prey (Crisp et al. 1998, Flaherty and Dodson 2005). The North Coast Regional Water Quality Control Board (NCRWQCB 2001) reported that non-point-source pollution is the cause of 50 to 80 percent of impairment to water bodies in California.

Additionally, the magnitude of peak flow and pollution increases with increased total impervious area (TIA; e.g., rooftops, streets, parking lots, sidewalks). Spence et al. (1996) recognized that channel damage from urbanization is clearly recognizable when TIA exceeds 10 percent, and that reduced fish abundance, fish habitat quality and macroinvertebrate diversity are seen with total impervious area levels from 7 to 12 percent (Klein 1979, Shaver et al. 1995). May et al.

(1997) showed almost a complete simplification of stream channels as total impervious area approached 30 percent and measured substantially increased levels of toxic storm water runoff in watersheds with greater than 40 percent total impervious area. Booth and Jackson (1997) found that total impervious area greater than 10 percent caused increased peak flows, decreased base flows, simplified channel conditions, increased non-point-source storm water pollution, and resulted in a loss of aquatic system function.

#### Urban Growth Management

Urban growth management in both Oregon and California has some significant shortcomings that prevent the full protection of coho salmon habitat. Inside Oregon's urban growth boundaries, some upgraded riparian area protection was afforded under the Oregon Coastal Salmon Restoration Initiative (The Oregon Plan; State of Oregon 1997) and local governments amended their local comprehensive county general plans to implement these new requirements. Unfortunately, this goal only provides general guidance and does not require establishment and protection of riparian vegetation and wetlands. Buffer widths or types for riparian and wetlands are not included in these guidelines, resulting in insufficient stream bank and riparian vegetation protection, and continuing to allow for the degradation of coho salmon habitat. Rapid population growth in California has caused harm to coho salmon and their habitat and may constitute a reason to evaluate urban growth management practices and their effectiveness at protecting SONCC coho salmon.

County and city planning in both Oregon and California (Mendocino, Humboldt, Siskiyou, Trinity, Del Norte, Lake, Curry, Josephine, Jackson, and Klamath counties) benefit from the development and implementation of comprehensive general plans that include some protective measures for fish and wildlife species and habitat. The Humboldt County General Plan helps to sustain and enhance water resources throughout Humboldt County. Through its policies and standards, the General Plan is an effective tool to ensure that any new development occurs without damaging water resources on an individual and cumulative basis. The Plan also serves to guide the County in its interaction with neighboring counties, state, and federal agencies and lawmakers and guides the County's activities and commitment of resources. The plan includes a water resources element, which addresses water planning issues including river and stream water quality, stormwater runoff, groundwater management, water needs of fish and wildlife, water consumption, conservation and re-use methods, and state and federal regulations. The goals of the water resources element include: high quality and abundant surface and groundwater water resources that satisfy the water quality objectives and beneficial uses; river and stream habitat capable of supporting abundant salmon and steelhead populations and sufficient water flows; support of salmon and steelhead recovery plans, recreation activities, and the economic needs of river dependent communities; and no additional upper or mid-level watershed exports from rivers flowing through the county. Siskiyou County also has a comprehensive General Plan that works towards protection of water quality, ecosystem processes and the natural environment.

### 3.2.7 High Severity Fire

Fires provide for many ecological functions including recycling woody and detritus fuels, preparing mineral seed beds, facilitating vegetative reproduction, and reducing understory vegetation (Stephens and Fry 2005). Fire has always been an important part of the disturbance process in the western United States (Bisson et al. 2003). Recent findings support the notion that fire can also be a valuable restorative tool because it has the capacity to increase physical and biological diversity and can support the maintenance of complex and productive aquatic habitats (Reeves et al. 1995; Benda et al. 2003; Bisson et al. 2003). Frequent yet dispersed surface fires were once a dominant fire regime in many forests. That regime has been altered throughout the ESU range due to the loss of Native American ignition sources, implementation of fire suppression policies starting in the 1930s, and other changes brought about by Euro-American settlement and land-use (Brown 2007; Scanlon 2007;). High severity fire is ranked as a high or very high threat in 9 of the 40 populations in the ESU (Table 3-8, Chapters 7 to 46).

Low severity fires are beneficial to coho salmon habitat because they burn on the ground and remove many of the smaller trees and shrubs, while leaving the larger, more fire resistant trees (Minshall 2003). This type of fire dampens fuel loading and forest vegetation crowding, while potentially boosting invertebrate production (Minshall 2003). High severity fires, on the other hand, refer to severe surface burns or crown fires that result in the creation of an entirely new stand (stand replacing fire; Agee 1998). High severity fires threaten aquatic organisms via direct physical effects, such as mortality from rapid increases in temperature and accumulation of toxic chemicals, and indirect effects, such as habitat destruction, reduced extent and connectivity of habitat, and the temporary reduction or elimination of food resources (Rieman et al. 2012, Reeves et al. 1995). Fires pose the greatest threat to coho salmon in terrestrially dry, inland areas where high severity fire naturally occurs. Many watersheds have experienced a change in their fire regime due to past land use, drought and climate change (Fried et al. 2004).

High severity fire may cause significant changes to the ecosystem, including: alteration of soil structure, such as increased hydrophobicity (water repellency) and iron oxidation; increased air and water temperatures as a result of tree canopy mortality; white ash deposition and charred organic matter; and the consumption of the soil organic layer and surface litter of all sizes (Turner et al. 1994; Ryan 2002). Fire severity is an important indicator of the potential for water runoff and erosion (Robichaud et al. 2000; Keeley 2009) and hydrophobic soils have been linked to floods and increased erosion (Rieman et al. 2012). Snow pack and water retention are also reduced in denuded areas, which affects the hydrology of the basin (Minshall 2003). Instream wood typically declines immediately after fires due to fire consumption, and declines may be significant if a large portion of the riparian vegetation (including debris jams) is burned completely, or if remaining wood is transported out of the stream system during periods of elevated flows (Rieman et al. 2012). Fire in upslope areas can lead to increased soil erosion and sediment delivery, which may result in stream aggradation, pool filling, and in extreme cases landsliding, debris torrents, or other forms of mass wasting (Elder et al. 2002). Population level implications of wildfire appear to depend on longer-term processes, and there are no known examples of population extirpation associated with the immediate effects of wildfires (Rieman et al. 2012).

Catastrophic fires are known to fully expose riparian areas, which may temporarily increase water temperatures through the loss of riparian shading (Dwire and Kauffman 2003, Minshall 2003, Spencer et al. 2003). Riparian plants have evolved a tolerance to disturbance and ability to rapidly recover following fires, as evidenced by epicormic and basal sprouting as well as strategic seed dispersal adaptations (Reeves et al. 2006). In some cases, water temperature changes can become permanent if a fire initiates a transition to vegetation types that are better suited to a warming climate (Isaak et al. 2010, Rieman et al. 2012). For example, if riparian vegetation transitions from mature native trees to herbaceous non-native species as a result of fire, and the conversion is amplified by climate change, then the pre-fire mesic (cool, wet) conditions may never be restored due to intense competition and eventual displacement.

According to a report completed by the Intergovernmental Panel on Climate Change, climate in the western United States is projected to warm substantially before the end of this century (Young 2012). Climate variability affects fire occurrence, with more frequent and larger fires associated with warmer, drier regimes (Bisson et al. 2003). Higher temperatures, reduced snowpack, and earlier spring snowmelt all contribute to the frequency, intensity, and extent of fires. Combined effects of climate change and fire places populations at even greater risk of extirpation during or shortly after a severe fire. The reduction in habitat connectivity, reduction of refugia, and lack of shading from stand-replacing fires in the riparian zone may threaten already reduced numbers of coho salmon. Subsequent increases in water temperature may result in areas becoming uninhabitable for cold water species (Young 2012). Many watersheds have experienced a change in their fire regime due to past land use, drought and climate change (Fried et al. 2004). The probability of large fires (more than 500 acres) might increase by more than 75 percent in areas within the Klamath and Smith River basins, with increases of 50 percent predicted throughout the inland areas of Northern California and Southern Oregon (Luers et al. 2007). However, active forest management through thinning second growth stands, creating fuel breaks, and completing controlled understory burns has reduced the potential threat of catastrophic fire in some areas by increasing the number of fire resistant stands (Pollet and Omi 2002).

### 3.2.8 Mining and Gravel Extraction

Currently, mining within the SONCC coho salmon ESU is primarily in the form of instream gravel mining, placer mining, suction dredging and upslope hardrock mining. The greatest threat from instream gravel mining is the alteration of channel morphology and hydraulic processes that alter the quantity and quality of instream habitat (e.g., pools and riffles) (Kondolf 1997). The greatest threat from upslope mining is the increased potential for chemicals, sediment or other types of contaminants to enter watercourses. Threats from placer mining and suction dredging include the rearrangement or destabilization of substrate and subsequent changes to macroinvertebrate assemblages (Kondolf and Wolman 1993). Mining and gravel extraction are listed as a high or very high threat in five populations of 40 SONCC coho salmon populations (Table 3-8).

Gravel extraction has the potential to impact channel form, sediment delivery, and hydrologic functions in a river or stream (Brown et al. 1998). The severity of this threat is primarily dependent on the location of activity, the intensity, and the types of methods used. Instream gravel mining affects habitat primarily through the removal of gravel from the top of gravel bars by skimming. Lowered bars result in unstable riffles that scour redds, wider and shallower channels that present migration barriers, and simplified habitat with fewer pools for juvenile rearing and adult holding (Kondolf and Swanson 1993). Extensive mining for sand, gravel, construction aggregate and gold in a stream's floodplain and channel can create major habitat impacts already exacerbated by flow regulation in systems such as the Trinity River, Mad River, and Eel River. Flow reductions and the associated reduction in sediment transport into a regulated, mined system can modify a stream's geomorphological and hydrological processes. These modifications can result in very limited gravel recruitment and sediment transport (Kondolf 1997). With altered hydrologic and geomorphological processes, remaining salmonid spawning gravel is immobile and susceptible to compaction and/or armoring. When armoring occurs, the potential salmonid habitat becomes unavailable for salmonid production. Furthermore, mining tailings often leave much of the floodplain perched. These impacts, coupled with channel incision due to the sediment and hydrograph budget modification, can further reduce the availability of needed rearing habitat. Armored banks from remaining dredge tailings do not allow lateral channel migration, accelerating channel scour further decoupling the river from its floodplain and potentially eroding remaining spawning gravel (Brown et al 1998, Kanehl and Lyons 1992, Kondolf 1997). Instream gravel mining is regulated at the federal, state, and county levels in California and Oregon. Federal laws and regulations that apply in both states include permitting under Section 404 of the Clean Water Act (administered by the Army Corps of Engineers), the General Mining Law of 1872, the Federal Land Policy and Management Act (FLPMA), and ESA section 7 and implementing regulations requiring consultation on issuance of federal permits or other federal agency actions that may affect listed species or critical habitat.

Hydraulic mining (placer and suction dredging) can have a negative effect on habitat quality and lead to direct mortality through entrainment of eggs and offspring and the disturbance and alteration of streambed substrate (Griffith and Andrews 1981). Seasonal protections to minimize these effects have been effective by limiting the timing of permitted suction dredging to when eggs and larvae will not be entrained. Material is often deposited into tailing piles, creating unnatural channel formations and flows. The persistence of such features is variable and the impacts can be seasonal and site-specific or long-term and widespread. Tailings piles are unstable and egg-to-fry survival was found to be reduced for Chinook salmon that spawn in tailings (Harvey and Lisle 1999), a finding that likely also applies to coho salmon. Lode or hard-rock mining in upland areas has the potential to unearth contaminants, which can eventually make their way into tributary and river systems.

Placer mining has the potential to alter riparian areas, damage instream habitat, and input fine sediment and pollutants. Past placer mining has damaged some riparian areas to the point where future recruitment of vegetation is impossible. Additional threats from placer mining include removal of riparian vegetation leading to long-term increases in water temperature and lack of wood recruitment, potential water diversions, potential streambank failures and increased sediment. When stream channels are changed or sediment concentrations are increased through placer mining, it can affect benthic invertebrates in the stream. Their populations can decline, or the species types may change and these changes can place stress on fish populations (Wagener and LaPerriere 1985). Results showed that placer mining caused increased turbidity and increased amounts of settleable solids and suspended sediments. These effects were correlated with decreased density and biomass of invertebrates (Wagener and LaPerriere 1985).

### Federal Regulations

The Bureau of Land Management (BLM) has primary responsibility for administering the laws and regulations regarding the removal of all minerals from all federally owned lands. The BLM's statutory authority here is derived from the General Mining Law of 1872, as amended (30 U.S.C.

§ 21 et seq.), the original public land authority in 43 U.S.C. §§ 2, 15, 1201 and 1457, and FLPMA (43 U.S.C. 1701 et seq.). These statutes, together with the implementing regulations (43 CFR Parts 3710-3870) generally make up the body of the mining law system. Most Federal agencies have regulations to protect the surface resources of Federal lands during exploration and mining activities. In addition, CWA section 404 and Army Corps of Engineers (Corps) implementing regulations require a permit from the Corps for placement of material, impoundments, or other control of water in waters of the United States.

### California Regulations

In California, state requirements include the need to obtain a Streambed Alteration Agreement from CDFW, and compliance with the Surface Mining and Reclamation Act (SMARA). SMARA is implemented by each individual county through the issuance of Conditional Use Permits. For suction dredging, new regulations in California including special closed areas, closed seasons, and restrictions on methods and operations have been developed to minimize and prevent negative impacts from mining operations. These new regulations are in place to help protect habitat, but careful monitoring of mining activity must occur to ensure that there is compliance.

In August 2009, all California instream suction dredge mining was suspended following enactment of state law SB 670 (Wiggins),which prohibits the use of vacuum or suction dredge equipment in any California river, stream or lake regardless of whether the operator has an existing permit issued by CDFW. The moratorium does not apply to suction dredging operations performed for the regular maintenance of energy or water supply management infrastructure, flood control, or navigational purposes. While CDFW was in the process of completing a court-ordered environmental review of its permitting program, a new state law, AB 120, was enacted to extend the moratorium until June 30, 2016. Two other specifications of AB 120 are that any “new regulations fully mitigate all identified significant environmental impacts.” and that the suction dredge permit fees be increased to fully fund all of CDFW’s costs for administrating the suction dredge program.

### Oregon Regulations

The State of Oregon has a number of mining regulations. Many state prohibitions exist, and most public lands are off-limits to exploration or development of mining claims. The Oregon Department of Environmental Quality requires issuance a permit before mining can begin. Operating an in-stream suction dredge and discharging the resultant wastewater requires a national pollutant discharge elimination system (NPDES) General Permit 700-PM. Persons assigned to the NPDES 700-PM permit must not operate a suction dredge more than 16 horsepower or with an inside diameter intake nozzle greater than four inches in essential salmon habitat. Suction dredging is allowed only during the in-water work schedule to protect fish and wildlife resources (ODFW 2008c), and measures must be taken to prevent the spread of invasive species. Suction dredging is prohibited on any stream segment that is listed as water quality limited for sediment, turbidity, or toxics on the list published by ODEQ. Mining must not cause any measureable increase in turbidity in selected wilderness and reserve areas. A measureable increase in turbidity is measured as visible turbidity. Performing small-scale, non-chemical off-stream placer mining adjacent to a waterway requires a Water Pollution Control Facility (WPCF)

General Permit 600, which prohibits discharge of wastewater generated by the operation to the waters of the state. These permit requirements were set in place to protect and preserve fish and wildlife species inhabiting the waterways of the state of Oregon (Oregon Division of State Lands 1999). In July 2013, Senate bill 838 passed the Oregon legislature and included several measures to better protect Oregon streams from suction dredging, including an increase in permit fees to cover the cost of a more rigorous permitting and enforcement program and a limit of 850 permits. Under the Senate bill, the state is required to draft new protective measures by the end of 2014 with an implementation date of 2015. If new measures are not implemented, a five year moratorium will go into effect in January of 2016.

Oregon state law currently restricts equipment size, nozzle diameter, and suction speed and efficiency. In the SONCC coho salmon ESU, as of June 1998, portions of the Rogue, Illinois, and Elk rivers, as well as areas of the North Fork of the Smith River are closed to mineral entry except for federal mining claim holders working within valid claims under approved Plans of Operations. While these prohibitions and requirements help curtail mining activities, illegal mining has been recently documented in the SONCC coho salmon ESU (e.g., Preusch 2009, Learn 2011).

### National Marine Fisheries Service Gravel Extraction Guidance

In 2005, the 1996 NMFS National Gravel Extraction Policy was revised and reissued as the NMFS National Gravel Extraction Guidance (Hogarth 2005). The revised Gravel Guidance includes updated information, recommendations and references that can provide meaningful assistance to NMFS staff and other managers involved in regulatory activities were gravel mining in or near streams may affect anadromous fishes and their habitat. The guidance document is meant to be adaptable and address regional needs and local physical and biological settings.

Recommendations in the guidance are as follows: 1) upland aggregate sources, terraces and inactive floodplains be used preferentially to active channels, their deltas and floodplains. 2) pit excavations located on the adjacent floodplain or terraces should be preferentially sited outside the channel migration zone, and as far from the stream as possible. NMFS recommends pits be separated from the active channel by a bugger designed to maintain this separation for several decades, 3) larger rivers and streams by used preferentially to small rivers and streams, 4) braided river systems be used preferentially to other river systems, 5) instream gravel removal quantities be strictly limited so that gravel recruitment and accumulation rates are sufficient to avoid prolonged impacts on channel morphology and anadromous fish habitat, 6) gravel bar skimming be allowed only under restricted conditions, 7) prior to gravel removal, a thorough review of sediments and point and non-point sources of contaminants be conducted, 8) removal or disturbance of instream roughness elements during gravel extraction activities be avoided, and that those that are disturbed be replace or restored, 9) gravel extraction operations be managed to avoid or minimize damage to stream/river banks and riparian habitats, 10) cumulative impacts of gravel extraction operations to anadromous fishes and their habitats be addressed by the Federal, state, and local resource management and permitting agencies and be considered in the permitting process, 11) an integrated environmental assessment, management, and monitoring program be a part of any gravel extraction operation, and encouraged at Federal, state, and local levels, 12) mitigation be an integral part of the management of gravel extraction projects, and 13) gravel extraction projects proposed as stream restoration activities be regarded with caution.

### 3.2.9 Dams and Diversions

Dams and diversions are among the most significant threats to SONCC coho salmon populations. Permanent dams are almost always associated with water control features for flood control, municipal or agricultural water uses, and/or hydropower operations. Temporary dams are usually built for recreational or agricultural purposes on private land. Many dams are associated with water diversions. Dams and diversions can be potential barriers to fish passage, and if diversions are not screened, fish can be entrained and die. In addition, dams and diversions can alter stream flows (Magilligan and Nislow 2005), sediment transport (Graf 2006), channel morphology (Ligon et al. 1995), water quality (USDOI and CDFG 2012), and food webs (Power et al. 1996). These changes can lead to reduced survival and production of coho salmon. NMFS analyzed stream flow, precipitation, water use, reservoir storage, and Geographic Information Systems (GIS) data to calculate a series of quantitative indicators, which were then used in conjunction with other information to inform professional judgments of the magnitude of the threat of dams and diversions for each coho salmon population and life stage (Asarian 2014). NMFS ranked dams and diversions as a high or very high threat in 18 of 40 populations (Table 3-8, Chapters 7 to 46).

Dams and diversions alter the hydrologic regime by shifting the timing and magnitude of flow. The hydrologic effects of dams vary according to factors such as management objectives (e.g., flood control, hydropower, summer water supply, and/or conservation of aquatic resources), the volume of the reservoirs relative to stream flow, and the location of dams within the hydrologic network. Large dams often reduce the magnitude and frequency of high flow events, and reduce differences between annual minimum and annual maximum flows (Graf 2006). The primary purpose of most large dams within the SONCC coho salmon ESU is to store water from high flows in the fall, winter, and spring so that it can be used for irrigation and municipal supply during the low-flow summer months. This can affect coho salmon by reducing flows when juveniles and smolts are migrating downstream in spring and adults are returning in the fall to spawn. While large reservoirs generally have greater hydrologic impacts, if a large number of small reservoirs are present they can act cumulatively to substantially alter the hydrology, particularly at the start of the rainy season (Deitch et al. 2013); however this phenomenon likely affects only a very small portion of the SONCC coho salmon ESU. Both juveniles and adults use flow events as migratory cues and depend on natural flow regimes for migration and access to habitat. Additional information on the hydrologic effects of dams and diversions is provided in Section 3.1.7 (altered hydrologic function).

Dams also impede the geomorphological processes that maintain stream health (Ligon et al. 1995). By halting recruitment of coarse sediment from upstream (Kondolf 1997) and decreasing the frequency and magnitude of bed-mobilizing flows, dams simplify channels and degrade salmonid habitat (Ock and Kondolf 2012, Ligon et al. 1995). Re-establishing flow regimes that mimic the natural hydrograph has the potential to reduce the detrimental effects of dams on geomorphology, fish habitat, and riparian vegetation (USFWS and HVT 1999, Burke et al. 2009).

Dams and diversions can also degrade water quality. As discussed in section 3.1.7 , water diversions can deplete stream flows and increase summer water temperatures. By stagnating water and exposing it to solar radiation, shallow reservoirs can increase summer water temperatures (Spence et al. 2006). In contrast, deeper reservoirs that stratify and release water from their depths can provide an important source of cold water during the summer, such as occurs at dams on the Trinity and Rogue rivers. When nutrient-rich water is impounded, reservoirs can host prolific summer blooms of blue-green algae that degrade downstream water quality, such as occurs on the mainstem Klamath River (USDOI and CDFG 2012). As human population growth continues, the number of water diversions increase and threaten SONCC coho salmon populations. For example, recent investments in residential water storage have significantly reduced summer water withdrawals in areas such as the headwaters of the Mattole River (Klein 2012).

An emerging threat to SONCC coho salmon is water diversion related to marijuana cultivation. Although the number of plants grown each year is unknown, the water diversion required to support these plants is placing a high demand on a limited supply of water (Bauer, S., pers. comm. 2013a). Most diversions for marijuana cultivation occur at headwater springs and streams, thereby removing the coldest, cleanest water at the most stressful time of the year for coho salmon (Bauer, S., pers. comm. 2013b). Based on an estimate from the medical marijuana industry, each marijuana plant may consume 900 gallons of water per growing season (Humboldt Growers Association 2010).

Permanent and seasonal dams can be partial or complete barriers to coho salmon migration. For example, dams completely block access to more than 15 percent of potential coho salmon habitat in the following populations: Upper Rogue River (16%), Shasta River (18%), Upper Klamath River (43%), Upper Trinity (47%), and Upper Mainstem Eel River (80%) (Asarian 2014). Recent dam removal projects throughout the ESU have allowed for improved passage in the Rogue River, and efforts towards installing fish screens have significantly decreased impacts to salmonids. For example, many diversions in the Shasta basin now have CDFG- and NMFS-approved fish screens, and Scott Valley has 100 percent of the diversions located in coho habitat screened to reduce impacts to SONCC coho salmon.

Recent efforts in the Klamath Basin have brought about the creation of the Klamath Basin Hydroelectric Settlement Agreement (KHSA) and the Klamath Basin Restoration Agreement (KBRA). The KHSA describes the process for conducting necessary additional studies, environmental reviews, and a decision by the Secretary of Interior (Secretarial Determination) as to whether removal of the lower four dams on the Klamath River owned by PacifiCorp 1) will advance restoration of the salmonid fisheries of the Klamath Basin, and 2) is in the public interest, which includes but is not limited to consideration of potential impacts on affected local communities and Tribes. The KHSA includes provisions for the interim operation of the dams prior to dam removal as well as the process to transfer, decommission, and remove the dams if the Secretarial Determination is affirmative. The KHSA establishes 2020 as the target date for dam removal. This timeline allows for completion of necessary environmental and regulatory reviews and the collection of $200 million for dam removal from PacifiCorp customers if the Secretarial Determination is affirmative.

The KBRA is a settlement agreement among many diverse parties that creates a solid path forward on long-standing, resource disputes in the Klamath Basin. The KBRA takes a multi-dimensional approach that resolves complex problems by focusing on species recovery while recognizing the interdependence of environmental and economic problems in the Basin's rural communities. The goals of the KBRA are to 1) restore and sustain natural production and provide for full participation in harvest opportunities of fish species throughout the Klamath Basin; 2) establish reliable water and power supplies that sustain agricultural uses and communities and National Wildlife Refuges; and 3) contribute to the public welfare and the sustainability of all Klamath Basin communities. The key negotiated outcomes of the KBRA include mutually-beneficial agreements for the Klamath, Karuk, and Yurok Tribes not to exercise water right claims that would conflict with water deliveries to the Bureau of Reclamation's Klamath Project water users and for project water users to accept reduced water deliveries. As a result, there would be more support for fisheries restoration programs, greater certainty about water deliveries at the beginning of each growing season, and agreement and assurances that certain of the parties will work collaboratively to resolve outstanding water-right contests pending in the Oregon Klamath Basin Adjudication process. In addition, the KBRA includes an Off-Project voluntary Water Use Retirement Program in the Upper Basin, three restoration projects intended to increase the amount of water storage in the Upper Klamath Basin, regulatory assurances, county and tribal economic development programs, and tribal resource management programs. Copies of the KHSA and KBRA in their entirety are available electronically at: http://klamathrestoration.gov/. The implementation of these two agreements will be a significant step forward in restoring fish populations in the Klamath River Basin, once a stronghold for SONCC coho salmon.

Several timber companies have developed HCPs that include improved water diversion practices. These activities will help to reduce the impact of these diversions on the SONCC coho salmon landscape. The HCPs are described in Section 3.2.5.

**Federal and State Acts and Water Allocation**

Federal statutes that include provisions relevant to instream flow protection include the ESA, CWA, National Environmental Policy Act (NEPA), and the Federal Power Act.

Given the lack of federal regulatory authority over instream flow in many areas and waterbodies, state water laws are the primary mechanism for protecting instream flow in many areas. In the SONCC coho salmon ESU, the states of Oregon and California are charged with allocating and adjudicating water quantities to qualified users, as well as enforcing water rights.

Oregon's water rights system is based primarily on the doctrine of prior appropriation, although some form of riparian water rights still exist (Oregon Water Resources Department [OWRD] 2009) and instream flow rights can be established through water right purchase or lease. Surface and groundwater use in Oregon is administered by the OWRD, which is responsible for implementing Oregon's water policy.

Oregon was one of the first western states to recognize instream flow as a beneficial use. In 1955, the state adopted minimum stream flows to support aquatic life through administrative rules, and in 1983 amendments were adopted that authorized ODFW, ODEQ, and the Oregon

Department of Parks and Recreation to apply for minimum instream flow rights. In 1987 and 1993, further amendments strengthened instream flow rights, allowing for transfers and for the use of water markets to acquire instream flow rights (OWRD 2009). Instream flows for particular watersheds can be found under the relevant "basin program" (e.g., Rogue Basin Program contains Rogue tributaries) here: http://www.oregon.gov/owrd/pages/law/oar.aspx.

State resource managers in Oregon have also attempted to protect and conserve instream flows, and promote water conservation, through the implementation of voluntary programs for private water users. The allocation of conserved water program, administered by OWRD, allows a water user who conserves water to use a portion of the conserved water on additional lands, lease or sell the water, or dedicate the water to instream use. The program is intended to promote the efficient use of water to satisfy current and future needs, both out of stream and instream. Oregon's instream leasing program is also designed to provide a voluntary means to aid the restoration and protection of stream flow. This arrangement provides water users with options that protect their water rights while leasing water for instream benefits. The success of this program is largely dependent on the participation of landowners and therefore the program may be unable to meet the instream flow needs of coho salmon populations in some areas.

In Oregon, a permit is generally necessary to use water from any source, including underground. Certain activities are exempt from this requirement (e.g., stock watering, watering lawns or noncommercial gardens, domestic, industrial, or commercial purposes) (OWRD 2009). Groundwater withdrawal has a cumulatively substantial effect on the amount of water available in streams (Barlow and Leake 2012). Groundwater withdrawal works together with the removal of water through surface water rights to alter availability of water at low flows. The analysis of altered hydrologic function in this document, which describes the amount and timing of water availability, finds it ranks a high or very high stress for many Oregon populations (see Chapters 7-9, 12-14, and 30-32).

Responsibility for water allocation and use enforcement in California is shared among several agencies. California courts have jurisdiction over the use of percolating ground water, riparian use of surface waters, and the appropriate use of surface waters initiated prior to 1914 (California Department of Water Resources [CDWR] 2001). The State Water Resources Control Board (SWRCB) is responsible for the water rights and water quality functions of the state (CDWR 2001). The SWRCB has the jurisdiction to issue permits and licenses for appropriation of water from surface and underground streams. This board also has the authority to declare watercourses fully appropriated. Many of the streams and rivers in the California portion of the ESU have been deemed to be fully appropriated by the SWRCB (SWRCB 1998). A declaration that a stream system is fully appropriated means that the supply of water in the stream system is being fully applied to beneficial uses, and the SWRCB has determined that no water remains available for appropriation. From and after the date of adoption of a declaration that a stream system is fully appropriated, and subject to subdivision b of California Water Code section 1206, the SWRCB shall not accept any application for a permit to appropriate water from the stream system and the board may cancel any application pending on that date.

Table 3-9. Stream systems declared fully appropriated by the SWRCB.

| County | Stream | Tributary to | Critical Reach |
|---|---|---|---|
| Del Norte County | Smith River | Pacific Ocean | refer to Section 5093.54 of California Wild and Scenic Rivers Act for specific critical reaches |
| | Jordan Creek | Lake Earl | from the confluence with Lack Earl upstream |
| Humboldt County | Eel River | Pacific Ocean | the main stem from 100 yards below Van Arsdale Dam to the Pacific Ocean |
| | Klamath River | Pacific Ocean | from the main stem about 100 yards below Iron Gate Dam to the Pacific Ocean |
| | South Fork Eel River | Eel River | the south fork of the Eel from the mouth of Section Four Creek near Branscomb to the river mouth below Weott |
| | South Fork Trinity River | Trinity River | from the junction of the river with State Highway Route 36 to the river mouth near Salyer |
| | Trinity River | Klamath River | the main stem from 100 yards below Lewiston Dam to the river mouth at Weitchpec |
| | Van Duzen River | Eel River | from Dinsmore Bridge downstream to the river mouth near Fortuna |
| | Jacoby Creek | Humboldt/Arcata Bay | from the confluence of Jacoby Creek and Humboldt/Arcata Bay upstream |
| | Mad River | Pacific Ocean | from the mouth of the Mad River at the Pacific Ocean upstream |
| Mendocino County | Middle Fork Eel River | Eel River | from the intersection of the river with the southern boundary of the Middle Eel-Yolla Bolly Wilderness Area to the river mouth at Dos Rios |
| | North Fork Eel River | Eel River | from the Old Gilman Ranch downstream to the river mouth near Ramsey |
| | Mill Creek | Middle Fork Eel River | from the SE corner of Section 16, T22N, R12W, MDB&M where the accretion flow comes into Mill Creek upstream |
| Siskiyou County | North Fork Salmon River | Salmon River | from the intersection of the river with the south boundary of the Marble Mountain Wilderness Area to the River mouth |
| | Scott River | Klamath River | from the mouth of Shackleford Creek west of Fort Jones to the river mouth near Hamburg |
| | Wooley Creek | Salmon River | from the western boundary of the Marble Mountain Wilderness Area to its confluence with the Salmon River |
| | French Creek | Scott River | from the confluence of French Creek and the Scott River upstream |
| | Scott River | Klamath River | at the U.S. Geological Survey located on the Scott River near Fort Jones upstream |

| County | Stream | Tributary to | Critical Reach |
|---|---|---|---|
| Siskiyou County | Shackleford Creek | Scott River | from the confluence of Shackleford Creek and the Scott River upstream |
| | Willow Creek | Klamath River | from the York Bridge Road located within Section 8, T46N, R5W, MDB&M, upstream |
| | Seiad Creek | Klamath River | from the confluence of Seiad Creek and the Klamath River upstream |
| | Shasta River | Klamath River | from the confluence of the Shasta River and the Klamath River upstream |
| | Shasta River | Klamath River | from the confluence of Willow Creek located within Section23, T44N, R6W, MDB&M upstream |
| | McKinney Creek | Klamath River | about 1 1/2 miles downstream from the point of diversion on McKinney Creek upstream |
| | East Fork of SF of the Salmon River | Salmon River | at a point on the East Fork of South Fork Salmon River located within T39N, R10W, (Shadow Creek Campground( upstream |
| | Douglas Creek | Klamath River | from a point on Douglas Creek located within the NE1/4, Section 19, T15N, R7E, MBD&M upstream |
| Trinity County | New River | Trinity River | from the intersection of the river with the southern boundary of the Salmon-Trinity Primitive Area downstream to the river mouth near Burnt Ranch |
| | North fork Trinity River | Trinity River | from the intersection of the river with the southern boundary of the Salmon-Trinity Primitive Area downstream to the river mouth at Helena |
| | Mule Creek | Trinity River | from Clair Engle Lake upstream |

The CDWR is responsible for planning the use of state water supplies and consults with the California Water Commission to develop rules and regulations for this purpose (CDWR 2001). The vast majority of California's groundwater is unregulated and the state does not have a comprehensive groundwater permit process to regulate ground water withdrawal. The lack of groundwater regulation has led to overutilization of this resource, which has had major impacts on surface flow and constitutes a major shortcoming of California water law.

In 1991, California adopted changes to its water laws that permitted the transfer of existing consumptive water rights to the purpose of instream flow through either purchase or lease. When a new water use permit application is submitted, the State Water Board (Board) must notify CDFW, which has the authority to recommend amounts of water necessary to preserve fish, wildlife, and recreation in the affected stream. The Board then considers these recommendations and may set instream flow requirements as conditions for the new permit. In this way, current flows can be protected even though new appropriations for instream flow rights are prohibited (California Environmental Protection Agency 2011).

Other efforts to protect instream flows include the adoption of California Water Code section 1259.4, and the adoption and use of Section 1707. California Water Code section 1259.4

addresses the draft guidelines that CDFG and NMFS (2002) presented to the SWRCB for maintaining instream flows downstream of water diversions in mid-California coastal streams. The draft joint guidelines call for limiting new water diversions to only the winter period from December 15 to March 31, establishing bypass flows for new dams, establishing a cumulative maximum rate of withdrawal, and restricting construction of new on-stream dams. Water transfers for dedicated instream uses are accomplished through Section 1707. An instream flow dedication under Section 1707 allows a water user to transfer all or a portion of any water right to instream uses – for example, designating that such conserved water must remain in the watercourse for the benefit of aquatic habitat. It is available to owners of either riparian or appropriative water rights, and can be crafted for either short-term (less than a year) or long-term duration. These transfers may be used to ensure that water flows downstream to satisfy any applicable federal, state, or local regulatory requirements governing water quantity, water quality, instream flows, fish and wildlife, wetlands, recreation, and other instream beneficial uses.

In November 2009, the California State Legislature passed a series of bills that encourage stricter groundwater monitoring and enforcement of illegal diversions, more ambitious water conservation policy, and water recycling and conservation programs. If effectively implemented, these California water bills should contribute to improved instream habitat in the future.

### Instream Flow Requirements

Many rivers within the SONCC coho salmon ESU contain large dams. Dam operators at most of these dams have regulatory mandates to maintain adequate instream flows for the protection of fish and wildlife species. Examples of dams with flow requirements include J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams on the Klamath River; Trinity and Lewiston dams on the Trinity River; R.W. Matthews Dam (Ruth Lake) on the Mad River, and Scott Dam (Lake Pillsbury) in the Eel River. Large dams lacking instream flow requirements include William L. Jess Dam (Lost Creek Reservoir) on the Rogue River, Applegate Dam on the Applegate River, and Dwinnell Dam on the Shasta River.

On the Trinity River, the Bureau of Reclamation is required to release between 369,000 and 815,000 acre feet to the Trinity River annually depending on the water year type. Discharge from Lewiston Dam remains at 450 cubic feet per second (cfs) during the summer months, 300 cfs during the winter months, and has a variable flow regime in the spring depending on the water year type.

The total volume of water impounded and diverted by the Humboldt Bay Municipal Water District (HBMWD) represents a small percentage of the natural yield of the Mad River watershed. The Mad River's average annual discharge into the Pacific Ocean is just over 1,000,000 acre-feet (available at http://www.hbmwd.com/water_supply). Ruth Lake, in its entirety, represents less than 5 percent of the total average annual runoff from the Mad River basin. The entire 48,030 acre-feet capacity of Ruth Lake is not drawn down each year, so the amount of winter-season runoff captured in the reservoir is yet a smaller percentage of the total runoff. With respect to diversions, the current withdrawal rate at Essex is approximately 25 to 30 MGD (28,000 to 34,000 acre-feet per year), which is only 3 percent of the total annual average runoff of the Mad River watershed (available at http://www.hbmwd.com/water_supply). The full diversion capacity of 75 MGD (84,000 acre-feet per year) is just 8 percent of the total annual average runoff of the watershed.

From 1992 to 2004, up to approximately 160,000 acre-feet of Eel River water was annually diverted into the East Fork of the Russian River for hydropower production and agricultural uses. From 2007-2012 the Potter Valley Project annually diverted approximately 22% of the estimated unimpaired flow at the point of diversion (i.e., Cape Horn Dam), with an average diversion of 77,000 acre-feet (Kubicek, P., pers. comm. 2013). Until 2004, flows released downstream of Cape Horn Dam were approximately 3 cfs during most of the summer. In 2004, the Federal Energy Regulatory Commission issued an order requiring Pacific Gas and Electric (PG&E) to implement an instream flow regime consistent with the Reasonable and Prudent Alternative in the NMFS (2002b) Biological Opinion. The new flow requirement increased the minimum Cape Horn Dam release flows and incorporated within-year and between-year variability. Minimum flows are dependent on a number of factors and formulas, including cumulative inflow into Lake Pillsbury, current and previous water year, and time periods.

### Habitat Conservation Plans

Finalized in 2012 and valid through 2022 except under certain circumstances, the PacifiCorp's Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon (dated February 16, 2012) (PacifiCorp 2012) addresses the impacts of PacifiCorp's Klamath Project on coho salmon. The goals of PacifiCorp's HCP are to:

- Offset biological effects of blocked habitat upstream of Iron Gate dam by enhancing the viability of the Upper Klamath coho salmon population;
- Enhance coho salmon spawning habitat downstream of Iron Gate dam;
- Improve instream flow conditions for coho salmon downstream of Iron Gate dam;
- Improve water quality for coho salmon downstream of Iron Gate dam;
- Reduce disease incidence and mortality in juvenile coho salmon downstream of Iron Gate Dam;
- Enhance migratory and rearing habitat for coho salmon in the Klamath River mainstem corridor; and
- Enhance and expand rearing habitat for coho salmon in key tributaries.

These goals are accompanied by specific biological objectives and measures, which are detailed in the HCP.

Finalized in 2004 and valid through 2054, the Humboldt Bay Municipal Water District's Habitat Conservation Plan (HBMWD 204) addresses the impacts of HBMWD's Mad River operations on coho salmon, Chinook salmon, and steelhead. Activities covered under the HCP include:

- Flow release and management activities;
- Diversion activities in the Essex Reach of the Mad River;
- Maintenance activities, including repair of existing structures if damaged; and
- Periodic excavation and fill activities.

The primary benefit to coho salmon described in the HCP is augmented baseflow in the Mad River during the dry season.

### 3.2.10 Invasive/Non Native/Alien Species

Invasive or non-native alien species pose a high or very high threat to seven of 40 populations in the SONCC coho salmon ESU (Table 3-8, Chapters 7 to 46). Sacramento pikeminnow are prevalent throughout much of the Eel River basin and have recently been discovered in Martin Slough, a tributary to Elk River in Humboldt Bay; and brown trout have been observed in the Upper and Lower Trinity River (CDFG 1997, Waters 1983, Dewald and Wilzbach 1992, Wang and White 1994, McHugh and Budy 2006). Both species reduce native coho salmon populations by increasing competition for food resources, increasing predation on juveniles, and utilizing less than desirable water quality conditions to flourish and become more abundant, out-competing native salmonids. The effects of these species are explained under Section 3.1.4 (increased disease, predation, and competition). Additionally, recent reports have shown that the New Zealand mud snail has been observed in Redwood Creek (Benson, K., pers. comm. 2010), although little if any information exists on the effects that these animals have on local salmonids.

Reed canary grass is an invasive non-native perennial grass that was not identified as a threat at the time of SONCC coho salmon federal listing. The grass prohibits native riparian growth, chokes stream channels, provides poor to non-existent habitat for fish and other native aquatic wildlife, inhibits the mobility of fish at lower flows, increases sedimentation, contributes to low levels of dissolved oxygen, and causes overbank flooding during winter and spring base flow conditions (Miller et al. 2008). Over 150 adult unspawned coho salmon were found dead in a field dominated by reed canary grass, likely stranded by the dense reed canary grass when high flows receded quickly in an ill-defined channel (Carrasco 2000). The invasive grass is found throughout southern Oregon and northern California and is a threat to SONCC coho salmon and their habitat. Overall, the threat of reed canary grass has increased since the last status review.

Some basins in the SONCC coho salmon ESU, including Hunter, Strawberry, and Norton/Widow White creeks, have extensive residential development in their lower floodplains and riparian areas. In these areas, it is likely that invasive plant species will spread from residential landscaping into riparian areas, particularly if there are pre-existing gaps in the riparian vegetation. Some of these species could impede restoration of riparian forests and wetlands. The extent to which this has already occurred is unknown.

### 3.2.11 Hatcheries

Hatcheries can pose a significant threat to populations where they occur in the SONCC coho salmon ESU. As discussed in Section 3.1.1, hatcheries and the introduction of hatchery fish into wild populations can have direct and indirect effects on wild, native fish populations. More information regarding hatcheries can be found under adverse hatchery related effects in the above-mentioned stress section.

### 3.2.12 Fishing and Collecting

#### Fisheries Harvest Management

Significant changes in fisheries harvest management have occurred in recent decades, resulting in substantial reductions in harvest of SONCC coho salmon. Currently, fishing-related incidental mortality of SONCC coho salmon occurs primarily from hooking and handling in Chinook-directed commercial and recreational fisheries off the coasts of California and Oregon. Incidental hooking and handling mortality occurs in the mark-selective hatchery coho salmon fishery in the Rogue River, and also in Chinook and steelhead-directed fresh water fisheries in both Oregon and California

In establishing fishing seasons and regulations each year, the Pacific Fishery Management Council (PFMC) considers the potential impacts on various ESA-listed stocks within the region. Because there are no data on exploitation rates on wild SONCC coho salmon, Rogue and Klamath (R/K) hatchery stocks have traditionally been used as a fishery surrogate stock for estimating exploitation rates on SONCC coho. The annual coho salmon exploitation rate averaged approximately 5% from 2000 to 2013, with a maximum exploitation rate of approximately 10% in 2003 to a low of 1.6% in 2008. California's statewide prohibition of coho salmon retention maintains consistently low impacts from freshwater recreational fisheries on SONCC coho salmon.

#### Collection for Research Purposes

NMFS authorizes scientific collection activities through ESA section 10(a)(1)(A) research permits and ESA section 4(d) programs. The authorized activities must not operate to the disadvantage of the listed species and must provide a bona fide and necessary or desirable scientific purpose or enhance the propagation or survival of the listed species. In addition, NMFS must determine whether the scientific collection is likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. These provisions ensure the threat from collection activities is low for all populations.

More information about the effects of fishing and collecting can be found in Section 3.1.10.

### 3.2.13 Inadequate Regulatory Mechanisms

Inadequate regulatory mechanisms were identified as a factor when SONCC coho salmon were listed in 1997, and the problems associated with these regulations continues to hinder salmon recovery. The set of regulatory mechanisms that will govern recovery of this species span a full range of protective strengths and weaknesses and provide a varying degree of protection for populations in the SONCC coho salmon ESU. Since 1997, many regulatory mechanisms that were originally cited as being inadequate have been strengthened in their ability to protect coho salmon and their habitat. In addition, many new management plans and programs have been implemented that either directly or indirectly benefit coho salmon. However, because of the lack of coordination in implementation and management, some regulations are not fully implemented or monitored for compliance and therefore do not provide adequate, or even minimal protection. In addition, there is an overall lack of regulations to fully address the range and magnitude of current and future threats to recovery. As discussed below, the regulatory landscape in which recovery will take place has both strengths and weaknesses in terms of its ability to protect and restore SONCC coho salmon and habitat.

Although some of the current land and resource management policies in place are specifically designed to protect SONCC coho salmon and their habitat (e.g., Federal and State Endangered Species Acts), many are designed for other purposes and only indirectly protect the species (e.g., state forest practice rules). Several federal and state land management regulations and acts have been enacted to protect and preserve public lands for current and future public use, and to ensure that these lands are held in good condition, and species utilizing these lands are protected to ensure continued survival. Additionally, many federal and state regulations and acts aid in the protection of private lands and also work towards the protection of salmonids and other species not protected under state and federal laws for public lands. These regulatory mechanisms are in place to control and regulate mining activities, timber harvesting, instream dredging and construction, and urban growth. Many aspects of these regulations are regulated and monitored by both Federal and State agencies, and may apply to both public and private lands in both Oregon and California. Several inadequate regulatory mechanisms identified in the final rule listing the SONCC Coho Salmon ESU (62 FR 24588, 24596-24598; May 6, 1997) are discussed elsewhere in this chapter: Northwest Forest Plan (Section 3.2.5), State Forest Practices (Section 3.2.5), Water Quality Programs (Section 3.1.2), State Agricultural Practices (Section 3.2.4), Harvest Management (Section 3.2.12), and Hatchery Management (Section 3.2.11).

### Dredge, Fill, and In-water Construction Programs

The Army Corps of Engineers (ACOE) regulates removal/fill activities under section 404 of the Clean Water Act (CWA) (see http://www.epa.gov/OWOW/wetlands/laws/). When listing the SONCC coho salmon ESU under the ESA, NMFS noted that ACOE did not have a method to adequately assess the cumulative effects in issuing permits for removal/fill activities under CWA section 404 (62 FR 24588, 24596; May 6, 1997). Although currently the ACOE requires an evaluation of cumulative impacts from these permits, the effectiveness of such evaluations at preventing cumulative impacts is unknown. Similarly, the section 401 water quality certification program, which is regulated by the states of California and Oregon, applies only to activities that require a federal permit or license (i.e., 404 permit or FERC license, respectively). Because the 401 certification requirements depend on the initiation of the 404 permitting or FERC licensing process, the 401 program also does not address exclusively upland activities. Therefore, the lack of review and jurisdiction for upland activities limits the ability of the 404 and 401 regulatory programs to provide adequate protection for coho salmon and its habitat.

### California Endangered Species Act

In 2005, the state of California listed coho salmon between Punta Gorda and the Oregon border as threatened. The California listing protects coho salmon from direct take, and helps to ensure that projects or activities that have incidental adverse effects to coho salmon are reviewed and take is mitigated. In connection with the California state listing, a coho salmon recovery strategy was formally approved and adopted by the California Fish and Game Commission on February 4, 2004 (CDFG 2004a). The recovery strategy includes over 700 conservation recommendations covering a wide variety of land use activities, and over 200 more related to agricultural practices within the Scott and Shasta rivers, tributaries to Klamath River. To facilitate implementation, the CDFG has integrated the recovery strategy with the Fisheries Restoration Grant Program (FRGP). Currently the recovery plan is being implemented throughout the California portion of the ESU and a 5-year progress report is under development. Limited funding and staff have impacted the state's ability to fully implement the plan in recent years.

### Federal Endangered Species Act Protections

The major provisions of the Endangered Species Act of 1973, as amended,16 U.S.C. § 1531 et seq., set forth eligibility and procedural requirements for listing species as endangered or threatened, provide protections for those listed species, require Federal agencies to ensure that their actions are not likely to jeopardize listed species or result in the destruction or adverse modification of their designated critical habitat without special exemption, and create a framework for cooperation with states to conserve listed species and their habitat. The most direct mechanism for protection under the ESA is the section 9 take prohibition. Section 7(a)(1) makes it clear that Federal agencies must utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of endangered species and threatened species. Although Federal agencies have an affirmative obligation to conserve, an agency's 7(a)(1) actions are discretionary and priorities are often obligated to other management objectives.

Section 7(a)(2) states, in part, "[e]ach Federal agency shall, in consultation with and with the assistance of the Secretary [of Interior or Commerce, as appropriate], insure that any action authorized, funded, or carried out by such agency…is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat of such species...unless such agency has been granted an exemption for such action by the Committee pursuant to subsection (h) of this section." Since the time of listing, NMFS has conducted over 1,000 consultations on the effects of Federal actions on SONCC coho salmon and their critical habitat, including major projects on the Rogue, Trinity, Klamath, and Eel rivers. Interagency consultation, including technical assistance and section 7 consultations (both informal and formal) have often reduced or eliminated adverse effects to SONCC coho salmon, their designated critical habitat, or both.

Section 10(a)(1)(B) of the ESA allows NMFS to issue permits to non-Federal parties for incidental take of listed species, as long as, among other requirements, the impacts of the taking are minimized and mitigated to the maximum extent practicable and the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild. Neither section 7(a)(2) consultations nor section 10 permits are intended to require Federal agencies or permit holders to contribute to the recovery of listed species. However, in section 7(a)(2) consultations and in issuance of section 10(a)(1)(B) permits, the action or taking must not appreciably reduce the likelihood of survival and recovery of the listed species in the wild. Further, in biological opinions, NMFS frequently provides discretionary conservation recommendations, which, if implemented, would assist the action agency in meeting its section 7(a)(1) responsibilities.

Whenever a species is listed as threatened under the federal ESA, section 4(d) authorizes the Secretary to issue regulations as he deems necessary and advisable to provide for the conservation of such species, including taking prohibition or limitation of the taking prohibition for certain identified activities.

### 3.2.14 Ocean Conditions

Poor ocean conditions have played a prominent role in the decline of coho salmon in California and Oregon and will greatly influence the ability to recover SONCC coho salmon. In general, coho salmon marine survival is about 10 percent (Bradford 1995), although there is a wide range in survival rates (from less than one percent to about 21 percent) depending upon population location and ocean conditions (Beamish et al. 2000, Quinn 2005). Marine survival and successful return as adults to spawn in natal streams is critically dependent on an individual's first few months at sea (Peterman 1982, Unwin 1997, Ryding and Skalski 1999, Koslow et al. 2002). In addition, large smolts have higher ocean survival than small smolts (Bilton et al. 1982, Henderson and Cass 1991, Lum 2003, Quinn 2005, Jokikokko et al. 2006, Muir et al. 2006). In addition, larger smolts produce larger adults (Lum 2003, Henderson and Cass 1991), which have higher fecundity than smaller adults (Weitkamp et al. 1995, Fleming 1996, Heinimaa and Heinimaa 2004).

The ocean upwelling process (and resulting productivity) is important to the growth and survival of juvenile salmonids in the upwelling zone off the west coast (Nickelson 1986; Fisher and Pearcy 1990; Pearcy 1992; Logerwell et al. 2003). Two aspects of upwelling are of greatest importance to juvenile salmonids during their first summer at sea: the strength of upwelling (Nickelson 1986) and the starting date of the upwelling season, also called the date of spring transition (Logerwell et al. 2003). Upwelling-supported zooplankton production correlates well with juvenile salmon survival (Ruzicka et al. 2011).

For Pacific salmon, the conditions of the waters in the California Current are a key to understanding ocean survival. Differences from year to year in both the source of waters that feed the California Current and the volume of water transported each year seem to be controlled by the phase of the Pacific Decadal Oscillation (PDO) (Jacobson et al 2012). The PDO is a spatial pattern in sea surface temperature seen across the entire Northern Pacific Ocean. When the PDO was first described by Mantua el al. (1997) it was noted that the phase of the PDO shifted on a decadal time scale. Since 1998, the phase of the PDO has oscillated with a much higher frequency of about five years. Recently the frequency of the oscillation appears to have increased again, with a two-year cool phase from 2008 to 2009 followed by one warm phase year (mid-2009 – mid 2010) and one cool year (mid-2010 -2011). Jacobson et al. (2012) has used this extreme variability to compare the response of juvenile salmon to a large variety of ocean conditions. New research suggests that the mechanistic link between PDO and salmon growth and survival is due to shifts at the base of the food chain between lipid-poor and lipid-rich plankton communities. These changes in the food chain lead to changes in feeding conditions for salmon and forage fishes (Peterson and Keister 2003; Peterson and Schwing 2003; Peterson and Hooff 2005; Hoof and Peterson 2006; Daly et al. 2010; Litz et al. 2010; Keister et al. 2011; Bi et al. 2011)

When PDO is in a negative (cold) phase, boreal, lipid-rich cold-water copepod species dominate the lower trophic levels in the California Current. When the PDO is in positive (warm) phase, warm water and lipid-poor copepod species become important in the Northern California Current and in some years dominate. Shifts in the PDO also result in other changes in the coastal food web (Jacobson et al 2012). Warm ocean conditions associated with the positive-phase PDO result in changes in the abundance of fish predators and fish prey in coastal waters of the Northern California Current. Adult and juvenile hake move up the shelf waters during warm ocean periods, resulting in increased predation on juvenile salmon (Emmett and Krutzikowsky 2008). Forage fishes (anchovy and smelts), which as juveniles are prey of juvenile salmonids, tend to be less abundant during warm ocean conditions (Emmett et al. 2006; Emmett and Sampson 2007). Thus, the PDO may affect the survival of salmon through both its effects at the base of the food web as well as on salmon predators at higher trophic levels.

Pacific salmon sustain heavy and highly variable losses in the ocean, with natural mortality rates often exceeding 90-95% (Bradford 1995). Most of this mortality is thought to occur in coastal marine ecosystems during two critical periods: an early period of predation-based mortality that occurs within the first few weeks or months of ocean entry, and a later period of starvation-based mortality that occurs following the first winter at sea (Beamish and Mahnken 2001).

Both predation- and starvation-based mortality are size-dependent (Willette et al. 2001; Hurst 2007). Therefore, ocean conditions that lead to slower growth likely increase mortality during these critical periods of marine life, thereby reducing adult returns (Pearcy 1992; Beamish et al. 2004). Slower marine growth may also reduce the ability of adult salmon to complete their spawning migration (Crossin et al. 2004). Production in freshwater and riparian ecosystems may consequently be reduced through a reduction in marine-derived nutrients (Cederholm et al. 1999, Kiffney et al. 2014). Moreover, smaller adult fish tend to produce smaller eggs and fry, which are more vulnerable to predation than larger cohorts (Ruggerone and Rogers 1993; Quinn et al. 2004). In multiple populations of coho salmon Jacobson et al (2012) found a positive and significant relationship between marine growth and adult abundance, providing strong evidence that variation in marine productivity directly controls marine abundance of salmon. Furthermore, the data suggest that estimates of juvenile salmon growth soon after ocean entry may be used to estimate adult salmon returns.

Changes in the marine environment over the past decade demonstrate the impacts that changing ocean conditions can have on coho salmon populations (Beamish et al. 2000, Logerwell et al. 2003). For at least two decades, beginning about 1977, marine productivity conditions were unfavorable for the majority of salmon populations in the Pacific Northwest. Recent data from across the range of coho salmon on the coast of California and Oregon reveal there was a 72 percent decline in returning adults in 2007/08 compared to the same cohort in 2004/05 (MacFarlane et al. 2008). The Wells Ocean Productivity Index, a measure of Central California ocean productivity, revealed poor conditions during the spring and summer of 2006, when juvenile coho salmon from the 2004/05 cohort entered the ocean (MacFarlane et al. 2008). Poor ocean productivity can be especially detrimental to coho salmon along the Oregon and California coast, because these regions lack extensive bays, straits, and estuaries which could buffer adverse oceanographic effects (Bottom et al. 1986).

### 3.2.15 Stochastic Pressure from Small Population Size

A recent development in the field of conservation biology is the hypothesis that random events in small populations may have a large impact on population dynamics and population persistence.

The peril that small populations face may be either deterministic (the result of systematic forces that cause population decline such as overexploitation, development, deforestation, loss of pollinators, inability to find mates, or inability to defend against predators) or stochastic (the result of random fluctuations that have no systematic direction). These forces have been shown to reduce population size, and when populations are reduced to very low densities, they can experience reduced rates of survival and reproduction (Allee 1938, Wood 1987). Over the long term, a series of unlucky generations in which there are successive declines in population size can lead to extinction even if the population is growing, on average.

Most independent populations in the SONCC coho salmon ESU have declined in numbers to below the depensation threshold and are therefore being influenced by stochastic (random natural) processes that may make recovery of the ESU more difficult than currently thought (CDFG 2004a). As natural populations get smaller, the number of interacting stochastic processes that influence the population increases. These stochastic processes can create alterations in genetics, breeding structure, and population dynamics that may interfere with recovery efforts and need to be considered when evaluating how populations within the ESU are going to respond to recovery actions. This stochastic pressure can express itself in three ways: genetic, demographic and environmental.

Genetic stochasticity refers to changes in the genetic composition of a population that are unrelated to systematic forces (selection, inbreeding, or migration, i.e., genetic drift). Genetic stochasticity can have a large impact on the genetic structure of populations, both by reducing diversity within populations and by increasing the chance that deleterious recessive alleles are expressed. When populations are at levels below depensation, stochasticity can make both population viability and survival difficult to predict, due to the random variables that are now acting on the population. These processes, when working together, can cause reduced genetic diversity in a population (or populations), further decreases in population size, or shifts in life-history traits. Reduced diversity could limit a population's ability to respond adaptively to future environmental changes. In addition, the increased frequency with which deleterious recessive alleles are expressed (because of increased homozygosity) could reduce the viability and reproductive capacity of individuals.

Demographic stochasticity refers to the variability in population growth rates arising from random differences among individuals in survival and reproduction within a season. This variability will occur even if all individuals have the same expected ability to survive and reproduce and if the expected rates of survival and reproduction don't change from one generation to the next. Even though it will occur in all populations, it is generally important only in populations that are already fairly small. Environmental stochasticity is the type of variability in population growth rates that refers to variation in birth and death rates from one season to the next in response to weather, disease, competition, predation, ocean conditions, or other factors external to the population.

In these small populations, recovery from low densities may be significantly delayed or not occur at all and the populations may suffer a decrease in population growth rate. This reduced population growth rate at low densities is also known as depensation (Liermann and Hilborn 2001). Many mechanisms can lead to depensation, and depensatory effects are usually displayed through changes in the following mechanisms: reduced probability of fertilization, impaired group dynamics, conditioning of the environment, and predator saturation (Liermann and Hilborn 2001). A population's dynamics are depensatory if the growth rate decreases along with density or abundance decreasing to low levels. Components of the life-history, such as fecundity or survival, or the mechanisms that affect these components, are called depensatory if they decrease the growth rate along with density or abundance. At extremes, these depensatory dynamics have negative population growth rates at low densities and are called critical depensation (Clark 1985). The critical density at which the per-individual growth rate becomes negative is of particular interest, since populations reduced below this density face further decline and possibly extinction (Liermann and Hilborn 2001). The ability to recognize when populations are entering or are in a depensatory state is therefore vitally important in the efforts leading to recovering a species. Recognizing when depensation is occurring has proven to be difficult; current research utilizing parametric statistical analyses is now used to help better understand the population dynamics occurring in these small populations.

Stochastic processes are likely influencing populations throughout the SONCC ESU. These processes and pressures should be taken into account when prioritizing watersheds and associated recovery actions to ensure that efforts made to recover extremely small populations are successful, and that other processes are not hindering or defeating recovery efforts. These processes, while not serious when acting alone, can become significant contributors to population instability and decline when acting synergistically with other threatening processes. It may be difficult to know when additional stochastic factors are playing a role in a population's recovery and viability, and so including, where possible, statistical population models to determine current pressures and threats is needed. Models like the Population Viability Analysis (PVA) have been shown to be extremely useful in obtaining a better understanding of the processes and pressures that are affecting small populations like those seen in the SONCC coho salmon ESU.

This page intentionally left blank.

# 4. Recovery Goals, Objectives, and Criteria

The following goals guide recovery of SONCC coho salmon as described in recovery documents from the State of Oregon, the State of California, and NMFS.

First, the populations must reach desired levels of biological viability and the recovery effort must sufficiently reduce the impact of the stresses and threats in order to warrant removal of the SONCC coho salmon ESU from the threatened and endangered species list (referred to in this plan as either delisting or ESA recovery). Section 4.1 describes the recovery goals and criteria.

Second, the States of California and Oregon seek to rebuild wild populations to reach 'broad sense recovery' to provide for sustainable fisheries and other ecological, cultural, and social benefits. Section 4.2 describes broad sense recovery goals.

## 4.1 ESA Recovery Goals

The goal of this recovery plan is to recover the Southern Oregon/Northern California Coast Coho Salmon (*Oncorhynchus kisutch*) ESU to the point where the species is viable and so no longer needs the protections afforded by the federal ESA and can be removed from the ESA threatened and endangered species list. A viable SONCC coho salmon ESU is naturally self-sustaining, with a low risk of extinction. Recovery of SONCC coho salmon requires a viable ESU and a sufficient reduction in the factors that contributed to the need for the protections of the ESA, which are reflected in the stresses and threats; both elements are assessed against recovery criteria. The specific recovery objectives and criteria are provided below.

Delisting criteria are objective, measurable criteria that, when met, would result in a determination by NMFS that the ESU is not endangered and is not likely to become endangered within the foreseeable future throughout all or a significant portion of its range. The delisting criteria for biological parameters are the biological recovery criteria, and the delisting criteria that address listing factors are the stress and threat criteria. As new information emerges, NMFS may revisit the delisting criteria through the status review process, described in Chapter 6.

### 4.1.1 Recovery Objectives

Chapter 2 describes the biological characteristics of an ESU that is at low risk of extinction (viable). Chapter 4 describes the criteria to be met by each population to reach lower risks of extinction, and to achieve a viable ESU. Section 4.1.2 lists the biological recovery objectives and criteria that describe the desired characteristics of the populations that make up the ESU. The stress and threat criteria that describe when these factors will be sufficiently addressed are described in Section 4.1.3.

Recovery criteria can be viewed as the targets, or values, by which progress toward recovery objectives can be measured. We identify what a species' populations, habitat, stresses, and threats are expected to look like when the species is recovered so that we will be better able to determine how far the species needs to move to reach those objectives, and the actions needed to achieve each objective.

### 4.1.2 Biological Recovery Objectives and Criteria

**Biological Recovery Objectives**

NMFS developed biological objectives based on ESU and population viability metrics established by Williams et al. (2008). At the ESU level, SONCC coho salmon must demonstrate representation, redundancy, and connectivity (Williams et al. 2008). Representation relates to the genetic and life-history diversity of the ESU, which is needed to conserve its adaptive capacity. Redundancy addresses the need to have a sufficient number of populations so the ESU can withstand catastrophic events. Connectivity refers to the dispersal capacity of populations to maintain long-term demographic and genetic processes.

At the population level, biological recovery objectives are based on the viable salmonid population (VSP) parameters (McElhany et al. 2000). Each SONCC coho salmon population must achieve sufficient abundance, growth rates, spatial structure, and diversity. However, the minimum needed conditions for each population vary depending on each population's role in recovery as described in this recovery plan (Figure 4-1). Spawner abundance is an important parameter because, all else being equal, small populations are at greater risk of extinction than larger populations. Large populations are generally better able to withstand the detrimental effects of environmental variation, genetic processes, demographic stochasticity, ecological feedback, and catastrophes than small populations (Shaffer 1981). Productivity describes the growth rate of a population. Spatial distribution is important to reduce extinction risks from genetic risks and demographic stochasticity. A population's spatial distribution depends on habitat quality (including accessibility), population dynamics, and dispersal characteristics of individuals in the population. Genetic and life-history diversity allows species to adapt to a variety of environments that provide for the needs of the species and protect against short-term environmental change while also providing the genetic material necessary to survive environmental change.

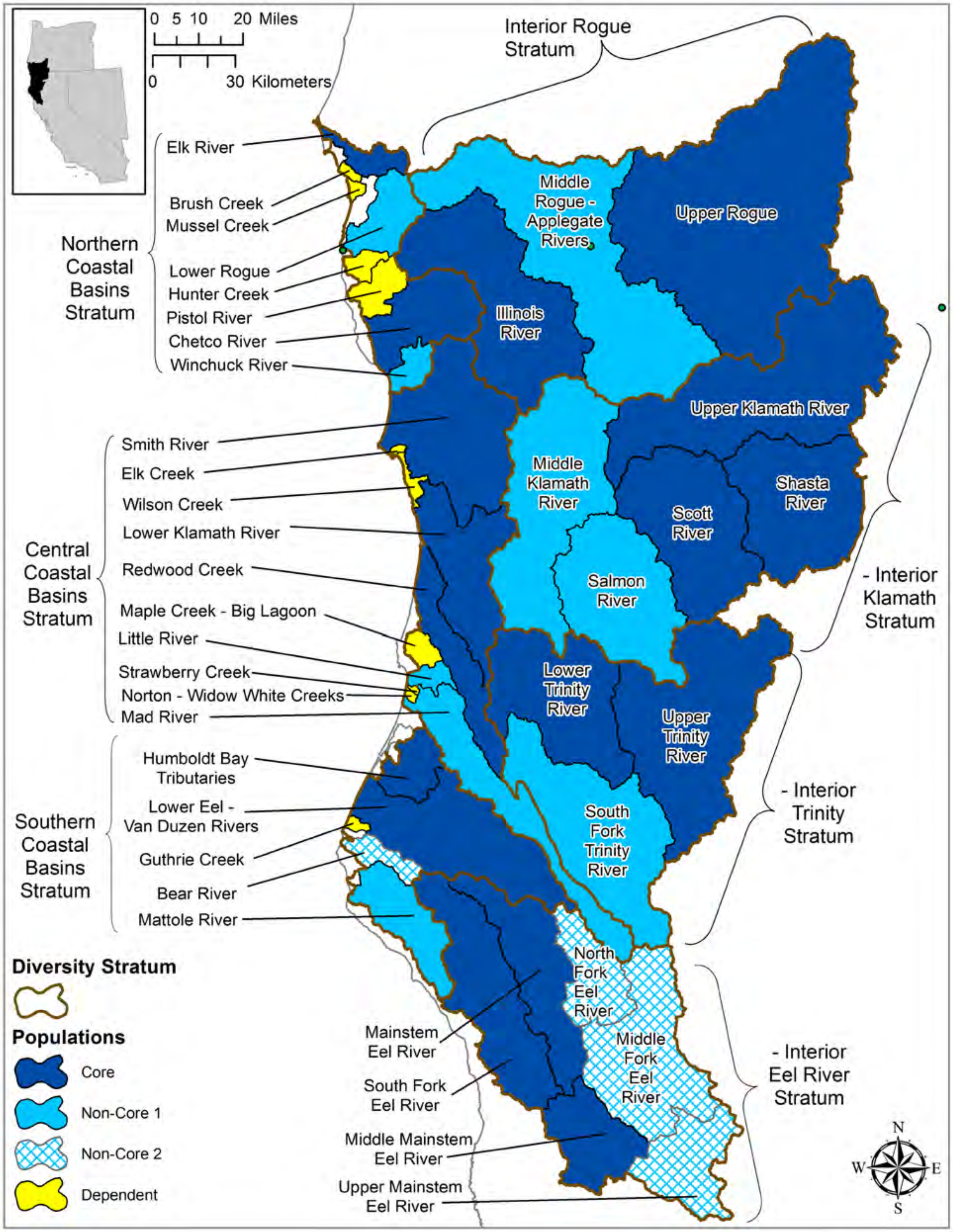



Figure 4-1. Core, non-core, and dependent populations within diversity strata of the SONCC coho salmon ESU.

### Biological Recovery Criteria

The biological recovery criteria for each population type are described in Table 4-1 and the specific abundance criterion to be met by each population is shown in Table 4-2. The biological recovery criteria described in this section reflect NMFS' opinion of how to best achieve a viable ESU most quickly. **In a recovered ESU, biological recovery criteria for all four parameters (abundance, productivity, spatial structure, and diversity) must be met** [Emphasis added].

Each population plays a role in recovery, and NMFS identifies four categories of populations as described in Chapter 2: Core, Non-Core 1, Non-Core 2, and Dependent. Core populations are independent populations that are likely to respond to recovery actions and achieve a low risk of extinction[7] most quickly[8]. All but four of the remaining independent populations are categorized as "Non-Core 1". In a recovered ESU, these Non-Core 1 populations will be at least at a moderate risk of extinction. The remaining four Independent populations are categorized as "Non-Core 2", as their populations are thought to be extirpated. In a recovered ESU, Non-Core 2 and Dependent populations will support emigrants from other populations. Figure 4-1 shows the category assigned to each population. Table 4-1 and Table 4-2 describe the recovery objectives and criteria for each population category.

[7] Excluding the areas above some dams; see footnote 3 in Table 4-1.

[8] The rationale for choice of core populations is described in Appendix C.

Table 4-1. Biological recovery objectives and criteria for SONCC coho salmon. All biological recovery criteria must be met in a recovered ESU.

| VSP Parameter | Population Role | Biological Recovery Objective | Biological Recovery Criteria[1] |
|---|---|---|---|
| Abundance | Core | Achieve a low risk of extinction[2] | The geometric mean of wild adults over 12 years meets or exceeds the "low risk threshold" of spawners for each core population[2,3,4] |
| | Non-Core 1 | Achieve a moderate or low risk of extinction[2] | The annual number of wild adults is greater than or equal to four spawners per IP-km for each non-core population[2] |
| Productivity | Core and Non-Core 1 | Population growth rate is not negative | Slope of regression of the geometric mean of wild adults over the time series ≥ zero[4] |
| Spatial Structure | Core and Non-Core 1 | Ensure populations are widely distributed | Annual within-population juvenile distribution ≥ 80%[4] of habitat[5,6] (outside of a temperature mask[7]) |
| | Non-Core 2 and Dependent | Achieve inter- and intra-stratum connectivity | ≥ 80% of accessible habitat[4] is occupied in years[8] following spawning of cohorts that experienced high marine survival[9] |
| Diversity | Core and Non-Core 1 | Achieve low or moderate hatchery impacts on wild fish | Proportion of hatchery-origin adults (pHOS) < 0.05 |
| | Core and Non-Core 1 | Achieve life-history diversity | Variation is present in migration timing, age structure, size and behavior. The variation in these parameters[10] is retained. |

1 All applicable criteria must be met for each population in order for the ESU to be viable.
2 See Table 4-2 for specific spawner abundance requirements needed to meet this objective.
3 In the Shasta River, Upper Trinity River, and Upper Rogue River populations, IP above some anthropogenic dams was excluded from the spawner target, so the low-risk threshold for these populations is based on the IP downstream of those dams.
4 Assess for at least 12 years, striving for a coefficient of variation (CV) of 15% or less at the population level (Crawford and Rumsey 2011).
5 Based on available rearing habitat within the watershed (Wainwright et al. 2008). For purposes of these biological recovery criteria, "available" means accessible. 80% of habitat occupied relates to a truth value of +1.0,(true: juveniles occupy a high proportion of the available rearing habitat within the watershed (p. 56, Wainwright et al. 2008).
6 The average for each of the three year classes over the 12 year period used for delisting evaluation must each meet this criterion. Strive to detect a 15% change in distribution with 80% certainty (Crawford and Rumsey 2011).
7 Williams et al. (2008) identified a threshold air temperature, above which juvenile coho salmon generally do not occur, and identified areas with air temperatures over this threshold. These areas are considered to be within the temperature mask.
8 If young-of-year are sampled, sampling would occur the spring following spawning of the cohorts experiencing high marine survival. If 1+ juveniles are sampled, sampling would occur approximately 1.5 years after spawning of the cohorts experiencing high marine survival, but before outmigration to the estuary and ocean.
9 High marine survival is defined as 10.2% for wild fish and 8% for hatchery fish; Sharr et al. 2000. If marine survival is not high, then this criterion does not apply.
10 This variation is documented in the population profiles in Chapters 7 to 46 of this plan.

Table 4-2. The minimum number of spawners (male and female) needed in each population to meet the biological recovery criteria.

| Diversity Stratum | Independent Population | Population Role | Minimum Number of Spawners[1] |
|---|---|---|---|
| Northern Coastal Basins | Elk River | Core | 2,400 |
| | Brush Creek | Dependent | None- Juv. Occupancy |
| | Mussel Creek | Dependent | None- Juv. Occupancy |
| | Lower Rogue River | Non-Core 1 | 320 |
| | Hunter Creek | Dependent | None- Juv. Occupancy |
| | Pistol River | Dependent | None- Juv. Occupancy |
| | Chetco River | Core | 4,500 |
| | Winchuck River | Non-Core 1 | 230 |
| Interior Rogue River | Illinois River | Core | 11,800 |
| | Middle Rogue and Applegate rivers | Non-Core 1 | 2,400 |
| | Upper Rogue River | Core | 13,800 |
| Central Coastal Basins | Smith River | Core | 6,800 |
| | Elk Creek | Dependent | None- Juv. Occupancy |
| | Wilson Creek | Dependent | None- Juv. Occupancy |
| | Lower Klamath River | Core | 5,900 |
| | Redwood Creek | Core | 4,900 |
| | Maple Creek/Big Lagoon | Dependent | None- Juv. Occupancy |
| | Little River | Non-Core1 | 140 |
| | Strawberry Creek | Dependent | None- Juv. Occupancy |
| | Norton/Widow White Creek | Dependent | None- Juv. Occupancy |
| | Mad River | Non-Core 1 | 550 |
| Interior Klamath River | Middle Klamath River | Non-Core 1 | 450 |
| | Upper Klamath River | Core | 8,500 |
| | Salmon River | Non-Core 1 | 450 |
| | Scott River | Core | 6,500 |
| | Shasta River | Core | 4,700 |
| Interior Trinity River | Lower Trinity River | Core | 3,600 |
| | Upper Trinity River | Core | 5,800 |
| | South Fork Trinity River | Non-Core 1 | 970 |
| Southern Coastal Basins | Humboldt Bay tributaries | Core | 5,700 |
| | Lower Eel and Van Duzen rivers | Core | 7,900 |
| | Guthrie Creek | Dependent | None- Juv. Occupancy |
| | Bear River | Non-Core 2 | None- Juv. Occupancy |
| | Mattole River | Non-Core 1 | 1,000 |
| Interior Eel River | South Fork Eel River | Core | 9,300 |
| | Mainstem Eel River | Core | 2,600 |
| | Middle Fork Eel River | Non-Core 2 | None- Juv. Occupancy |
| | North Fork Eel River | Non-Core 2 | None – Juv. Occupancy |
| | Middle Mainstem Eel River | Core | 6,300 |
| | Upper Mainstem Eel River | Non-Core 2 | None- Juv. Occupancy |

[1]See Table 4-1 for biological recovery criteria. Abundance estimates should strive for a CV of 15 percent or less at the population level (Crawford and Rumsey 2011).

***High Risk Spawner Threshold***

If only a single spawner were present in a 1-mile reach within a population, the salmon population as a whole would likely to face significant demographic risks such as difficulties in finding mates (Wainwright et al. 2008). Therefore, Williams et al. (2008) chose 1 spawner per mile density as the high risk (depensation) threshold and converted the density into IP-km for the SONCC coho salmon ESU, which is approximately 1 spawner per IP-km.

***Moderate Risk Spawner Threshold***

Because one spawner per IP-km is the depensation threshold, Williams et al. (2008) identified the minimum spawner density needed to achieve a moderate risk of extinction as any number greater than 1 adult per IP-km (Table 4-3). To provide a reasonable buffer against falling below the threshold, the abundance criterion for Non-Core 1 populations is set at four spawners per IP-km (Table 4-1). Four spawners per IP-km was chosen based on the following rationale.

Other authors have identified a number of spawners per IP-km below which depensation occurs, and these numbers of spawners are typically much higher than that chosen by Williams et al. (2008; Table 4-3). Wainwright et al. (2008) considered a population with value of 4.2 spawners/IP-km to have an uncertain probability of incurring depensation, a value similar to that of Sharr et al. (2000) and Chilcote (1999). Barrowman et al. (2003) note that there is little evidence for depensation in coho salmon, unless less than one female per kilometer of river returned to spawn. Parameter estimates for the upper 95% confidence interval presented in Barrowman et al. (2003) are given in Table 4-3. NMFS chose 4 spawners per IP-km as the moderate risk target, because according to Sharr et al. (2000), four spawners per IP-km would translate into an extinction risk of approximately 10% over four generations (Table 4-3 and Figure 4-2).

Table 4-3. Depensation levels identified by various authors. Results are standardized to IP-km.

| Reference | Value below which depensation occurs |
|---|---|
| Barrowman et al. (2003) 95% Upper CI Type 2 Beverton-Holt Model | 2.26 spawners/IP-km |
| Barrowman et al. (2003) 95% Upper CI Type 2 Logistical Hockey Stick Model | 1.6 spawners/IP-km |
| Sharr et al. (2000) | 4.2 spawners/IP-km |
| Chilcote (1999) | 4.1 spawners/IP-km |

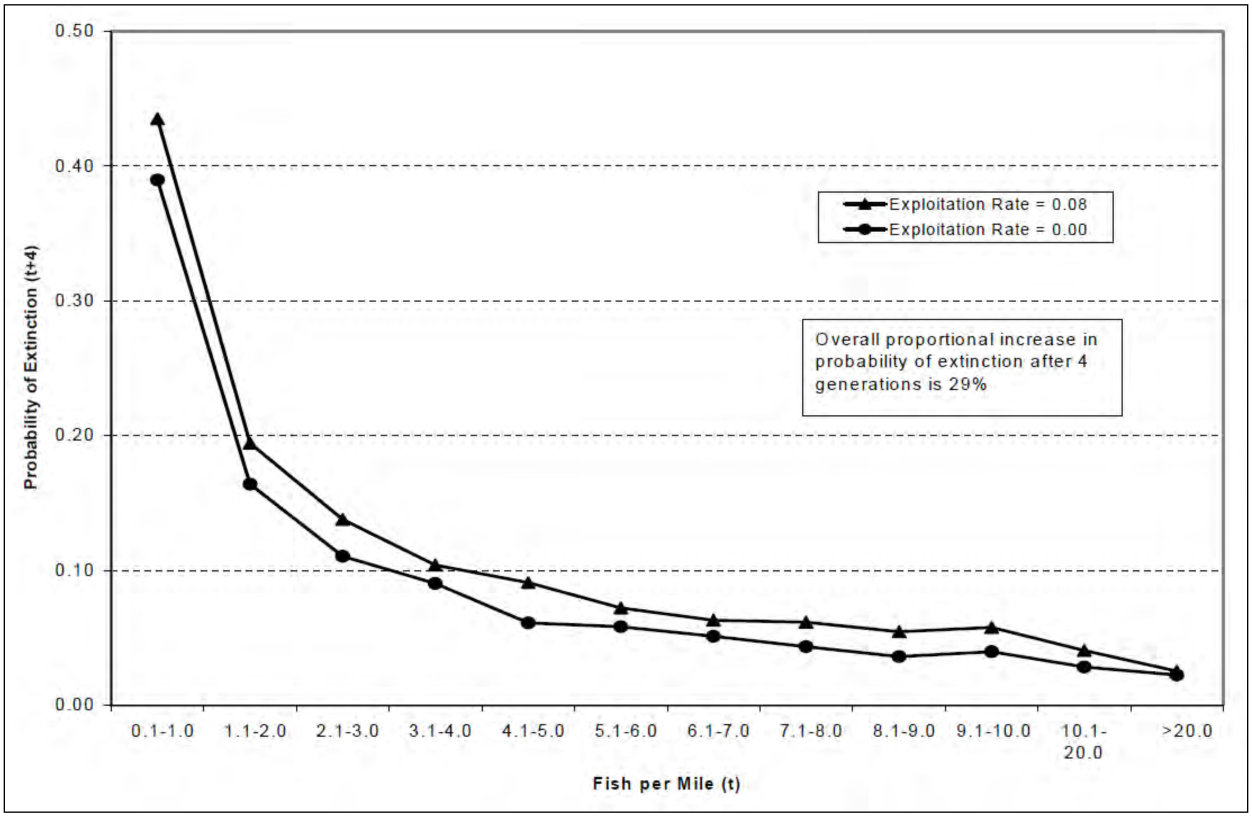



Figure 4-2. Probability of basin level extinction in four generations as a function of spawner density. For fishery exploitation rates of 0.0 and 0.8 in all Oregon coastal basins combined. Source: Sharr et al. (2000).

***Low-Risk Spawner Threshold***

As shown in Table 4-1, the biological recovery criterion for Core population abundance is the low-risk threshold, which is the number of IP-km multiplied by the applicable spawner density used by Williams et al. (2008; Figure 4-3). Spawner density is based primarily on Bradford et al.'s (2000) finding that an average density of 19 females/km is required to fully seed freshwater habitats with juveniles. Assuming males generally outnumber females (Jensen and Hyde 1971, Spindle et al. 1998, Holtby and Healey 1990, Nickelson 2001), Williams et al. (2008) approximated 19 females/km to be equivalent to 40 spawners/km. Because IP-km is weighted, one km of habitat averages to about 0.6 IP-km. Therefore 40 spawners/km is approximately equal to an average of 66 spawners/IP-km.

Williams et al. (2008) may have used 40 spawners/IP-km as the density to fully seed juveniles in freshwater habitat and to establish the low-risk threshold for populations, as opposed to 66 spawners/IP-km, in order to avoid overestimating the historical spawner abundance. Williams et al. (2008) decreased the spawner density requirement to a minimum of 20 spawners/IP-km for larger watersheds based on their assumption that larger populations can diverge farther from historical conditions before extinction risk is substantially increased. A population with ten times more habitat potential (i.e., IP-km >340) than the smallest population will likely require an average spawner density of half that of the smallest population (Williams et al. 2008), and populations between these two sizes required spawner densities linearly between the two reference points (Williams et al. 2008). This approach establishes a population-specific abundance that is scaled to the amount of potential habitat and avoids the use of fixed abundance criteria.

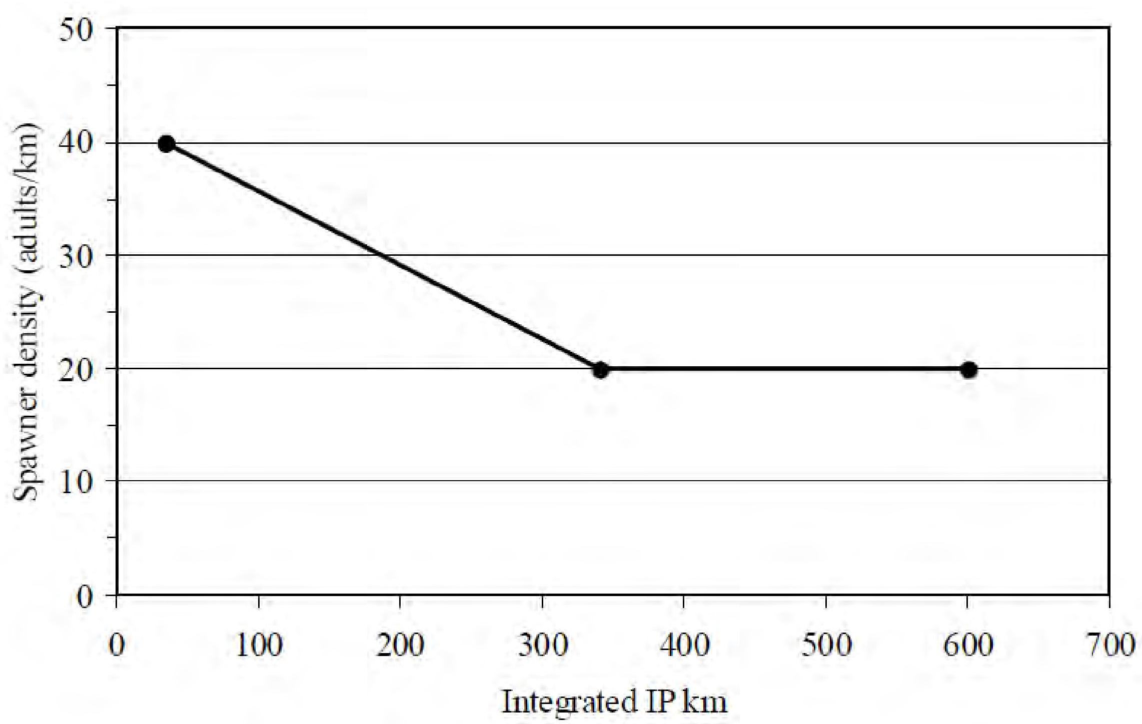



Figure 4-3. Minimum required spawning density based on amount of coho salmon IP-km (Williams et al. 2008).

***Comparison of targets to historical abundance estimates***

Despite efforts to not overestimate, the low risk spawner targets may appear overly ambitious when compared to current conditions. However, these targets should be viewed in the context of historical conditions. Williams et al. (2008) compared these spawner targets to historical estimates along the Oregon Coast, the Rogue River, and in the Eel River. Comparisons with these datasets suggest that the spawner targets do not overestimate the historical carrying capacities of coho salmon populations.

Using cannery records from 1892 to 1915, Meengs and Lackey (2005) estimated historical run sizes of Oregon coho salmon populations by 1) converting salmon pack data (in cases) into pounds of salmon caught (by assuming a certain constant "waste" in processing); 2) converting pounds of salmon captured into numbers of adult fish (by assuming an average weight for adult fish of 4.46 kg); 3) converting numbers of harvested salmon into an estimate of total population sizes (assuming a specific catch efficiency rate); and 4) using the five years of highest abundance in each watershed as indicative of run size. The historical abundance estimates for these Oregon coho salmon populations (Table 4-4) are well over the spawner targets derived from Williams et al.'s (2008) method. All the spawner targets were between 3% and 12% of historical estimates of abundance (Table 4-4).

Table 4-4. Comparison of abundance estimates and IP model-driven density-based abundance targets for coastal watersheds in Oregon (Williams et al. 2008). IP-km are integrated IP-km values.

| Population | Historical estimates of abundance derived from cannery records (Meengs and Lackey 2005) | IP km | Estimated historical spawner density (spawners/IP km) | Projected abundance target based on MRSD (20 spawners/IP km)[a] | Projected abundance target as percent of historical estimate |
|---|---|---|---|---|---|
| Nehalam | 236,000 | 1,116 | 211 | 22,300 | 9.3% |
| Tillamook | 234,000 | 537 | 436 | 10,700 | 4.7% |
| Nestucca | 107,000 | 299 | 358 | 6,800 | 6.4% |
| Siletz | 122,000 | 310 | 394 | 6,800 | 5.6% |
| Siuslaw | 547,000 | 902 | 607 | 18,000 | 3.3% |
| Yaquina | 65,000 | 385 | 169 | 7,700 | 12.3% |
| Alsea | 153,000 | 466 | 328 | 9,300 | 5.9% |
| Coquille | 342,000 | 883 | 387 | 17,700 | 5.3% |
| Coos | 161,000 | 552 | 292 | 11,000 | 6.8% |

[a] – The Nestucca and Siletz populations have less than 340 IP km, therefore the MRSD values used for these calculations were 23 spawners/IP km for the Nestucca population and 22 spawners/IP km for the Siletz population.

In the Rogue River, Meengs and Lackey (2005) estimated the Rogue River had about 114,000 coho salmon during the late 1800s when land use in this watershed already included mining, water diversions, and timber harvesting (Atwood and Gray 2002 *in* Spence et al. 2008). In addition, Mullen (1981) estimated 58,000 coho salmon were harvested in the Rogue River in 1892. In order for the ESU to be recovered, the four populations in the Rogue River needs to contribute at least 28,320 spawners (Table 4-2) which is about 25 percent of Meengs and Lackey's (2005) historic estimate.

Relatively recent spawner estimates are available for the Upper Rogue River population to compare with the spawner target of 13,800 for this population (Table 4-2). As recently as 2000, the wild coho salmon spawner count at the Gold Ray Dam in the Upper Rogue River population was approximately 15,500 (ODFW 2010). Because the dam is not at the downstream-most location of the population unit, coho salmon spawners counted at the Gold Ray Dam represent only a portion of the Upper Rogue River population and the total number of coho salmon spawners in the Rogue River population is likely to be higher than the count at Gold Ray Dam for that year.

In the South Fork Eel River, the average number of coho salmon spawners counted at Benbow Dam from 1941[9] to 1950 was 14,900. Benbow Dam is located about 67 km upstream of where the South Fork Eel River enters the mainstem Eel River. Counts at this dam, consequently, represent only a portion of the South Fork Eel River population. To compare with this historic average, Williams et al. (2008) estimated the fraction of total IP-km upstream of Benbow Dam and multiplied this fraction by the overall abundance target to obtain estimates of the coho salmon spawner target upstream of Benbow Dam. The resulting coho salmon spawner target upstream of Benbow Dam is 6,836, which is about 46 percent of the average returns from 1941 to 1950.

In summary, where there are estimates of abundance of coho salmon to compare with spawner targets, the methods described in Williams et al. (2008) and any of NMFS' adjustments to Williams et al. (2008) targets do not appear to overestimate the historical carrying capacities of coho salmon populations.

***Possible change to low-risk threshold***

NMFS developed biological recovery criteria based on the productivity, spatial structure, and diversity components of the viability salmonid population (VSP) framework described by McElhany et al. (2000). Chapter 4 describes the biological recovery criteria for all four VSP parameters, including the low-risk threshold abundance targets identified by Williams et al. (2008). Future research is needed to determine whether the low-risk threshold abundance target could be increased or decreased if the other VSP parameters are well-estimated. Recovery actions for this research are identified in Chapter 5.

### 4.1.3 Stress and Threat Reduction Objectives and Criteria

Chapter 1 describes the listing factors identified when SONCC coho salmon were listed as a threatened species under the Endangered Species Act (ESA). Listing factors are those factors

[9] While records of fish counts at Benbow Dam began in 1938, 1941 is used as the starting period here to exclude hatchery influences on the spawner counts. Hatchery releases in the Eel River basin occurred from 1935 to 1938 (Williams et al. 2008).

that contributed to the decline of the species to the point where ESA protection was warranted. The possible delisting of coho salmon in the future would require that the biological recovery criteria in 4.1.2 are met. In addition, delisting would require that NMFS determine that the factors that led to the listing of SONCC coho salmon are sufficiently addressed. By establishing criteria for each of the five listing factors, the recovery plan will ensure that the underlying causes of decline have been addressed and mitigated prior to considering a species for delisting.

In order to develop criteria responsive to the listing factors, NMFS identified those stresses and threats associated with each listing factor (Table 4-5). Stresses are attributes of the ecology of a particular life stage of coho salmon that are impaired, directly or indirectly, by human activities. For example, impaired water quality, specifically high water temperature, can impair growth or kill coho salmon. Threats are activities or processes that have caused, are causing, or may cause a stress. For example, land management activities may require withdrawal of water from a river. This reduced flow can result in higher water temperature, impairing water quality and harming or killing coho salmon. The stresses and threats are described in Chapter 3, the methods used to assess them are described in Appendix B, and the results of the assessment for each population are summarized in Chapters 7 to 46.

The stress and threat reduction objectives and criteria are presented in Table 4-5, organized according to the five listing factors introduced in Chapter 3. The ratings of some stresses are informed by comparison of site-specific data to reference data values, which reflect the needed habitat conditions (Table 4-6). Appendix B describes how these indicators are used to inform the stress ranks. The indicators used in the assessment of stresses in this plan are shown in Table 4-6. Other indicators may be used instead of, or in addition to, these indicators in future assessments of stresses.

Table 4-5. Recovery objectives and criteria for stresses and threats.

| Listing Factor | Stress/Threat | Recovery Objective | Recovery Criteria |
|---|---|---|---|
| A. Habitat Destruction, Modification or Curtailment | Lack of floodplain and channel structure | Habitat destruction, modification or curtailment does not limit attainment of population-specific recovery criteria | Lack of floodplain and channel structure is rated a medium or low stress[1] for all life stages of coho salmon in Core and Non-Core 1 populations based on GRTS[2] sampling of each population area. |
| | Altered sediment supply | | Altered sediment supply is rated a medium or low stress[1] for all life stages of coho salmon in Core and Non-Core 1 populations based on GRTS[2] sampling of each population area. |
| | Altered hydrologic function | | Altered hydrologic function is rated a medium or low stress[1] for all life stages of coho salmon in Core and Non-Core 1 populations based on GRTS[2] sampling of each population area. |
| | Impaired water quality | | Impaired water quality is rated a medium or low stress[1] for all life stages of coho salmon in Core and Non-Core 1 populations based on GRTS[2] sampling of each population area. |
| | Degraded riparian forest conditions | | Degraded riparian forest conditions is rated a medium or low stress[1] for all life stages of coho salmon in Core and Non-Core 1 populations based on GRTS[2] sampling of each population area. |
| | Barriers | | Barriers do not limit access to areas determined to be necessary to attain coho salmon recovery[3]. |
| | Impaired Estuary Function | | Impaired estuarine function is rated a medium or low stress[1] for all life stages of coho salmon in Core and Non-Core 1 populations based on GRTS[2] sampling of each population area. |
| A. Habitat Destruction, Modification or Curtailment | Roads, Timber Harvest, Channelization, Diking, Agricultural Practices, Dams, Diversions, Mining, Gravel Extraction, and Urbanization | Threats to habitat do not limit attainment of population-specific recovery criteria | The recovery criteria listed above for all the stresses associated with Listing Factor A are met. |
| B. Over-utilization for commercial, recreational, scientific or educational purposes | Fisheries | Commercial, recreational and tribal fisheries impacts do not limit attainment of population-specific recovery criteria. | Commercial, recreational and tribal fisheries impacts do not, and likely will not, limit attainment of the desired status of populations relative to population-specific viability criteria. The desired status is identified in plans to manage these fisheries, and the plans are approved by NMFS. |
| | Collection | Collection impacts do not limit attainment of population-specific recovery criteria. | All scientific collection is authorized under Sections 10(a)(1)(a) or 4(d) of the Endangered Species Act. |

| Listing Factor | Stress/Threat | Recovery Objective | Recovery Criteria |
|---|---|---|---|
| C: Disease and predation | Disease | Disease does not limit attainment of population-specific recovery criteria. | Mean mortality and infection from diseases is not higher than natural background levels[4] for coho salmon juveniles in populations where disease is identified as a high or very high stress. |
| C: Disease and predation | Predation | Predation does not limit attainment of population-specific recovery criteria. | Predation does not, and likely will not, limit attainment of population-specific recovery criteria[5]. |
| D: The inadequacy of existing regulatory mechanisms | Land and resource management | Regulatory mechanisms have been maintained and/or established and are being implemented in a way that allows the desired status of the ESU and its constituent populations, as defined by the biological criteria in this recovery plan, to be attained and maintained. | Regulatory programs that govern land use and resource extraction are in place, enforced, monitored, and adaptively managed adequately to ensure effective protection of coho salmon habitat, including water quality, water quantity, and stream structure and function, and do not limit the continued attainment of the biological recovery criteria in this recovery plan.<br>Regulatory programs are in place and are being implemented, monitored, evaluated and adaptively managed adequately to manage fisheries at levels consistent with the biological recovery criteria of this recovery plan.<br>Regulatory programs have adequate funding, prioritization, enforcement, and coordination mechanisms to ensure habitat protection and effective management of fisheries.<br>Regulatory programs are in place and are being implemented, monitored, evaluated and adaptively managed adequately to manage the effects of climate change (e.g., management for droughts, floods, and sea level rise). |
| E: Other natural or man-made factors affecting continued existence | Climate change | Other natural or man-made factors must not limit attainment of population-specific recovery criteria. | Recovery criteria are met for stresses in Listing Factor A affected by climate change (altered hydrologic function, impaired water quality, degraded riparian forest conditions, impaired estuary/mainstem function, disease/predation/competition) and recovery criteria in Listing Factor D are met relating to land and resource management of climate change effects. |
| | Invasive species | | Regulatory measures to minimize the risk of introduction of additional or spread of existing exotic species in the range of the ESU have been developed and implemented. |
| | Hatchery management | | All hatcheries affecting SONCC coho salmon have NMFS-approved HGMPs, and the effects[6] of these hatcheries are within the levels described in the respective HGMPs. |

[1] NMFS will consider the ratings of applicable indicators (Poor, Fair, Good, or Very Good) shown in Appendix B, Table B.3 in order to determine the current level of stress or threat (Very High, High, Medium, or Low). This consideration process is described in Appendix B, Section B.3.
[2] Generalized Random Tessellation Stratified technique (Stevens and Olsen 2004)
[3] Recovery action will determine which areas blocked by barriers are necessary to attain coho salmon recovery.
[4] NMFS assumes natural background levels of *C. shasta* equates to the lowest recorded mortality in coho salmon sentinel juveniles at the Beaver Creek site in the Klamath River in May and June (i.e., 10% mortality; Bartholomew 2012). These background levels will be used as the NMFS recovery criterion for this threat.
[5] Recovery actions will determine what levels of predation do not limit attainment of population-specific recovery criteria.
[6] The concept of the proportion of natural influence (PNI), developed by the Hatchery Science Review Group (HSRG 2004), may be a useful tool for limiting the risks of fitness loss in natural populations due to straying of hatchery fish.

Table 4-6. Indicators of aquatic habitat suitability for coho salmon habitat, to used to rate applicable stresses and determine if stresses are rated “medium” or “low”. Adapted from Kier Associates and NMFS (2008).

| Stress | Indicators | Good | Very Good |
|---|---|---|---|
| Lack of Floodplain and Channel Structure | Pool Depths | 3-3.3 ft | >3.3 ft. |
| | Pool Frequency (length) | 41-50% | >50 |
| | Pool Frequency (area) | 21-35% | >35% |
| | D50 (median particle size) | 51-60 & 95-110 mm | 60-95 mm |
| | LWD (key pieces[1]/100 m) | 2-3 | >3 |
| | LWD <20 ft. wide[2] | 54-84 pieces[3]/mi | >85 pieces[3]/mi |
| | LWD 20-30 ft. wide[2] | 37-64 pieces[3]/mi | >65 pieces[3]/mi |
| | LWD >30 ft. wide[2] | 34-60 pieces[3]/mi | >60 pieces[3]/mi |
| Altered Sediment Supply | % Sand <6.4mm (wet) | 15-25% | <15% |
| | % Sand <6.4mm (dry) | 12.9-21.5% | <12.9% |
| | % Fines <1mm (wet) | 12-15% | <12% |
| | % Fines <1mm (dry) | 8.9-11.1% | <8.9% |
| | V Star (V*) | 0.15 - 0.21 | <0.15 |
| | Silt/Sand Surface (% riffle area) | 12-15% | <12% |
| | Turbidity (FNU)[4] | 120-360 hrs > 25 FNU | <120 hrs >25 FNU |
| | Embeddedness (%) | 25-30 | <25 |
| Impaired Water Quality | pH (annual maximum) | 8.25-8.5 | <8.25 |
| | D.O. (COLD) (mg/l 7-DAMin) | 6.6-7.0 mg/l | >7.0 mg/L |
| | D.O. (SPAWN) (mg/l 7-DAMin) | 10.1-11 mg/l | >11.0 mg/l |
| | Temperature (MWMT[5]) | 16-17 °C | <16 °C |
| | Aq Macroinverts (EPT) | 19-25 | >25 |
| | Aq Macroinverts (Richness) | 31-40 | >40 |
| | Aq Macroinverts (B-IBI) | 60.1-80 | >80 |
| Degraded Riparian Forest Conditions | Canopy Cover (% shade) | 71-80% | >80% |
| | Canopy Type (% Open + Hardwood) | 20-30% | <20% |
| | Riparian Condition (conifers >36" dbh / 1000ft for 100 ft wide buffer) | 125.1-200 | >200 |
| Disease | *Ceratonova shasta* | No greater than 10% mortality of sentinel coho salmon juveniles at Beaver Creek confluence in the Klamath River during May and June | |

[1] Key pieces of large woody debris are pieces with a minimum diameter of 60 cm (2 feet) and a minimum length of 100 m (33 feet) (Foster et al. 2001).

[2] The number of pieces of wood in streams with a wetted width of less than 20 feet, between 20 and 30 feet, or greater than 30 feet (The Nature Conservancy 2006).

[3] Pieces of wood are defined as all wood pieces that are greater than 12 inches in diameter at 25 feet from the large end (The Nature Conservancy 2006).

[4] Formazin Nephelometric Units.

[5] Maximum weekly maximum temperature: Average of the daily maximum temperatures during the warmest 7-day period of the year.

## 4.2 Broad-Sense Recovery Goals

When the SONCC coho salmon ESU is recovered under the ESA and delisted, returning wild coho salmon spawners may number in the tens of thousands but may not be numerous enough to use all available spawning habitat throughout the ESU. Many streams may remain unoccupied or under-occupied by coho salmon. Tens of thousands of coho salmon may not be enough to maintain a fishery. The cultural, economic, and ecological benefits of having numerous coho salmon spawning throughout the ESU are not maximized under a scenario where only ESA recovery is achieved. While the delisting criteria need to be objective and measurable, broad-sense recovery is more open-ended.

The recovery objectives and criteria in this plan define which populations must be at low risk of extinction to delist, but other populations have the potential to achieve a low risk of extinction as well. Broad-sense recovery means maximizing the viability of all populations. The goal of broad-sense recovery is to achieve a low risk of extinction for all independent populations in the SONCC, both Core and Non-Core populations. Broad sense recovery is a long-term goal. Enhancing the abundance, spatial structure, diversity and productivity of the Non-Core and dependent populations beyond the ESA delisting criteria is not required to delist SONCC coho salmon. However, doing so will increase resiliency of SONCC coho salmon, with associated opportunities for cultural, economic, and ecological benefits.

### 4.2.1 Recovery Action Implementation

All 40 populations of SONCC coho salmon have a profile that summarizes available scientific data and other pertinent information, including the stresses and threats affecting that population (Chapters 7 to 46). These population profiles help guide restoration and recovery efforts for coho salmon and their habitats. Population profiles are available for stakeholders to work toward broad-sense recovery. The recovery action table in each profile includes actions needed for each population to contribute to ESU viability. ESA delisting is expected to require implementation of those recovery actions with all priorities except Broad-Sense Recovery actions (those coded BR). Implementation of BR actions, in addition to implementation of those actions necessary to provide for ESA recovery of the species/ESU, would facilitate broad-sense recovery.

### 4.2.2 Oregon's Broad-Sense Recovery Goals and Criteria

Oregon's broad sense recovery goal is to achieve populations of naturally produced salmon and steelhead that are sufficiently abundant, productive, and diverse (in terms of life histories and geographic distribution) that the ESU as a whole (a) will be self-sustaining, and (b) will provide significant ecological, cultural, and economic benefits. This recovery goal was developed under Oregon's native fish conservation policy (ODFW 2003) to fulfill the mission of the Oregon Plan for Salmon and Watersheds (State of Oregon 1997). The Oregon Plan for Salmon and Watersheds is founded on the principle that citizens throughout the region value and enjoy the substantial ecological, cultural and economic benefits that derive from having healthy, diverse populations of salmon and steelhead. The goal is consistent with ESA delisting, and is designed to achieve a level of performance for the ESU and its constituent populations that is more robust than needed to remove the ESU from ESA protection. Broad-sense recovery incorporates ESA delisting goals in the sense that ESA delisting goals would be achieved first during an extended and stepwise process of achieving broad sense recovery goals.

Oregon's broad-sense recovery goal for the SONCC coho salmon ESU has not yet been agreed upon by a public advisory committee. The goal described above was developed for other recovery plans in Oregon and will be used as a placeholder until a public advisory committee has been formed and provided guidance on the broad-sense goal for SONCC coho salmon populations in Oregon.

The State of Oregon developed broad-sense criteria that go beyond the criteria for ESU delisting. These broad-sense criteria are designed to attain population goals that will provide significant ecological, cultural, and economic benefits consistent with the Oregon Plan (State of Oregon 1997).

Oregon's broad-sense recovery criteria for salmonids are:

• All SONCC coho salmon populations have a "very low" extinction risk and are "highly viable"[10] over 100 years throughout their historical range; and

• The majority of SONCC coho salmon populations are capable of contributing social, cultural, economic and aesthetic benefits on a regular and sustainable basis.

### 4.2.3 California's Broad-Sense Recovery Goal

The primary purpose of the *Recovery Strategy for California Coho Salmon* (CDFG 2004a), which the California Department of Fish and Wildlife submitted to the California Fish and Game Commission in February 2004, is to recover coho salmon to the point where the regulations or other protections for coho salmon listed under the California Endangered Species Act are not necessary.

To achieve recovery of coho salmon in California, the *Recovery Strategy* lists five delisting goals and associated criteria, concerned with increasing populations and restoring suitable habitats. In addition, Goal VI of the *Recovery Strategy* seeks to reach and maintain adequate coho salmon population levels to allow for the resumption of Tribal, recreational, and commercial fisheries for coho salmon in California.

---

[10] Having a "very low" extinction risk is equivalent to being "highly viable" in the parlance of population status assessment for recovery plans. A "highly viable" naturally-producing salmonid population with a "very low" extinction risk has less than a 1% probability of extinction over a 100-year period, corresponding to at least a 99% persistence probability. Probabilities result from an integrated assessment of the population's abundance, productivity, spatial structure, and diversity status.

This page intentionally left blank.

# 5. Monitoring and Adaptive Management

## 5.1 Information needed to delist a species

Chapter 4 describes the objective, measurable criteria by which NMFS will determine whether the SONCC coho salmon ESU should be removed from the list of threatened and endangered species. Monitoring provides information to track progress toward recovery by evaluating the species' status relative to these criteria, and to identify if the species can be delisted using the listing status decision framework (Figure 5-1). NMFS recommends the monitoring described in this chapter be carried out, and may determine that other monitoring is also appropriate and necessary.

### 5.1.1 Adaptive management

In addition to its role in assessing the status of coho salmon relative to recovery targets, monitoring data is essential for adaptive management. Adaptive management is the process of improving management policies and practices as conditions change. Adaptive management is an approach to natural resources policy that embodies the idea that policies are experiments; monitoring data are collected and examined so that expectations can be compared to what was observed – adaptive management is not trial and error (Lee 1993). Information is rarely complete and there is often uncertainty. What is known is researched, examined, and tested, knowledge is extended, and management is adjusted. Adaptive management requires care and consideration both before monitoring (by employing sampling designs that adequately inform decision making) and after monitoring (by using results to improve future conservation efforts).

New scientific research may provide information that may warrant adjustments to the recovery plan, implementation, or both. In addition, adaptive management for this recovery plan relies on tracking of stresses and threats and assessment of the effectiveness of restoration actions. Adaptive management guides the implementation of salmon recovery activities through repeated adjustments in strategies and actions, as information from monitoring and evaluation become available (Figure 5-2). Strategies and actions needed for recovery can evolve as effectiveness of actions increases through monitoring and evaluation. Figure 5-2 shows the steps on the road to recovery, including adaptive management.

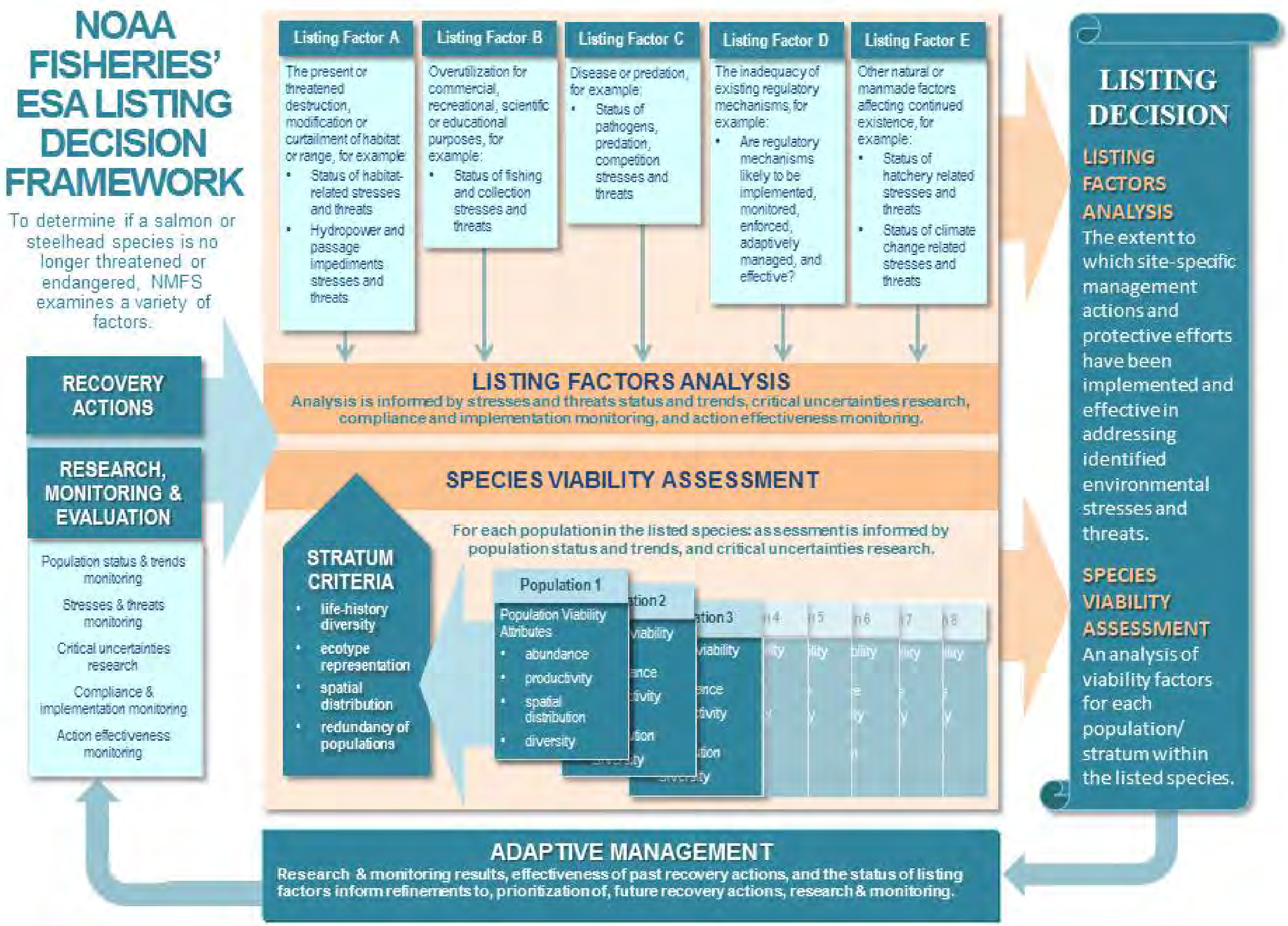



Figure 5-1. NMFS listing status decision framework.


Figure 5-2. The steps on the road to recovery.

## 5.2 Methods for monitoring coho salmon populations

For the purposes of describing SONCC coho salmon and its habitat, the spatial scale to be characterized is the population. Sampling at a coarser spatial scale (e.g., diversity stratum) would not provide the information needed to assess the status and trends of SONCC coho salmon populations. In addition, it is necessary to detect population changes with an appropriate level of certainty (Chapter 4); for example, spawner abundance estimates should strive to achieve a coefficient of variation (CV) of 15% or less at the population level (Crawford and Rumsey 2011).

The States of California and Oregon have established programs and methods for monitoring salmonids. Data designed to measure progress toward meeting SONCC coho salmon recovery criteria should be collected using the methods described below.

### 5.2.1 California's Coastal Monitoring Program

The California Department of Fish and Wildlife and the National Marine Fisheries Service designed California's Coastal Salmonid Monitoring Program (CMP) (Adams et al. 2011) to guide biological monitoring of salmonid populations in the state. The following excerpt from Adams et al. (2011) describes the overall strategy, design and methods of the monitoring plan.

The goals and objectives of the CMP are to develop broad and intensive monitoring strategies and techniques that:

1) Create a monitoring framework that includes all coho salmon, Chinook salmon and steelhead in coastal California;

2) Provide regional (ESU-level) and population abundance estimates for both status and trend of salmonid populations;

3) Estimate pro4ductivity trends from status abundance data;

4) Provide estimates of regional and population level spatial structure of coastal salmonids;

5) Consider the diversity of life-history and ecological differences in the three species of interest; and

6) Create permanent LCM [Life Cycle Monitoring] stations that will allow deeper evaluation of both freshwater and marine fish-habitat relationships and provide long-term index monitoring.

Methods for collection of adult and juvenile coho salmon data in California are described in Adams et al. (2011). California plan implementers should use these methods to collect data to be used to measure progress toward recovery.

### 5.2.2 Oregon Plan for Salmon and Watersheds

The Oregon Plan is a comprehensive plan to restore salmonids and the systems they rely on by combining scientifically sound actions with local watershed-based public support (State of Oregon 1997). This plan has four key elements:

1) Voluntary restoration actions by landowners, with support from local government;

2) Coordinated state and federal agency and tribal actions to support restoration efforts, implement regulatory programs, manage public lands, and promote public education and awareness;

3) Monitor watershed health, water quality, and salmon recovery to document existing conditions, track changes, and determine the impact of programs and actions.

4) Strong scientific oversight by the Independent Multidisciplinary Science Team to evaluate the plan's effectiveness, identify needed changes, and guide research investments (State of Oregon 2013).

Methods for collection of adult and juvenile coho salmon data in Oregon are described in Stevens (2002). Methods for assessment of coho salmon habitat in Oregon are described in Moore et al. (1997) and Rodgers et al. (2005). Plan implementers should use these methods to collect data to be used to measure progress toward recovery.

## 5.3 Population Viability

Monitoring spawner abundance and distribution, juvenile distribution, diversity, and productivity is necessary to assess progress toward recovery. The monitoring goals, purpose, and potential methods are described in Table 5-1 by population role. At a minimum, adults and juveniles should be monitored in all Core and Non-Core 1 populations, while juveniles should be monitored in all Dependent and Non-Core 2 populations. Table 5-2 shows the monitoring needed for each population. Monitoring entities should strive for spawner and juvenile data with an average coefficient of variation of 15 percent or less per population (Crawford and Rumsey 2011).

In addition to the adult and juvenile monitoring described above, life cycle monitoring (LCM) stations should be established. Adams et al. (2011) describes the utility and needed components of LCM stations. LCM stations are places where smolt and adult abundance are monitored. LCM stations are an integral component of monitoring for SONCC coho salmon. LCM stations can be used to: (1) estimate abundance of adult coho salmon and downstream migrating juveniles; (2) estimate marine and freshwater survival rates; (3) track abundance of juveniles coincident with habitat modifications, and (4) calibrate the spawning ground surveys used to estimate adult abundance, based on observations of live adults, redds, or carcasses. LCM stations should be located and designed for complete counts of smolts and adults from the entire basin or a defined portion of the basin using weirs, fences, traps, live mark/recapture techniques, sonar, or other techniques. At least one LCM station should be monitored in each diversity stratum (see Table 5-1) so that a regional estimate of freshwater survival is available for every diversity stratum, and a regional estimate of marine survival is available for every coastal diversity stratum.

Given the amount of data to be collected at LCM stations, they may serve as the focal point for evaluating the status of SONCC coho salmon populations and restoration efforts, as well as encouraging further research. LCM stations in close proximity to the ocean can be used to determine marine survival. Large rivers may not be appropriate or feasible locations for LCM stations if all coho salmon adults cannot be counted, smolt trapping efficiencies are low, or flows are too high or unsafe for operation. Alternatively, an LCM station could be established on a tributary of a large river. LCM stations are likely to be located opportunistically and at existing counting stations within each stratum.

Table 5-1. Population viability monitoring needs by population role.

| Population Role | Monitoring Goal | Purpose and Methods |
|---|---|---|
| Core and Non-Core 1 | Annually estimate number of adults | Track abundance of spawners relative to spawner targets. **Methods**: Carry out total counts, mark/recapture, or spawner surveys [Adams et al. (2011) (for California) and Stevens (2002) (for Oregon)]. Monitoring entities should strive for adult spawner data with a coefficient of variation on average of 15 percent or less per population (Crawford and Rumsey 2011). |
| Core and Non-Core 1 | Annually monitor the spatial distribution of coho salmon adults spawning in the wild | If fish spawn and rear in a variety of freshwater habitats in a sub-basin, the population will be buffered against year-to-year environmental variations. |
| | Annually estimate the distribution of juvenile coho salmon | Track population productivity and spatial distribution. **Methods**: Carry out snorkel surveys [following Rodgers (2000 and 2001) in Oregon and Adams et al. (2011) in California] to determine juvenile occupancy (% area occupied) and density using GRTS technique (Stevens and Olsen 2004, Adams et al. 2011). |
| | Annually estimate the proportion of adults of hatchery origin | Determine extent of hatchery influence on spawners in order to assess possible impacts of domestication/hatchery selection on non-hatchery origin fish. **Methods**: During spawner counts, note whether specimen has internal or external hatchery mark. |
| | Periodically monitor key life-history characteristics | Document life-history diversity, which is important to understanding the long-term resilience and adaptability of SONCC coho salmon populations. **Methods**: Track characteristics such as spawner run timing, age at maturation, spawn timing, outmigration timing, smoltification timing, developmental rate, egg size, fecundity, freshwater and ocean distribution, size at maturation, and timing of ascension to natal stream. |
| Core with LCM station | Annually estimate the number of adults in area sampled by LCM station | Track abundance of spawners over time and, with smolt numbers, determine survival rate. **Methods**: Carry out total counts, mark/recapture, or spawner surveys [Adams et al. (2011) (for California) and Stevens (2002) (for Oregon)]. Monitoring entities should strive for adult spawner data with a coefficient of variation on average of 15 percent or less per population (Crawford and Rumsey 2011). |
| | Annually estimate smolt abundance in areas sampled by LCM station | Assess population productivity, and, with adult numbers, determine survival rate. **Methods**: Compare adult and smolt numbers to determine survival rate; in coastal LCMs, compare adult and smolt numbers to determine marine survival rate. |
| | Annually estimate marine survival | Assess influence of marine survival on abundance of coastal populations. Methods: Divide smolt abundance by spawner abundance for each coastal LCM station. |
| Dependent and Non-Core 2 | Annually estimate juvenile occupancy | Track population productivity and spatial distribution. **Methods**: Juvenile occupancy surveys (% area occupied) and density in a spatially balanced random sampling design. |

Table 5-2. Population viability monitoring actions for each population.

| Stratum | Population | Population Role | Adult | Juvenile | LCM Eligible* |
|---|---|---|---|---|---|
| Northern Coastal | Elk River | Core | X | X | X |
| | Brush Creek | Dependent | | X | |
| | Mussel Creek | Dependent | | X | |
| | Lower Rogue River | Non-Core 1 | X | X | |
| | Hunter Creek | Dependent | | X | |
| | Pistol River | Dependent | | X | |
| | Chetco River | Core | X | X | X |
| | Winchuck River | Non-Core 1 | X | X | |
| Interior Rogue | Illinois River | Core | X | X | X |
| | Mid Rogue/Applegate | Non-Core 1 | X | X | |
| | Upper Rogue River | Core | X | X | X |
| Central Coastal | Smith River | Core | X | X | X |
| | Elk Creek | Dependent | | X | |
| | Wilson Creek | Dependent | | X | |
| | Lower Klamath | Core | X | X | X |
| | Redwood Creek | Core | X | X | X |
| | Maple Cr./Big Lagoon | Dependent | | X | |
| | Little River | Non-Core 1 | X | X | |
| | Strawberry Creek | Dependent | | X | |
| | Norton/Widow White Creek | Dependent | | X | |
| | Mad River | Non-Core 1 | X | X | |
| Interior Klamath | Middle Klamath | Non-Core 1 | X | X | |
| | Upper Klamath | Core | X | X | X |
| | Salmon River | Non-Core 1 | X | X | |
| | Scott River | Core | X | X | X |
| | Shasta River | Core | X | X | X |
| Interior Trinity | Lower Trinity | Core | X | X | X |
| | Upper Trinity | Core | X | X | X |
| | South Fork Trinity | Non-Core 1 | X | X | |
| Southern Coastal | Humboldt Bay Tributaries | Core | X | X | X |
| | Lower Eel/Van Duzen | Core | X | X | X |
| | Guthrie Creek | Dependent | | X | |
| | Bear River | Non-Core 2 | | X | |
| | Mattole River | Non-Core 1 | X | X | |
| Interior Eel | South Fork Eel | Core | X | X | X |
| | Mainstem Eel | Core | X | X | X |
| | Middle Fork Eel | Non-Core 2 | | X | |
| | North Fork Eel | Non-Core 2 | | X | |
| | Middle Mainstem Eel | Core | X | X | X |
| | Upper Mainstem Eel | Non-Core 2 | | X | |

* LCM stations should be established in at least one core population in each diversity stratum.

## 5.4 Research

Numerous questions remain about the best means to collect and interpret population viability and habitat data. Table 5-3 describes research needs. These research needs correspond to recovery actions listed in Table 5-9.

Table 5-3. Research needs and methods.

| Research Need | Purpose and Methods |
|---|---|
| Obtain better information on the extent and distribution of spawning in each Core and Non-Core 1 population area. | Accurate expansion of survey data to population estimates requires accurate information on current population range. |
| Develop efficient survey designs for assessing patchily-distributed populations | Understanding factors that influence distribution will aid in the design of more precise and efficient surveys. |
| Consider carrying out abundance surveys in consistently occupied, higher abundance patches and spatial structure surveys outside these patches | The appropriate survey method could differ based on the distribution of the animals to be surveyed. |
| Further develop the spatial structure monitoring protocol outlined in Adams et al. (2011) for California | Standard protocol for documenting spatial structure should be fully developed and followed by plan implementers to ensure consistent data collection. |
| Determine how juvenile distribution is influenced by streamflow, temperature, and sediment barriers | Annually monitor streamflow, temperature, and sediment barriers/extent of dry areas along with juvenile spatial structure to allow formal hypothesis testing of influence of one on another. |
| Develop cost-effective survey designs and methods for assessing spawning populations in streams where conditions (stream size, turbidity, cover) reduce the efficacy of traditional visual survey methods | Some parts of the SONCC coho salmon ESU's range are not amenable to traditional visual spawning survey protocols due to site-specific conditions. |
| Develop estimator for number of redds within a sample reach. | Adult abundance is sometimes estimated based on redd observations. Redds may be obscured from view over the course of the spawning season. Estimates of the number of redds deposited over the spawning survey must account for redds that cannot be observed during the periodic surveys. **Methods**: Model the redd deposition/ obscurement process as an open population mark-recapture problem. Use flagged redd recaptures on successive surveys to estimate rate at which existing redds cannot be detected in subsequent surveys. Adjust the number of new redds observed on new survey by survival rate since last survey. Use a non-parametric bootstrap routine to estimate within-reach uncertainty in number of redds. |

| Research Need | Purpose and Methods |
|---|---|
| Estimate total redd construction over regional space, incorporating within- and between-sample uncertainty. | Use of a Simple Random Sample Estimator is documented in Adams et al. (2011). However, small population sample frames are likely to lead to poor estimates of uncertainty using large sample variance equations. **Methods**: Use a bootstrap routine over large sample variance estimators for small frame and sample sizes. Using the outcome of estimator for number of redds within a sample reach (see Item 7 in this table, above), develop an algorithm for generating estimates of the number of redds over a sample space including the variance at the within-reach and between reach (sample error) levels. |
| Estimate the number of fish from estimates of redds. | At LCM stations, immigrating adults can be intercepted and either counted directly or marked for later recapture to create a spawner population estimate. Redds can also be directly counted or a number can be estimated using mark-recapture. The number of redds can be used to estimate the number of spawners. The relationship between the number of redds and the “true” number of spawners is used to adjust regional estimates of redds for reporting of the number of spawners. This approach assumes that the LCM station relationship between redds and spawners is the same as the regional relationship. Preliminary analysis suggests large variability between LCM redd to fish relationships in California. |
| Determine the number of reaches that should be sampled within a population to achieve a target coefficient of variation in annual status, and determine over what time period a trend of a specified magnitude can be detected at what spatial scale given specified sample rates. | NMFS’ evaluation of salmonid viability uses the population as the fundamental unit, building up to Diversity Strata. The status of the ESU is therefore based on the status of its component populations. Based on sample frames previously constructed in California, most independent populations have between 40 and 120 stream reaches. Crawford and Rumsey (2011) recommend that spawner abundance estimates achieve a CV of 15% or less at the population level. The number of reaches to be sampled to obtain that CV in each population is unknown. **Methods**: Conduct a power analysis to determine: 1. the number of reaches that should be sampled to achieve the target CV in each population, and 2. over what time period a trend of specified magnitude can be detected at what spatial scale given specific sample rates. |
| Develop techniques to estimate spawner abundance in remote areas. | Some remote areas of the ESU (e.g., in the Rogue and Eel River basins) cannot be sampled using traditional methods. |
| Evaluate the potential to restore extirpated populations. | Several populations in the ESU appear to be extirpated or nearly so. These populations may have less potential for recovery than those that currently support coho salmon. |
| Research supplemental or alternative means to develop population targets. | Methods other than those used in Williams *et al.* (2008) could be effectively used to delineate populations. |

| Research Need | Purpose and Methods |
|---|---|
| Determine whether the abundance targets for independent populations could be decreased if other VSP parameters are well-estimated. | Williams et al. (2008) did not include criteria for spatial structure and diversity, rather abundance served as a proxy for these parameters: "The high-risk thresholds [which define the low end of the spawner density criteria] identify densities at which populations are at a heightened risk of a reduction in per capita growth rate (i.e., depensation). Populations exceeding the low-risk density thresholds [which define the high end of the spawner density criteria] are expected to inhabit a substantial portion of their historical range, which serves as a proxy indicator that resultant spatial structure and diversity will reasonably represent historical conditions (Williams et al. 2008)". This recovery plan includes criteria that explicitly measure spatial structure and diversity. If these criteria are met, the number of spawners needed could be less than that identified in Williams *et al.* (2008). |
| Determine how to differentiate salmonid species observed using DIDSON[11]. | DIDSON is an acoustic camera which uses sonar and so is not affected by turbidity (Adams et al. 2011). DIDSON is a recommended method for counting steelhead in Southern California, but not in Northern California because when two or more salmonid species inhabit a stream, it is difficult to reliably distinguish them based on the DIDSON images (Adams et al. 2011). If salmonid species could be reliably distinguished, the DIDSON camera could be a powerful tool for tracking adult coho salmon abundance in the SONCC coho salmon ESU. |
| Determine whether chosen LCM locations capture existing spatial differences in marine survival due to different "marine environments". | One reason to have at least one LCM in each coastal diversity stratum is to capture the conditions in different "marine environments" across the marine range of SONCC coho salmon. The assumption that one LCM in each diversity stratum will adequately describe the effects of these "marine environments" remains untested. |
| Refine understanding of the accuracy of field protocols to detect juvenile occupancy. | Presence of juveniles in samples is proof of occupancy, but absence cannot be proven although the probability of absence can be determined. The frequency of "false" absences depends on the abundance and distribution of individuals, the sampling method and intensity, and the scale of sampling. This can be particularly problematic for species that are rare or patchily distributed, or as species and populations decline in abundance and distribution leading to errors in estimates that vary with habitat and environmental conditions and species abundance. **Methods**: Develop a juvenile spatial structure protocol that estimates detection probability. |

[11] Dual-Frequency Identification Sonar.

| Research Need | Purpose and Methods |
|---|---|
| Develop a quantitative limiting factors life cycle model. | Integrate information about the ecology of the salmon life cycle, the factors that may limit the survival of key life stages and the effects of human activities such as landscape management, habitat rehabilitation, and exploitation. Results of the model can be used to reprioritize recovery actions or identify additional actions needed to achieve SONCC coho salmon recovery. |
| Track ocean productivity | Compile data obtained from ocean net surveys, hatchery returns, and oceanic data collected by satellite and buoy arrays throughout the northeastern Pacific ocean. |
| Determine which life-history traits or other diversity parameters are the most meaningful measures of diversity, particularly in the context of future climate change impacts. | Development of meaningful measures of diversity is difficult largely because of the lack of understanding of the expression of individual life-history traits (the genetic and environmental effects) and the degree of correlation between these traits, survival, and reproduction. |
| Determine best approach to conduct effectiveness and validation monitoring. | Determine whether goals of effectiveness and validation monitoring can be achieved by measuring a subset of restoration actions, rather than all of them. Determine appropriate subset. |

## 5.5 Stress and Threat Monitoring

In order to achieve recovery, the stresses and threats faced by coho salmon populations in the ESU must be sufficiently abated to facilitate the long term sustainability. The objectives for abatement of stresses and threats are as follows: (1) the stresses currently affecting SONCC coho salmon have been sufficiently reduced and (2) the threats identified at the time of listing, as well as any new threats, have been sufficiently removed or reduced.

Monitoring is needed to gauge progress toward meeting the stress and threat objectives. Monitoring needs for stresses and threats are described for each population in Table 5-4, Table 5-5, Table 5-6, and Table 5-7. Table 5-10 through Table 5-49 describe the recovery actions necessary to obtain information on these stresses and threats for each population.

An initial, comprehensive field-based habitat survey should be carried out for all populations as soon as possible (1; Table 5-6 and Table 5-7). The purpose of these surveys is to describe the current habitat conditions in each population area to inform restoration actions and for future statistical sampling of the area to support the GRTS approach. The surveys should be followed by monitoring of indicators related to those stresses ranked high or very high for each population. Such indicators should be monitored every 5 years beginning as soon as possible (3; Table 5-6 and Table 5-7). For those stresses ranked medium or low for each population, indicators should be monitored every 10 years beginning as soon as possible (4; Table 5-6 and Table 5-7). Monitoring needs for stresses are described for each population in Table 5-5 (for coastal diversity strata) and Table 5-6 (for interior diversity strata). Some stresses can cause habitat to worsen rapidly, and some of these changes in habitat could be fatal to coho salmon. For this reason, indicators for water temperature, barriers (due to sediment or dry areas), altered hydrologic function, adverse fishery-related effects, increased disease, predation, and competition, and adverse hatchery-related effects should be monitored annually for populations that rated high or very high for these stresses (2; Table 5-5 and Table 5-6). Threat monitoring is described in Table 5-7. NMFS will describe the status and trends of stresses related to particular threats, along with other identified information, as part of the status review to be completed every five years.

Table 5-4. Recommended monitoring to assess stresses associated with listing factors.

| Listing Factor | Stress | Monitoring[1] |
|---|---|---|
| **A:** Habitat Destruction, Modification or Curtailment | Lack of Floodplain and Channel Structure | Habitat indicators[2] for the stresses rated *high* or *very high* should be monitored[3] every 5 years. |
| | Altered Sediment Supply | |
| | Impaired Water Quality | |
| | Degraded Riparian Forest Condition | |
| | Impaired Estuarine Function[4] | |
| | Barriers (due to sediment, dry areas, or high temperature) | Annually monitor the extent of barriers due to sediment or seasonally dry areas in independent populations where such barriers are identified as a *high* or *very high* stress. |
| | Altered Hydrologic Function | Annually monitor the hydrograph, where appropriate, in independent populations where altered hydrologic function is identified as a *high* or *very high* stress. |
| **B:** Overutilization for commercial, recreational, scientific, or educational purposes | Adverse Fishery-Related Effects | Annually estimate the commercial and recreational ocean fisheries bycatch and mortality rate for wild SONCC coho salmon. Annually estimate the in-river bycatch and tribal harvest for all rivers and streams in the SONCC recovery domain. |
| **C:** Disease or predation | Increased Disease/Predation/ Competition | Annually estimate the infection and mortality rate of juvenile coho salmon from pathogens, such as *Ceratonova shasta*, in the mainstem Klamath River at Beaver Creek during May and June |
| **C:** Disease or predation | Increased Disease/Predation/ Competition | Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin, in independent populations where predation is identified as a *high* or *very high* stress. |
| **D:** The inadequacy of existing regulatory mechanisms | All | Monitor changes in adequacy of existing regulatory mechanisms. |
| **E:** Other natural or manmade factors affecting the species' continued existence | Climate Change | Refer to monitoring associated with Impaired Hydrologic Function and Water Quality. |
| | Adverse Hatchery-Related Effects | Annually determine the percent of hatchery origin spawners (PHOS) in independent populations where hatchery effects are a *high* or *very high* stress. |

[1]The first habitat monitoring should be comprehensive and occur as soon as possible in both freshwater and estuarine (if applicable) habitat, in order to inform restoration activities and statistical sampling of population area.
[2] A list of habitat indicators is presented in Table 4-6.
[3] Habitat monitoring will be based on GRTS (use of this method for habitat monitoring is described in Rodgers et al. (2005)).
[4] NMFS has no recommendation regarding the habitat parameters to be measured in estuaries. A recovery action to identify the appropriate estuarine parameters is included for each population where such monitoring is needed.

Table 5-5. Monitoring actions to assess stresses for each population in the coastal diversity strata.

| | **Northern Coastal Basins** | | | | | **Central Coastal Basins** | | | | | | **Southern Coastal Basins** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitoring Action: Track indicators related to: | Chetco River **C** | Winchuck **NC1** | Elk River **C** | Lower Rogue **NC1** | Dependent Populations | Lower Klamath **C** | Redwood Creek **C** | Mad River **NC1** | Smith River **C** | Little River **NC1** | Dependent Populations | Humboldt Bay Tribs. **C** | Lower Eel/Van Duzen **C** | Mattole River **NC1** | Bear River **NC2** | Dependent Populations |
| Spawning, rearing, and migration | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lack of Floodplain and Channel Structure | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| Degraded Riparian Forest Conditions | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| Altered Sediment Supply | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Impaired Water Quality (Temperature) | 2 | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 4 |
| Impaired Water Quality (Non-Temperature) | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 4 |
| Altered Hydrologic Function | 2 | 2 | 2 | 4 | 3 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 |
| Impaired Estuarine Function | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 4 |
| Adverse Fishery- and Collection-Related Effects | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Adverse Hatchery-Related Effects | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Disease/Predation/ Competition | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 |
| Barriers | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 4 | 4 | 4 |

1 = Conduct initial comprehensive habitat survey.
2= Monitor every year.
3= Monitor applicable habitat or population indicators every five years, to begin after initial comprehensive habitat survey completed.
4= Monitor applicable habitat or population indicators every 10 years, to begin after initial comprehensive habitat survey completed.

C = core population

NC1 = non-core 1 population

NC2 = non-core 2 population

Table 5-6. Monitoring actions to assess stresses for each population in the interior diversity strata.

| | Interior Rogue | | | Interior Klamath | | | | | Interior Trinity | | | Interior Eel | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitoring Action: Track indicators related to: | Illinois River **C** | Upper Rogue **C** | Mid Rogue/ Applegate **NC1** | Upper Klamath **C** | Shasta River **C** | Scott River **C** | Salmon River **NC1** | Middle Klamath **NC1** | South Fork Trinity **NC1** | Upper Trinity **C** | Lower Trinity **C** | South Fork Eel River **C** | Middle Mainstem Eel **C** | Mainstem Eel **C** | Upper Mainstem Eel **NC2** | Middle Fork Eel **NC2** | North Fork Eel **NC2** |
| Spawning, rearing, and migration | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lack of Floodplain and Channel Structure | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Degraded Riparian Forest Conditions | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 |
| Altered Sediment Supply | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Impaired Water Quality | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 3 |
| Altered Hydrologic Function | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 3 |
| Impaired Estuarine Function | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 3 |
| Adverse Fishery-Related Effects | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Adverse Hatchery Related Effects | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 |
| Disease/ Predation/ Competition | 4 | 2 | 2 | 2 | 2 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| Barriers | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 4 |

| | |
|---|---|
| 1 = Conduct initial comprehensive habitat survey.<br>2 = Monitor applicable habitat or population indicators every year, to begin as soon as possible.<br>3 = Monitor applicable habitat or population indicators every five years, to begin as soon as possible.<br>4= Monitor applicable habitat or population indicators every 10 years, to begin after initial comprehensive habitat survey completed. | C = core population<br><br>NC1 = non-core 1 population<br><br>NC2 = non-core 2 population |

Table 5-7. Monitoring for threats rated high or very high, with associated listing factors.

| Listing Factor[1] | Threat | Monitoring[2] |
|---|---|---|
| **A:** The present or threatened destruction, modification, or curtailment of the species' habitat or range | Roads | Describe the status and trend of related stresses[3]. Describe status and trends of road treatments and road density. |
| | Timber Harvest | Describe the status and trend of related stresses[3]. |
| | Dams/Diversion | Describe the status and trend of related stresses[3]. |
| | Road-Stream Crossing Barriers | Describe status and trends of identified fish passage barriers[3]. |
| | High Intensity Fire | Describe trends in occurrence of high-intensity fire as well as trends in change of related stresses[3]. |
| | Agricultural Practices | Describe the status and trend of related stresses[3]. |
| | Channelization/ Diking | Evaluate the status and trend of related stresses[3]. Describe new channelization/diking and changes to existing channelization/diking. |
| | Urban/Residential /Industrial Development | Evaluate the status and trend of related stresses[3]. Describe new development and changes to existing development. |
| | Mining/Gravel Extraction | Evaluate the status and trend of related stresses[3]. Describe any new mining or gravel extraction. |
| **B**: Over-utilization for commercial, recreational, scientific or educational purposes | Fishing and Collecting | Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon. Recreational fishing in freshwater and marine habitats should be assessed through development of Fisheries Monitoring and Evaluation Plans specifically designed to monitor and track catch and mortality of wild and hatchery coho salmon. Annually estimate the in-river bycatch and tribal harvest for all rivers and streams in SONCC recovery domain. |
| **D:** The inadequacy of existing regulatory mechanisms[4] | All | Monitor changes in adequacy of existing regulatory mechanisms. |
| **E:** Other natural or manmade factors affecting the species' continued existence | Climate Change | Evaluate the status and trend of related stresses[3]. |
| | Hatcheries | Evaluate the status and trend of related stresses[3]. Describe status of HGMP development and implementation. |
| | Invasive Non-Native Alien Species | Evaluate the status and trend of abundance and occurrence of invasive, non-predatory species that may adversely affect SONCC coho salmon. |

[1] Listing Factor C is not included in this table because disease and predation are considered stresses, and the preceding three tables describe monitoring actions to assess stresses.
[2] For each population with this threat rated as high or very high (Chapters 7 to 46), describe status at least once every five years during NMFS' status review of the SONCC coho salmon ESU.
[3] See Table 3-2 to determine related stresses for each threat.
[4] Timber harvest and dams/diversions should also be evaluated under this listing factor.

## 5.6 Limiting Factors Modeling

A quantitative limiting factors life cycle model is designed to integrate information about the ecology of the salmon life cycle, the factors that may limit the survival of key life stages, and human activities such as landscape management, habitat rehabilitation, and exploitation. Modeling limiting factors may provide insight into what elements of the habitat, or which life stages of coho salmon, are acting as roadblocks to recovery. Models can validate assumptions on which recovery actions are most essential to achieve recovery as well as identify factors which may have been overlooked. As recovery actions are implemented, limiting factors may change. Periodic use of and updates to the limiting factors models that are validated with habitat surveys may help recovery practitioners redirect efforts where they are most needed.

Typically these models associate fish abundance (density) and survival with each habitat type at important life stages. Both carrying capacity and density-independent survival are affected by habitat quantity and quality. Limiting habitat analyses at the basin-level are conducted using this life-stage specific approach. Two potential approaches are simplified limiting factor models and dynamic life cycle models. Both approaches are based on the salmon life cycle, and assess current and historical habitat conditions in a basin to estimate how habitat changes may have altered salmon abundance or survival at different life stages. However, the approaches differ in two main respects. First, each approach emphasizes different parameters driving life stage-to-life stage survivorship. Simplified limiting factors models focus on changes in capacity at each freshwater life stage and treat density-independent stage-to-stage survival as constants. The dynamic life cycle model incorporates both capacity and survival through the use of stage to stage stock-recruitment relationships, and estimates population abundance or other VSP parameters via iterative simulations.

An example of a simplified limiting factors model for coho salmon in Oregon coastal streams is the Habitat Limiting Factors Model (HLFM v7; Nickelson 1998). This model relies upon habitat typing information to determine total area of the various habitat types. The analyst then multiplies the area of each habitat by habitat-specific coho salmon density to estimate potential abundance. This process is done for each life stage/season using life-history-specific density values.

An example of a dynamic life cycle model is RIPPLE developed by Stillwater Sciences and UC Berkley (Dietrich and Ligon 2009). RIPPLE couples geomorphic information with biological and aquatic habitat data. Analysts are expected to ask questions such as “what is the expected population response to increasing the capacity or productivity (survival) of habitat in ‘X’ portion of the stream?” Additionally, the analyst could compare the abundance of fish at any given stage to the intrinsic potential of the basin and the current status of the habitat within the basin.

Such modeling efforts have implications for identifying habitats that may limit recovery of populations. They can provide a transparent framework to: (1) relate habitat to capacity and survival; (2) estimate stage specific abundance from a basin’s intrinsic potential; (3) apply knowledge of the current state of the habitat to stage specific capacity, survival and abundance; (4) identify model assumptions and parameters that can dramatically alter predictions of population responses to habitat changes; (5) indicate which life stages may be most sensitive to habitat change regardless of the assumptions about density dependence and therefore shift the focus of restoration efforts; and (6) identify parameter and model uncertainties that substantially alter conclusions about which habitats limit recovery. Such analyses motivate critical research to identify and characterize poorly understood habitats, their effects on salmon abundance and survival, and the extent to which they have been modified.

Development of a limiting factors model in one or more SONCC coho salmon populations is identified as a research need (Table 5-3).

## 5.7 Assessing Restoration Actions

The restoration of physical habitat is one of the fundamental strategies used to achieve recovery. Therefore, the effectiveness of certain habitat restoration activities in achieving the desired habitat improvements should be identified, as well as the change or response in coho salmon populations. Three types of monitoring can be employed to evaluate restoration actions: implementation, effectiveness, and validation. Each type serves a unique purpose.

### 5.7.1 Implementation Monitoring

Implementation monitoring is designed to assess whether restoration projects are carried out as planned (MacDonald et al. 1991), according to the intended purpose and design. For example, implementation monitoring would be used to determine whether a barrier replacement was carried out according to the planned design.

### 5.7.2 Effectiveness Monitoring

Effectiveness monitoring is used to determine whether restoration actions result in the expected physical effect. For instance, effectiveness monitoring could be used to assess the short-term structural integrity (e.g., instream structure anchoring) and physical objectives (e.g., scouring due to instream structure placement) of implemented restoration actions. Much of this can be done through on-site observations. Effectiveness monitoring of restoration actions has two parts: (1) pre-treatment site characterization for establishing the conditions prior to restoration and (2) post-treatment monitoring to determine if the restoration is having the intended effects.

### 5.7.3 Validation Monitoring

Validation monitoring is designed to assess whether an anticipated biological response actually occurred. Validation monitoring can range from measuring short-term response (1 to 3 years) of coho salmon to restoration actions implemented at the project level (e.g., successful passage through a former barrier). In addition, validation monitoring may evaluate the long term response of coho salmon populations to the cumulative basin restoration.

Implementation monitoring should occur in conjunction with restoration actions, while effectiveness and validation monitoring are appropriate for a subset of restoration actions[12]. Many effectiveness or validation monitoring efforts should be undertaken in the same area where intense biological sampling occurs. Careful planning and implementation of restoration

[12] Chapter 5 contains a research recovery action to accomplish this.

activities within the same areas as LCMs will allow for these analyses to be conducted with little additional costs for status or biological information.

An accurate evaluation of the effectiveness of a restoration action requires a clear statement of the desired effect of the project on the environment. Restoration objectives should be expressed as quantifiable changes in environmental conditions. For example, if installation of an in-stream structure is intended to improve rearing habitat, the desired changes could be expressed in terms of pool frequency, in-stream cover, or some other measurable environmental characteristic. The objectives should be stated as desired outcomes (e.g., 50 percent of reach length in pools). If objectives are vague, it will be difficult to evaluate effectiveness (Harris et. al 2005).

It may be difficult or impossible to detect how much of a biological response is due to a restoration action, as opposed to other influences. Validation monitoring may be confounded by other potentially limiting factors or variables that are not addressed by the restoration action. Similarly, single project restoration actions may not have enough impact to see a measurable response at the basin scale (MacDonald et al. 1991). Therefore, validation monitoring may be best for restoration actions that result in a quick response to the quality of instream salmonid habitat, such as instream habitat and fish passage improvement projects. Validation monitoring of other restoration actions should occur as part of an intensively monitored watershed, or IMW. IMWs are intensive watershed-scale research and monitoring efforts. A project level effectiveness monitoring study might include a single restoration action implemented in one location. In contrast, an IMW would look at an entire suite of restoration actions at a larger watershed scale and attempt to determine how these combined restoration actions would affect physical and biological conditions (OWEB 2014). IMWs are used to evaluate assumptions about what should be done to improve habitat and resulting fish response. IMWs also allow evaluation of critical uncertainties for the limiting factors models. Monitoring efforts conducted in IMW may find that using the Before-After-Control-Impact (BACI) approach (Stewart-Oaten et al. 1986) will provide the most useful information to evaluate biological and physical response to restoration activities. BACI study designs are often used to determine if a restoration action had the intended effect. The spatial and temporal scale of both the treatment and response must be carefully considered for this type of design to be informative. For example, a large road decommissioning project may not reduce sediment delivery for a number of years after project implementation. Road decommissioning may have a short term negative effect on sediment delivery. The spatial scale might be considered a reach, stream, or basin while the temporal scale of response might be 10 years or more.

## 5.8 Database Management

As research and monitoring actions are carried out, a great deal of data will be generated. Data on the VSP parameters, stresses and threats, restoration actions, and other pertinent monitoring and adaptive management elements are expected to be collected into one or more electronic databases that will be accessible to conservation partners. Standards for data collection methods and calculations (for example, population estimates) should be developed with resource agencies and tribes to ensure data quality and consistency.

Table 5-8. Population names and associated Population ID codes to be used in conjunction with Table 5-9 to describe population-specific research actions.

| **Population Name** | **Population ID** | | **Population Name** | **Population ID** |
|---|---|---|---|---|
| Bear River | BeaR | | Middle Mainstem Eel River | MMER |
| Brush Creek | BruC | | Middle Rogue/Applegate R. | MRAR |
| Chetco River | CheR | | Mussel Creek | MusC |
| Elk Creek | ElkC | | North Fork Eel River | NFER |
| Elk River | ElkR | | Norton/Widow White Creek | NWWC |
| Guthrie Creek | GutC | | Pistol River | PisR |
| Humboldt Bay Tribs. | HBT | | Redwood Creek | RedC |
| Hunter Creek | HunC | | Salmon River | SalR |
| Illinois River | IllR | | Scott River | ScoR |
| Lower Eel/Van Duzen R. | LEVR | | South Fork Eel River | SFER |
| Little River | LitR | | South Fork Trinity River | SFTR |
| Lower Klamath River | LKR | | Shasta River | ShaR |
| Lower Rogue River | LRR | | Smith River | SmiR |
| Lower Trinity River | LTR | | Strawberry Creek | StrC |
| Mad River | MadR | | Upper Klamath River | UKR |
| Maple Creek | MapC | | Upper Mainstem Eel River | UMER |
| Mattole River | MatR | | Upper Rogue River | URR |
| Mainstem Eel River | MER | | Upper Trinity River | UTR |
| Middle Fork Eel River | MFER | | Wilson Creek | WilC |
| Middle Klamath River | MKR | | Winchuck River | WinR |

Table 5-9. Implementation schedule for research-related recovery actions. Use in conjunction with Table 5-8 to determine appropriate Action ID and Step ID. For example, if use of SONCC.Exam.27.1.1 is desired in the Chetco River, the code to use would be SONCC.CheR.27.1.1. Priority is described in Section 6.6.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-Exam.29.2.17 | Research | No | Determine best means to collect and interpret habitat data | Collect data using standard, consistent protocols | All | 3d |
| *SONCC-Exam.29.2.17.1* | *Develop standards for data collection methods and calculations* | | | | | |
| *SONCC-Exam.29.2.17.2* | *Apply standards for data collection and calculations* | | | | | |
| SONCC-Exam.29.2.25 | Research | No | Determine best means to collect and interpret habitat data | Determine best approach to conduct effectiveness and validation monitoring | All | 3d |
| *SONCC-Exam.29.2.25.1* | *Determine whether goals of effectiveness and validation monitoring can be achieved by measuring a subset of restoration actions, rather than all of them. Determine appropriate subset.* | | | | | |
| SONCC-Exam.29.2.24 | Research | No | Determine best means to collect and interpret habitat data | Track ocean productivity | All | 3d |
| *SONCC-Exam.29.2.24.1* | *Compile data obtained from ocean net surveys, hatchery returns, and oceanic data collected by satellite and buoy arrays throughout the northeastern Pacific ocean.* | | | | | |
| SONCC-Exam.29.1.1 | Research | No | Determine best means to collect and interpret population viability data | Assess patchily-distributed populations | All | 3d |
| *SONCC-Exam.29.1.1.1* | *Understand factors that influence distribution of coho salmon* | | | | | |
| *SONCC-Exam.29.1.1.2* | *Develop survey design which considers factors that influence distribution of coho salmon to best assess patchily-distributed populations. Consider carrying out abundance surveys in consistently occupied, higher abundance patches and spatial structures* | | | | | |
| SONCC-Exam.29.1.18 | Research | No | Determine best means to collect and interpret population viability data | Compile monitoring data into common databases | All | 3d |
| *SONCC-Exam.29.1.18.1* | *Collect monitoring data into one or more electronic databases accessible to conservation partners* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-Exam.29.1.5 | Research | No | Determine best means to collect and interpret population viability data | Determine accuracy of field protocols to detect juvenile occupancy and refine if needed | All | 3d |
| *SONCC-Exam.29.1.5.1* | *Develop a juvenile spatial structure protocol that estimates detection probability* | | | | | |
| *SONCC-Exam.29.1.5.2* | *If detection probability is too low, refine protocol to obtain higher probability of detection* | | | | | |
| SONCC-Exam.29.1.4 | Research | No | Determine best means to collect and interpret population viability data | Determine how to differentiate salmonid species observed using DIDSON. | Anywhere that DIDSON units are used to count salmonids | 3d |
| *SONCC-Exam.29.1.4.1* | *Obtain data from DIDSON in areas where more than one species of salmonid are present* | | | | | |
| *SONCC-Exam.29.1.4.2* | *Develop method to differentiate different salmonid species using DIDSON images* | | | | | |
| SONCC-Exam.29.1.11 | Research | No | Determine best means to collect and interpret population viability data | Determine needed number of reaches to sample, and needed time period over which to sample, to obtain target coefficient of variation and magnitude of trend | All | 3d |
| *SONCC-Exam.29.1.11.1* | *Conduct a power analysis to determine the number of reaches that should be sampled to achieve the target coefficient of variation in each population* | | | | | |
| *SONCC-Exam.29.1.11.2* | *Conduct a power analysis to determine, given specified sample rates, over what time period a trend of specified magnitude can be detected and at what spatial scale* | | | | | |
| SONCC-Exam.29.1.2 | Research | No | Determine best means to collect and interpret population viability data | Determine potential for recovery of populations | Populations which are extirpated or nearly extirpated | 3d |
| *SONCC-Exam.29.1.2.1* | *Develop analytical tool to determine probability of recovery populations at different population sizes* | | | | | |
| SONCC-Exam.29.1.13 | Research | No | Determine best means to collect and interpret population viability data | Determine whether chosen LCM locations capture existing spatial differences in marine survival due to different "marine environments" | Coastal LCM stations and adjacent ocean habitat | 3d |
| *SONCC-Exam.29.1.13.1* | *Determine marine survival rates at coastal LCMs* | | | | | |
| *SONCC-Exam.29.1.13.2* | *Identify different "marine environments" which affect coho salmon survival* | | | | | |
| *SONCC-Exam.29.1.13.3* | *Determine whether chosen LCM locations capture different "marine environments"* | | | | | |
| SONCC-Exam.29.1.3 | Research | No | Determine best means to collect and interpret population viability data | Determine whether the abundance targets for independent populations could be decreased if other parameters (spatial structure, diversity, productivity) were well-estimated | All | 3d |
| *SONCC-Exam.29.1.3.1* | *Apply measures of spatial structure, diversity, and productivity to populations in the SONCC coho salmon ESU* | | | | | |
| *SONCC-Exam.29.1.3.2* | *Determine whether abundance targets for populations could be reduced* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-Exam.29.1.10 | Research | No | Determine best means to collect and interpret population viability data | Determine whether the relationship between the number of redds and number of spawners is the same at Life Cycle Monitoring stations compared to elsewhere in the ESU. | All | 3d |
| *SONCC-Exam.29.1.10.1* | *Determine the relationship between the number of redds and number of spawners at locations other than where LCMs are located* | | | | | |
| *SONCC-Exam.29.1.10.2* | *Compare the relationship between the number of redds and number of spawners at these alternative locations to the relationship found at LCMs* | | | | | |
| SONCC-Exam.29.1.8 | Research | No | Determine best means to collect and interpret population viability data | Develop estimator for number of redds within a sample reach by modeling the redd deposition/obscurement process as an open population mark-recapture problem | All | 3d |
| *SONCC-Exam.29.1.8.1* | *Use flagged redd recaptures on successive surveys to estimate rate at which existing redds cannot be detected in subsequent surveys* | | | | | |
| *SONCC-Exam.29.1.8.2* | *Adjust the number of new redds observed on new survey by survival rate since last survey* | | | | | |
| *SONCC-Exam.29.1.8.3* | *Use a non-parametric bootstrap routine to estimate within-reach uncertainty in number of redds* | | | | | |
| SONCC-Exam.29.1.6 | Research | No | Determine best means to collect and interpret population viability data | Develop protocol for monitoring spatial structure | All areas in California | 3d |
| *SONCC-Exam.29.1.6.1* | *Further develop the protocol for spatial structure described in Adams et al. 2011* | | | | | |
| SONCC-Exam.29.1.7 | Research | No | Determine best means to collect and interpret population viability data | Develop survey designs and methods for assessing populations | Streams where traditional visual survey methods are not effective due to factors such as stream size, turbidity, and cover | 3d |
| *SONCC-Exam.29.1.7.1* | *Identify factors (such as stream size, turbidity, and cover) which reduce efficacy of traditional visual survey methods* | | | | | |
| *SONCC-Exam.29.1.7.2* | *Develop survey designs and methods which account for identified factors* | | | | | |
| *SONCC-Exam.29.1.7.3* | *Carry out both new survey designs and methods, and traditional visual survey methods, in the same stream* | | | | | |
| SONCC-Exam.29.1.12 | Research | No | Determine best means to collect and interpret population viability data | Estimate spawner abundance in remote areas | All | 3d |
| *SONCC-Exam.29.1.12.1* | *Develop techniques to estimate spawner abundance in remote areas* | | | | | |
| *SONCC-Exam.29.1.12.2* | *Identify remote areas for which new techniques should be used* | | | | | |
| *SONCC-Exam.29.1.12.3* | *Estimate spawner abundance in remote areas using new techniques* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-Exam.29.1.9 | Research | No | Determine best means to collect and interpret population viability data | Estimate total redd construction over regional space, incorporating within- and between-sample uncertainty. | All | 3d |
| *SONCC-Exam.29.1.9.1* | *Use a bootstrap routine over large sample variance estimators for small sample frames and small sample sizes* | | | | | |
| *SONCC-Exam.29.1.9.2* | *Using the outcome the estimator for number of redds within a sample reach obtained in previous action step, develop algorithm for generating estimates of the number of redds within a sample space including the variation at the within-reach and between-reach levels* | | | | | |
| SONCC-Exam.29.3.20 | Research | No | Improve understanding of SONCC coho salmon | Determine best means to develop population targets | All | 3d |
| *SONCC-Exam.29.3.20.1* | *Research supplemental or alternative means to develop population targets* | | | | | |
| *SONCC-Exam.29.3.20.2* | *If appropriate, utilize supplemental or alternative means to develop population targets.* | | | | | |
| SONCC-Exam.29.3.23 | Research | No | Improve understanding of SONCC coho salmon | Determine extent to which restoration actions result in the expected physical effect, and whether an anticipated biological response to actions occurred | All | 3d |
| *SONCC-Exam.29.3.23.1* | *Determine subset of restoration actions for which effectiveness and validation monitoring should occur* | | | | | |
| SONCC-Exam.29.3.14 | Research | No | Improve understanding of SONCC coho salmon | Ensure passage to areas sufficient for recovery | All | 3d |
| *SONCC-Exam.29.3.14.1* | *Determine which areas blocked by barriers are necessary to attain coho salmon recovery* | | | | | |
| SONCC-Exam.29.3.15 | Research | No | Improve understanding of SONCC coho salmon | Ensure predation does not limit attainment of recovery | All | 3d |
| *SONCC-Exam.29.3.15.1* | *Determine what levels of predation do not limit attainment of population-specific recovery criteria* | | | | | |
| SONCC-Exam.29.3.22 | Research | No | Improve understanding of SONCC coho salmon | Measure diversity of SONCC coho salmon populations | All | 3d |
| *SONCC-Exam.29.3.22.1* | *Determine which life-history traits or other diversity parameters are the most meaningful measures of diversity, particularly in the context of future climate change impacts* | | | | | |
| *SONCC-Exam.29.3.22.2* | *Measure those life-history traits or other diversity parameters that are most meaningful measures of diversity* | | | | | |
| SONCC-Exam.29.3.16 | Research | No | Improve understanding of SONCC coho salmon | Obtain better information on the extent and distribution of spawning in each Core and Non-Core 1 population area | All | 3d |
| *SONCC-Exam.29.3.16.1* | *Develop methods to assess extent and distribution of spawning* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-Exam.29.3.21 | Research | No | Improve understanding of SONCC coho salmon | Understand factors limiting recovery of SONCC coho salmon | All | 3d |
| *SONCC-Exam.29.3.21.1* | *Develop a quantitative limiting factors life cycle model* | | | | | |
| *SONCC-Exam.29.3.21.2* | *Utilize quantitative limiting factors life cycle model to better understand factors limiting SONCC coho salmon in particular populations.* | | | | | |
| SONCC-Exam.29.3.19 | Research | No | Improve understanding of SONCC coho salmon | Understand how juvenile distribution is influenced by environmental factors | All | 3d |
| *SONCC-Exam.29.3.19.1* | *Determine how juvenile distribution is influenced by streamflow, temperature, and sediment barriers* | | | | | |
| *SONCC-Exam.29.3.19.2* | *Incorporate understanding into juvenile distribution survey methods.* | | | | | |

Table 5-10. Monitoring-related recovery actions for Bear River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-BeaR.27.2.17 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-BeaR.27.2.17.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-BeaR.27.2.17.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-BeaR.27.2.18 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-BeaR.27.2.18.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-BeaR.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-BeaR.27.2.19.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-BeaR.27.2.21 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-BeaR.27.2.21.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-BeaR.27.2.22 | Monitor | No | Track habitat condition | Monitor stream temperature | Population wide | 3d |
| *SONCC-BeaR.27.2.22.1* | *Continue stream temperature monitoring at established locations* | | | | | |
| SONCC-BeaR.27.2.24 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-BeaR.27.2.24.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-BeaR.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-BeaR.27.2.29.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-BeaR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-BeaR.27.2.30.1* | *Identify habitat condition of the estuary* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-BeaR.27.2.35 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-BeaR.27.2.35.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-BeaR.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-BeaR.27.1.15.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-BeaR.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-BeaR.27.1.16.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-BeaR.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-BeaR.27.1.23.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-BeaR.27.1.23.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-BeaR.27.4.34 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-BeaR.27.4.34.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |

Table 5-11. Monitoring-related recovery actions for Brush Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-BruC.27.2.8 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-BruC.27.2.8.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-BruC.27.2.8.2* | | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | |
| SONCC-BruC.27.2.13 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-BruC.27.2.13.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-BruC.27.2.14 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-BruC.27.2.14.1* | | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | |
| SONCC-BruC.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | Population wide | 3d |
| *SONCC-BruC.27.2.25.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |
| SONCC-BruC.27.1.12 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-BruC.27.1.12.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-BruC.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-BruC.27.1.15.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-BruC.27.1.15.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-BruC.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-BruC.27.1.24.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon* | | | | |
| SONCC-BruC.27.4.21 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-BruC.27.4.21.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-BruC.27.4.22 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-BruC.27.4.22.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-BruC.27.4.23 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-BruC.27.4.23.1* | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | | |

Table 5-12. Monitoring-related recovery actions for Chetco River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-CheR.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-CheR.27.2.25.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-CheR.27.2.25.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-CheR.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-CheR.27.2.26.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-CheR.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-CheR.27.2.27.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-CheR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-CheR.27.2.28.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-CheR.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-CheR.27.2.29.1* | *Continuously measure the hydrograph* | | | | | |
| SONCC-CheR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-CheR.27.2.30.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-CheR.27.2.34 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-CheR.27.2.34.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-CheR.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-CheR.27.2.35.1* | *Identify habitat condition of the estuary* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-CheR.27.2.40 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-CheR.27.2.40.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-CheR.27.2.57 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | Population wide | 3d |
| *SONCC-CheR.27.2.57.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |
| SONCC-CheR.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-CheR.27.1.21.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-CheR.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-CheR.27.1.22.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |
| SONCC-CheR.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-CheR.27.1.23.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |
| SONCC-CheR.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-CheR.27.1.24.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-CheR.27.1.38 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-CheR.27.1.38.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-CheR.27.1.38.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-CheR.27.1.39 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Measure VSP parameters of coho salmon in remote areas | | 3d |
| *SONCC-CheR.27.1.39.1* | *Develop techniques to estimate abundance, productivity, spatial structure, and diversity in remote areas.* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-CheR.27.1.52 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-CheR.27.1.52.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-CheR.27.4.53 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-CheR.27.4.53.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-CheR.27.4.54 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-CheR.27.4.54.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-CheR.27.4.55 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-CheR.27.4.55.1* | | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | |
| SONCC-CheR.27.4.56 | Monitor | No | Track threat | Describe mining/gravel extraction threat | Population wide | 3d |
| *SONCC-CheR.27.4.56.1* | | *Describe any new mining or gravel extraction and any changes to existing mining and gravel extraction at least once every five years* | | | | |

Table 5-13. Monitoring-related recovery actions for Elk Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-ElkC.27.2.22 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-ElkC.27.2.22.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-ElkC.27.2.22.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-ElkC.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-ElkC.27.2.24.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-ElkC.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-ElkC.27.1.23.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-ElkC.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-ElkC.27.1.25.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-ElkC.27.1.25.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |

Table 5-14. Monitoring-related recovery actions for Elk River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-ElkR.27.2.23 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-ElkR.27.2.23.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-ElkR.27.2.23.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-ElkR.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-ElkR.27.2.24.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-ElkR.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-ElkR.27.2.25.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-ElkR.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-ElkR.27.2.26.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-ElkR.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-ElkR.27.2.27.1* | *Continuously measure the hydrograph* | | | | | |
| SONCC-ElkR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-ElkR.27.2.32.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-ElkR.27.2.34 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-ElkR.27.2.34.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-ElkR.27.1.20 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-ElkR.27.1.20.1* | *Determine annual abundance of adult coho salmon* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-ElkR.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-ElkR.27.1.21.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-ElkR.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-ElkR.27.1.22.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-ElkR.27.1.31 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-ElkR.27.1.31.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-ElkR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-ElkR.27.1.33.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-ElkR.27.1.33.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-ElkR.27.1.44 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-ElkR.27.1.44.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-ElkR.27.4.42 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-ElkR.27.4.42.1* | | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | |
| SONCC-ElkR.27.4.43 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-ElkR.27.4.43.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-15. Monitoring-related recovery actions for Guthrie Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-GutC.27.2.5 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-GutC.27.2.5.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-GutC.27.2.5.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-GutC.27.2.7 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-GutC.27.2.7.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-GutC.27.1.6 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-GutC.27.1.6.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-GutC.27.1.8 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-GutC.27.1.8.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-GutC.27.1.8.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-GutC.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-GutC.27.1.16.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-GutC.27.4.15 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-GutC.27.4.15.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |

Table 5-16. Monitoring-related recovery actions for Humboldt Bay Tributaries.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-HBT.27.2.28 | Monitor | No | Track habitat condition | Develop an instream sediment monitoring plan | Tributary streams; tidally influenced habitat of Arcata sub-basin; non-natal rearing habitat | 3d |
| *SONCC-HBT.27.2.28.1* | *Develop an in-stream sediment monitoring plan and establish monitoring stations* | | | | | |
| SONCC-HBT.27.2.29 | Monitor | No | Track habitat condition | Monitor stream temperature | Population wide | 3d |
| *SONCC-HBT.27.2.29.1* | *Conduct stream temperature monitoring at established stations, and establish additional stations in lower watershed to assess diel fluctuations in habitat availability* | | | | | |
| SONCC-HBT.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-HBT.27.2.34.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-HBT.27.2.34.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-HBT.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-HBT.27.2.35.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-HBT.27.2.36 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-HBT.27.2.36.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-HBT.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-HBT.27.2.37.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-HBT.27.2.38 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-HBT.27.2.38.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-HBT.27.2.39 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-HBT.27.2.39.1* | *Identify habitat condition of the estuary* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-HBT.27.2.42 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-HBT.27.2.42.1* | | *Determine best indicators of estuarine condition* | | | | |
| SONCC-HBT.27.2.48 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-HBT.27.2.48.1* | | *Assess barriers limiting coho salmon distribution* | | | | |
| SONCC-HBT.27.1.30 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-HBT.27.1.30.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-HBT.27.1.31 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-HBT.27.1.31.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-HBT.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-HBT.27.1.32.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-HBT.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-HBT.27.1.33.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-HBT.27.1.41 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-HBT.27.1.41.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-HBT.27.1.41.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-HBT.27.1.52 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-HBT.27.1.52.1* | | *Conduct presence/absence surveys for juveniles* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-HBT.27.4.49 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-HBT.27.4.49.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-HBT.27.4.50 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-HBT.27.4.50.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-HBT.27.4.51 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-HBT.27.4.51.1* | | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | |

Table 5-17. Monitoring-related recovery actions for Hunter Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-HunC.27.2.9 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-HunC.27.2.9.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-HunC.27.2.9.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-HunC.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-HunC.27.2.19.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-HunC.27.2.20 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-HunC.27.2.20.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-HunC.27.2.22 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-HunC.27.2.22.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-HunC.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-HunC.27.2.33.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-HunC.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-HunC.27.2.34.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-HunC.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-HunC.27.2.35.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-HunC.27.2.36 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-HunC.27.2.36.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-HunC.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | Population wide | 3d |
| *SONCC-HunC.27.2.37.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-HunC.27.1.18 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-HunC.27.1.18.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-HunC.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-HunC.27.1.21.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-HunC.27.1.21.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-HunC.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-HunC.27.1.32.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-HunC.27.4.29 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-HunC.27.4.29.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-HunC.27.4.30 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-HunC.27.4.30.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-HunC.27.4.31 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-HunC.27.4.31.1* | | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | |

Table 5-18. Monitoring-related recovery actions for Illinois River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-IIIR.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-IIIR.27.2.25.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-IIIR.27.2.25.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-IIIR.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-IIIR.27.2.26.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-IIIR.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-IIIR.27.2.27.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-IIIR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-IIIR.27.2.28.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-IIIR.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-IIIR.27.2.29.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-IIIR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-IIIR.27.2.30.1* | *Continuously measure the hydrograph* | | | | | |
| SONCC-IIIR.27.2.58 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-IIIR.27.2.58.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-IIIR.27.2.59 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | Population wide | 3d |
| *SONCC-IIIR.27.2.59.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |
| SONCC-IIIR.27.2.60 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-IIIR.27.2.60.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-IIIR.27.2.61 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-IIIR.27.2.61.1* | | *Identify habitat condition of the estuary* | | | | |
| SONCC-IIIR.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-IIIR.27.1.21.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-IIIR.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-IIIR.27.1.22.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-IIIR.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-IIIR.27.1.23.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-IIIR.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-IIIR.27.1.24.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-IIIR.27.1.39 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-IIIR.27.1.39.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-IIIR.27.1.39.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-IIIR.27.1.40 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Measure VSP parameters of coho salmon in remote areas | Population wide | 3d |
| *SONCC-IIIR.27.1.40.1* | | *Develop techniques to estimate abundance, productivity, spatial structure, and diversity in remote areas.* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-IIIR.27.1.62 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-IIIR.27.1.62.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-IIIR.27.4.54 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-IIIR.27.4.54.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-IIIR.27.4.55 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-IIIR.27.4.55.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-IIIR.27.4.56 | Monitor | No | Track threat | Describe mining/gravel extraction threat | Population wide | 3d |
| *SONCC-IIIR.27.4.56.1* | *Describe any new mining or gravel extraction and any changes to existing mining and gravel extraction at least once every five years* | | | | | |
| SONCC-IIIR.27.4.57 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-IIIR.27.4.57.1* | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | | |
| SONCC-IIIR.27.4.63 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-IIIR.27.4.63.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

Table 5-19. Monitoring-related recovery actions for Little River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-LitR.27.2.16 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-LitR.27.2.16.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-LitR.27.2.16.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-LitR.27.2.17 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-LitR.27.2.17.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-LitR.27.2.18 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-LitR.27.2.18.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-LitR.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-LitR.27.2.19.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-LitR.27.1.13 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-LitR.27.1.13.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-LitR.27.1.14 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-LitR.27.1.14.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-LitR.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-LitR.27.1.15.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-LitR.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-LitR.27.1.23.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-LitR.27.1.23.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-LitR.27.4.26 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-LitR.27.4.26.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |

Table 5-20. Monitoring-related recovery actions for Lower Eel/Van Duzen Rivers.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-LEVR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-LEVR.27.2.30.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-LEVR.27.2.30.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-LEVR.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-LEVR.27.2.31.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-LEVR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-LEVR.27.2.32.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-LEVR.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-LEVR.27.2.33.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-LEVR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-LEVR.27.2.34.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-LEVR.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-LEVR.27.2.35.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-LEVR.27.2.41 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-LEVR.27.2.41.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-LEVR.27.2.58 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-LEVR.27.2.58.1* | *Measure water temperature continuously during the summer period* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-LEVR.27.2.59 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-LEVR.27.2.59.1* | | *Identify instream flow needs for coho salmon* | | | | |
| SONCC-LEVR.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-LEVR.27.1.26.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-LEVR.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-LEVR.27.1.27.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-LEVR.27.1.28 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-LEVR.27.1.28.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-LEVR.27.1.29 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-LEVR.27.1.29.1* | | *Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin* | | | | |
| *SONCC-LEVR.27.1.29.2* | | *Identify the status and trend of invasive species* | | | | |
| SONCC-LEVR.27.1.39 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-LEVR.27.1.39.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-LEVR.27.1.40 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-LEVR.27.1.40.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-LEVR.27.1.40.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-LEVR.27.1.61 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-LEVR.27.1.61.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-LEVR.27.4.54 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-LEVR.27.4.54.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-LEVR.27.4.55 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-LEVR.27.4.55.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-LEVR.27.4.56 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-LEVR.27.4.56.1* | | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | |
| SONCC-LEVR.27.4.57 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-LEVR.27.4.57.1* | | *Describe status and trend of abundance and distribution of invasive species annually* | | | | |
| SONCC-LEVR.27.4.60 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-LEVR.27.4.60.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-21. Monitoring-related recovery actions for Lower Klamath River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-LKR.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-LKR.27.2.33.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-LKR.27.2.33.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-LKR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-LKR.27.2.34.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-LKR.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-LKR.27.2.35.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-LKR.27.2.36 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-LKR.27.2.36.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-LKR.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-LKR.27.2.37.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-LKR.27.2.37.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-LKR.27.2.38 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-LKR.27.2.38.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-LKR.27.2.44 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-LKR.27.2.44.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-LKR.27.1.29 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-LKR.27.1.29.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-LKR.27.1.30 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-LKR.27.1.30.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |
| SONCC-LKR.27.1.31 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-LKR.27.1.31.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |
| SONCC-LKR.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-LKR.27.1.32.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| *SONCC-LKR.27.1.32.2* | *Annually estimate the in-river tribal harvest of wild/natural SONCC coho salmon* | | | | | |
| SONCC-LKR.27.1.42 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Disease' | All IP habitat | 3d |
| *SONCC-LKR.27.1.42.1* | *Annually estimate the infection and mortality rate of juvenile coho salmon from pathogens, such as Ceratonova shasta and Parvicapsula minibicornis* | | | | | |
| SONCC-LKR.27.1.43 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-LKR.27.1.43.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-LKR.27.1.43.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-LKR.27.1.49 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-LKR.27.1.49.1* | *Conduct presence/absence surveys for juveniles* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-LKR.27.4.47 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-LKR.27.4.47.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-LKR.27.4.48 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-LKR.27.4.48.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |

Table 5-22. Monitoring-related recovery actions for Lower Rogue River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-LRR.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-LRR.27.2.19.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-LRR.27.2.19.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-LRR.27.2.20 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-LRR.27.2.20.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-LRR.27.2.21 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-LRR.27.2.21.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-LRR.27.2.22 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-LRR.27.2.22.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-LRR.27.2.23 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-LRR.27.2.23.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-LRR.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-LRR.27.2.24.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-LRR.27.2.31 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-LRR.27.2.31.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-LRR.27.2.42 | Monitor | No | Track habitat condition | Track water temperature | Population wide | 3d |
| *SONCC-LRR.27.2.42.1* | *Measure water temperature continuously during the summer period* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-LRR.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-LRR.27.1.16.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-LRR.27.1.17 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-LRR.27.1.17.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-LRR.27.1.18 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-LRR.27.1.18.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-LRR.27.1.28 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-LRR.27.1.28.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-LRR.27.1.30 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-LRR.27.1.30.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-LRR.27.1.30.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-LRR.27.4.39 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-LRR.27.4.39.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-LRR.27.4.40 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-LRR.27.4.40.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-LRR.27.4.41 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-LRR.27.4.41.1* | | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | |
| SONCC-LRR.27.4.43 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-LRR.27.4.43.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-23. Monitoring-related recovery actions for Lower Trinity River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-LTR.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-LTR.27.2.24.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-LTR.27.2.24.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-LTR.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-LTR.27.2.25.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-LTR.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-LTR.27.2.26.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-LTR.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-LTR.27.2.27.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-LTR.27.2.27.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-LTR.27.1.20 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-LTR.27.1.20.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-LTR.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-LTR.27.1.21.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |
| SONCC-LTR.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-LTR.27.1.22.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-LTR.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-LTR.27.1.23.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| *SONCC-LTR.27.1.23.2* | | *Annually estimate the in-river tribal harvest of wild/natural SONCC coho salmon* | | | | |
| SONCC-LTR.27.1.34 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-LTR.27.1.34.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-LTR.27.1.34.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-LTR.27.1.41 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Hatchery Management' | All IP habitat | 3d |
| *SONCC-LTR.27.1.41.1* | | *Annually determine the percent of hatchery origin spawners (PHOS), percent of natural origin spawners (PNOS), and the proportion of natural influence (PNI)* | | | | |
| SONCC-LTR.27.1.45 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-LTR.27.1.45.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-LTR.27.4.42 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-LTR.27.4.42.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-LTR.27.4.43 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-LTR.27.4.43.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-LTR.27.4.44 | Monitor | No | Track threat | Describe threat of hatcheries | Population wide | 3d |
| *SONCC-LTR.27.4.44.1* | | *Describe status of development and implementation of applicable HGMPs at least one every five years* | | | | |

Table 5-24. Monitoring-related recovery actions for Mad River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MadR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MadR.27.2.30.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MadR.27.2.30.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MadR.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MadR.27.2.31.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MadR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MadR.27.2.32.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MadR.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MadR.27.2.33.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MadR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MadR.27.2.34.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MadR.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-MadR.27.2.35.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MadR.27.2.40 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MadR.27.2.40.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-MadR.27.2.45 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-MadR.27.2.45.1* | *Measure water temperature continuously during the summer period* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MadR.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-MadR.27.1.25.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-MadR.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-MadR.27.1.26.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-MadR.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track surrogate for genetic diversity | Mad River Hatchery | 3d |
| *SONCC-MadR.27.1.27.1* | | *Describe annual ratio of naturally-produced fish to hatchery-produced fish spawned for hatchery production* | | | | |
| SONCC-MadR.27.1.28 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MadR.27.1.28.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-MadR.27.1.29 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Hatchery Management' | Population wide | 3d |
| *SONCC-MadR.27.1.29.1* | | *Annually determine the percent of hatchery origin spawners (PHOS), percent of natural origin spawners (PNOS), and the proportion of natural influence (PNI)* | | | | |
| SONCC-MadR.27.1.38 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MadR.27.1.38.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-MadR.27.1.39 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MadR.27.1.39.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-MadR.27.1.39.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MadR.27.4.42 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MadR.27.4.42.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-MadR.27.4.43 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-MadR.27.4.43.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-MadR.27.4.44 | Monitor | No | Track threat | Describe mining/gravel extraction threat | Population wide | 3d |
| *SONCC-MadR.27.4.44.1* | | *Describe any new mining or gravel extraction and any changes to existing mining and gravel extraction at least once every five years* | | | | |

Table 5-25. Monitoring-related recovery actions for Mainstem Eel River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MER.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MER.27.2.27.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MER.27.2.27.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MER.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MER.27.2.28.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MER.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MER.27.2.29.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MER.27.2.40 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MER.27.2.40.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MER.27.2.41 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MER.27.2.41.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MER.27.2.42 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MER.27.2.42.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-MER.27.2.42.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-MER.27.2.43 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MER.27.2.43.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MER.27.2.47 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MER.27.2.47.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MER.27.2.48 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-MER.27.2.48.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-MER.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-MER.27.1.23.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-MER.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-MER.27.1.24.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-MER.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MER.27.1.25.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-MER.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-MER.27.1.26.1* | | *Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin* | | | | |
| *SONCC-MER.27.1.26.2* | | *Identify the status and trend of invasive species* | | | | |
| SONCC-MER.27.1.30 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MER.27.1.30.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-MER.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MER.27.1.32.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-MER.27.1.32.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MER.27.1.50 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-MER.27.1.50.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |
| SONCC-MER.27.4.44 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MER.27.4.44.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-MER.27.4.45 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-MER.27.4.45.1* | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | | |
| SONCC-MER.27.4.46 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-MER.27.4.46.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |
| SONCC-MER.27.4.49 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-MER.27.4.49.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

Table 5-26. Monitoring-related recovery actions for Maple Creek/Big Lagoon.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MapC.27.2.17 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MapC.27.2.17.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-MapC.27.2.17.2* | | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | |
| SONCC-MapC.27.2.18 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MapC.27.2.18.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-MapC.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MapC.27.2.19.1* | | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | |
| SONCC-MapC.27.2.20 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-MapC.27.2.20.1* | | *Identify habitat condition of the estuary* | | | | |
| SONCC-MapC.27.2.23 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MapC.27.2.23.1* | | *Determine best indicators of estuarine condition* | | | | |
| SONCC-MapC.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MapC.27.2.24.1* | | *Continuously measure the hydrograph* | | | | |
| *SONCC-MapC.27.2.24.2* | | *Identify instream flow needs for coho salmon* | | | | |
| SONCC-MapC.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MapC.27.1.15.1* | | *Conduct presence/absence surveys for juveniles* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MapC.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MapC.27.1.16.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-MapC.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | BR |
| *SONCC-MapC.27.1.22.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-MapC.27.1.22.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-MapC.27.4.25 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MapC.27.4.25.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |

Table 5-27. Monitoring-related recovery actions for Mattole River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MatR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MatR.27.2.28.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MatR.27.2.28.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MatR.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MatR.27.2.29.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MatR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MatR.27.2.30.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MatR.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MatR.27.2.31.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MatR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MatR.27.2.32.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MatR.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MatR.27.2.33.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-MatR.27.2.33.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-MatR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-MatR.27.2.34.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MatR.27.2.38 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MatR.27.2.38.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MatR.27.2.53 | Monitor | No | Track habitat condition | Track water temperature | Population wide | 3d |
| *SONCC-MatR.27.2.53.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-MatR.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-MatR.27.1.25.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-MatR.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-MatR.27.1.26.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |
| SONCC-MatR.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MatR.27.1.27.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-MatR.27.1.36 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MatR.27.1.36.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-MatR.27.1.37 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MatR.27.1.37.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-MatR.27.1.37.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-MatR.27.4.50 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-MatR.27.4.50.1* | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | | |
| SONCC-MatR.27.4.51 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MatR.27.4.51.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-MatR.27.4.52 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-MatR.27.4.52.1* | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | | |

Table 5-28. Monitoring-related recovery actions for Middle Fork Eel River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MFER.27.2.18 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MFER.27.2.18.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MFER.27.2.18.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MFER.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MFER.27.2.19.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MFER.27.2.20 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MFER.27.2.20.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MFER.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MFER.27.2.26.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MFER.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MFER.27.2.27.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MFER.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MFER.27.2.28.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MFER.27.2.30 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-MFER.27.2.30.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-MFER.27.2.36 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MFER.27.2.36.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MFER.27.2.37 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MFER.27.2.37.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MFER.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MFER.27.1.16.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-MFER.27.1.17 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MFER.27.1.17.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| *SONCC-MFER.27.1.17.2* | *Annually estimate the in-river tribal harvest of wild/natural SONCC coho salmon* | | | | | |
| SONCC-MFER.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-MFER.27.1.21.1* | *Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin* | | | | | |
| *SONCC-MFER.27.1.21.2* | *Identify the status and trend of invasive species* | | | | | |
| SONCC-MFER.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MFER.27.1.24.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-MFER.27.1.24.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-MFER.27.4.31 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-MFER.27.4.31.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |
| SONCC-MFER.27.4.32 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MFER.27.4.32.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-MFER.27.4.33 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-MFER.27.4.33.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-MFER.27.4.34 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-MFER.27.4.34.1* | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | | |
| SONCC-MFER.27.4.35 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-MFER.27.4.35.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |

Table 5-29. Monitoring-related recovery actions for Middle Mainstem Eel River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MMER.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MMER.27.2.27.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MMER.27.2.27.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MMER.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MMER.27.2.28.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MMER.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MMER.27.2.29.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MMER.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MMER.27.2.30.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MMER.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MMER.27.2.31.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MMER.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MMER.27.2.32.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-MMER.27.2.32.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-MMER.27.2.45 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MMER.27.2.45.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MMER.27.2.46 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MMER.27.2.46.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MMER.27.2.47 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-MMER.27.2.47.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-MMER.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-MMER.27.1.23.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-MMER.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-MMER.27.1.24.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |
| SONCC-MMER.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MMER.27.1.25.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-MMER.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-MMER.27.1.26.1* | *Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin* | | | | | |
| *SONCC-MMER.27.1.26.2* | *Identify the status and trend of invasive species* | | | | | |
| SONCC-MMER.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MMER.27.1.33.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-MMER.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MMER.27.1.35.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-MMER.27.1.35.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MMER.27.1.49 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-MMER.27.1.49.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |
| SONCC-MMER.27.4.41 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MMER.27.4.41.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-MMER.27.4.42 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-MMER.27.4.42.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-MMER.27.4.43 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-MMER.27.4.43.1* | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | | |
| SONCC-MMER.27.4.44 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-MMER.27.4.44.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |
| SONCC-MMER.27.4.48 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-MMER.27.4.48.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

Table 5-30. Monitoring-related recovery actions for Middle Rogue/Applegate Rivers.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MRAR.27.2.23 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MRAR.27.2.23.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MRAR.27.2.23.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MRAR.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MRAR.27.2.24.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MRAR.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MRAR.27.2.25.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MRAR.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MRAR.27.2.26.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MRAR.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MRAR.27.2.27.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MRAR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MRAR.27.2.28.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-MRAR.27.2.28.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-MRAR.27.2.58 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MRAR.27.2.58.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MRAR.27.2.59 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MRAR.27.2.59.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MRAR.27.2.61 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-MRAR.27.2.61.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-MRAR.27.1.20 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-MRAR.27.1.20.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-MRAR.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MRAR.27.1.21.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-MRAR.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MRAR.27.1.22.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-MRAR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-MRAR.27.1.33.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-MRAR.27.1.36 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MRAR.27.1.36.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-MRAR.27.1.36.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-MRAR.27.4.52 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MRAR.27.4.52.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-MRAR.27.4.53 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-MRAR.27.4.53.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MRAR.27.4.54 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-MRAR.27.4.54.1* | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | | |
| SONCC-MRAR.27.4.55 | Monitor | No | Track threat | Describe mining/gravel extraction threat | Population wide | 3d |
| *SONCC-MRAR.27.4.55.1* | *Describe any new mining or gravel extraction and any changes to existing mining and gravel extraction at least once every five years* | | | | | |
| SONCC-MRAR.27.4.56 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-MRAR.27.4.56.1* | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | | |
| SONCC-MRAR.27.4.60 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-MRAR.27.4.60.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |
| SONCC-MRAR.27.4.62 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-MRAR.27.4.62.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

Table 5-31. Monitoring-related recovery actions for Middle Klamath River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MKR.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MKR.27.2.37.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MKR.27.2.37.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MKR.27.2.38 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MKR.27.2.38.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MKR.27.2.39 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MKR.27.2.39.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MKR.27.2.40 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-MKR.27.2.40.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-MKR.27.2.41 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MKR.27.2.41.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-MKR.27.2.41.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-MKR.27.2.47 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-MKR.27.2.47.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |
| SONCC-MKR.27.2.48 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MKR.27.2.48.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MKR.27.2.49 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MKR.27.2.49.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MKR.27.2.50 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-MKR.27.2.50.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-MKR.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate survival of juvenile coho salmon | Population wide | 3d |
| *SONCC-MKR.27.1.32.1* | | *Develop comprehensive PIT tagging and retrieval project that assesses habitat use and survival* | | | | |
| SONCC-MKR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-MKR.27.1.33.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-MKR.27.1.34 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MKR.27.1.34.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-MKR.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MKR.27.1.35.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-MKR.27.1.36 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Disease' | Population wide | 3d |
| *SONCC-MKR.27.1.36.1* | | *Annually estimate the infection and mortality rate of juvenile coho salmon from pathogens, such as Ceratonova shasta and Parvicapsula minibicornis* | | | | |
| SONCC-MKR.27.1.44 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MKR.27.1.44.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-MKR.27.1.44.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-MKR.27.4.46 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-MKR.27.4.46.1* | | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | |
| SONCC-MKR.27.4.51 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-MKR.27.4.51.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-32. Monitoring-related recovery actions for Mussel Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-MusC.27.2.10 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-MusC.27.2.10.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-MusC.27.2.10.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-MusC.27.2.13 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-MusC.27.2.13.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-MusC.27.2.14 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-MusC.27.2.14.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-MusC.27.2.16 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-MusC.27.2.16.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-MusC.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-MusC.27.2.27.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-MusC.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-MusC.27.2.28.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-MusC.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-MusC.27.2.29.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-MusC.27.2.29.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-MusC.27.1.12 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-MusC.27.1.12.1* | *Conduct presence/absence surveys for juveniles* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-MusC.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-MusC.27.1.15.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-MusC.27.1.15.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-MusC.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-MusC.27.1.26.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-MusC.27.4.23 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-MusC.27.4.23.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-MusC.27.4.24 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-MusC.27.4.24.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-MusC.27.4.25 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-MusC.27.4.25.1* | | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | |
| SONCC-MusC.27.4.30 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-MusC.27.4.30.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-33. Monitoring-related recovery actions for North Fork Eel River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-NFER.27.2.24 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-NFER.27.2.24.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-NFER.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-NFER.27.2.37.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-NFER.27.2.37.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-NFER.27.2.12 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-NFER.27.2.12.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-NFER.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | Population wide | 3d |
| *SONCC-NFER.27.2.27.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |
| SONCC-NFER.27.2.13 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-NFER.27.2.13.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-NFER.27.2.17 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-NFER.27.2.17.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-NFER.27.2.19 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-NFER.27.2.19.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-NFER.27.2.19.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-NFER.27.2.18 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-NFER.27.2.18.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-NFER.27.2.16 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-NFER.27.2.16.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-NFER.27.2.28 | Monitor | No | Track habitat condition | Track ocean productivity | Population wide | 3d |
| *SONCC-NFER.27.2.28.1* | | *Compile and analyze data obtained from ocean net surveys, hatchery returns, satellites and buoy arrays in the ocean* | | | | |
| SONCC-NFER.27.2.26 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-NFER.27.2.26.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-NFER.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-NFER.27.1.25.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-NFER.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-NFER.27.1.23.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon* | | | | |
| SONCC-NFER.27.1.14 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-NFER.27.1.14.1* | | *Identify the status and trend of invasive species* | | | | |
| SONCC-NFER.27.4.20 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-NFER.27.4.20.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-NFER.27.4.21 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-NFER.27.4.21.1* | | *Describe trends in occurrence of high severity fire at least once every five years* | | | | |
| SONCC-NFER.27.4.22 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-NFER.27.4.22.1* | | *Describe status and trend of abundance and distribution of invasive species annually* | | | | |

Table 5-34. Monitoring-related recovery actions for Norton/Widow White Creeks.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-NWWC.27.2.6 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-NWWC.27.2.6.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-NWWC.27.2.6.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-NWWC.27.2.11 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-NWWC.27.2.11.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-NWWC.27.2.12 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-NWWC.27.2.12.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-NWWC.27.1.10 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-NWWC.27.1.10.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-NWWC.27.1.13 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-NWWC.27.1.13.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-NWWC.27.1.13.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-NWWC.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-NWWC.27.1.21.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-NWWC.27.4.17 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-NWWC.27.4.17.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-NWWC.27.4.18 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-NWWC.27.4.18.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-NWWC.27.4.19 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-NWWC.27.4.19.1* | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | | |
| SONCC-NWWC.27.4.20 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-NWWC.27.4.20.1* | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | | |

Table 5-35. Monitoring-related recovery actions for Pistol River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-PisR.27.2.13 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-PisR.27.2.13.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-PisR.27.2.13.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-PisR.27.2.15 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-PisR.27.2.15.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-PisR.27.2.16 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-PisR.27.2.16.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-PisR.27.2.18 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-PisR.27.2.18.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-PisR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-PisR.27.2.30.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-PisR.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-PisR.27.2.31.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-PisR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-PisR.27.2.32.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-PisR.27.2.32.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-PisR.27.2.33 | Monitor | No | Track habitat condition | Track water temperature | Population wide | 3d |
| *SONCC-PisR.27.2.33.1* | *Measure water temperature continuously during the summer period* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-PisR.27.1.14 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-PisR.27.1.14.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-PisR.27.1.17 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-PisR.27.1.17.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-PisR.27.1.17.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-PisR.27.1.29 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-PisR.27.1.29.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-PisR.27.4.27 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-PisR.27.4.27.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-PisR.27.4.28 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-PisR.27.4.28.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-PisR.27.4.34 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-PisR.27.4.34.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-36. Monitoring-related recovery actions for Redwood Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-RedC.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-RedC.27.2.26.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-RedC.27.2.26.2* | | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | |
| SONCC-RedC.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-RedC.27.2.27.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-RedC.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-RedC.27.2.28.1* | | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | |
| SONCC-RedC.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-RedC.27.2.29.1* | | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | |
| SONCC-RedC.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-RedC.27.2.30.1* | | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | |
| SONCC-RedC.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-RedC.27.2.31.1* | | *Identify habitat condition of the estuary* | | | | |
| SONCC-RedC.27.2.35 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 2a |
| *SONCC-RedC.27.2.35.1* | | *Determine best indicators of estuarine condition* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-RedC.27.2.44 | Monitor | No | Track habitat condition | Continue long-term monitoring | Population wide | 3b |
| *SONCC-RedC.27.2.44.1* | | *Continue long term channel response and channel stability studies by the NPS.* | | | | |
| *SONCC-RedC.27.2.44.2* | | *Continue long term monitoring by the USGS and NPS of discharge and sediment transport at the Orick and O'Kane gaging stations on Redwood Creek to support monitoring of the CWA section 303d listing as sediment impaired.* | | | | |
| *SONCC-RedC.27.2.44.3* | | *Continue long term stream temperature monitoring of mainstem Redwood Creek and select tributaries by the NPS to support the CWA section 303d listing as temperature impaired* | | | | |
| SONCC-RedC.27.2.50 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-RedC.27.2.50.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-RedC.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3b |
| *SONCC-RedC.27.1.23.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-RedC.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-RedC.27.1.24.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-RedC.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-RedC.27.1.25.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-RedC.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-RedC.27.1.33.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-RedC.27.1.34 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-RedC.27.1.34.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-RedC.27.1.34.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-RedC.27.1.43 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Continue long-term monitoring | Population wide | 3b |
| *SONCC-RedC.27.1.43.1* | | *Continue long-term smolt abundance monitoring.* | | | | |
| SONCC-RedC.27.1.51 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-RedC.27.1.51.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-RedC.27.4.47 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-RedC.27.4.47.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-RedC.27.4.48 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-RedC.27.4.48.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-RedC.27.4.49 | Monitor | No | Track threat | Describe mining/gravel extraction threat | Population wide | 3d |
| *SONCC-RedC.27.4.49.1* | | *Describe any new mining or gravel extraction and any changes to existing mining and gravel extraction at least once every five yea* | | | | |

Table 5-37. Monitoring-related recovery actions for Salmon River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-SalR.27.2.18 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-SalR.27.2.18.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-SalR.27.2.18.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-SalR.27.2.21 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-SalR.27.2.21.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-SalR.27.2.22 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-SalR.27.2.22.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-SalR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | Population wide | 3d |
| *SONCC-SalR.27.2.28.5* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |
| SONCC-SalR.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-SalR.27.1.15.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-SalR.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-SalR.27.1.16.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-SalR.27.1.17 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-SalR.27.1.17.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-SalR.27.1.19 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-SalR.27.1.19.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-SalR.27.1.24 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-SalR.27.1.24.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-SalR.27.1.24.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |

Table 5-38. Monitoring-related recovery actions for Scott River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-ScoR.27.2.36 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-ScoR.27.2.36.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-ScoR.27.2.36.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-ScoR.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-ScoR.27.2.37.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-ScoR.27.2.38 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-ScoR.27.2.38.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-ScoR.27.2.39 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-ScoR.27.2.39.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-ScoR.27.2.40 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-ScoR.27.2.40.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-ScoR.27.2.41 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-ScoR.27.2.41.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-ScoR.27.2.41.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-ScoR.27.2.53 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-ScoR.27.2.53.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-ScoR.27.2.55 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-ScoR.27.2.55.1* | *Identify habitat condition of the estuary* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-ScoR.27.2.56 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-ScoR.27.2.56.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-ScoR.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Evaluate impacts to coho salmon from specific restoration project types | Population wide | 3d |
| *SONCC-ScoR.27.1.32.1* | *Develop a monitoring program that evaluates impacts to coho salmon from tailing pile removal, rock weir installation, and floodplain restoration projects* | | | | | |
| *SONCC-ScoR.27.1.32.2* | *Implement monitoring program, guided by the plan* | | | | | |
| SONCC-ScoR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-ScoR.27.1.33.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-ScoR.27.1.34 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-ScoR.27.1.34.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |
| *SONCC-ScoR.27.1.34.2* | *Develop comprehensive PIT tagging and retrieval project that assesses habitat use and survival* | | | | | |
| SONCC-ScoR.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-ScoR.27.1.35.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-ScoR.27.1.45 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-ScoR.27.1.45.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-ScoR.27.1.47 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-ScoR.27.1.47.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-ScoR.27.1.47.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-ScoR.27.1.57 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-ScoR.27.1.57.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-ScoR.27.4.51 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-ScoR.27.4.51.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-ScoR.27.4.52 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-ScoR.27.4.52.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-ScoR.27.4.54 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-ScoR.27.4.54.1* | | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | |

Table 5-39. Monitoring-related recovery actions for Shasta River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-ShaR.27.2.40 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-ShaR.27.2.40.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-ShaR.27.2.40.2* | | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | |
| SONCC-ShaR.27.2.41 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-ShaR.27.2.41.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-ShaR.27.2.42 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-ShaR.27.2.42.1* | | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | |
| SONCC-ShaR.27.2.43 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-ShaR.27.2.43.1* | | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | |
| SONCC-ShaR.27.2.44 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-ShaR.27.2.44.1* | | *Continuously measure the hydrograph* | | | | |
| *SONCC-ShaR.27.2.44.2* | | *Identify instream flow needs* | | | | |
| SONCC-ShaR.27.2.52 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | | 3d |
| *SONCC-ShaR.27.2.52.1* | | *Track habitat indicators related to the stress 'Barriers'* | | | | |
| SONCC-ShaR.27.2.57 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-ShaR.27.2.57.1* | | *Identify habitat condition of the estuary* | | | | |
| SONCC-ShaR.27.2.58 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-ShaR.27.2.58.1* | | *Determine best indicators of estuarine condition* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-ShaR.27.2.60 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-ShaR.27.2.60.1* | *Measure water temperature continuously during the summer period* | | | | | |
| SONCC-ShaR.27.1.37 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-ShaR.27.1.37.1* | *Determine annual abundance of adult coho salmon* | | | | | |
| SONCC-ShaR.27.1.38 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-ShaR.27.1.38.1* | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | | |
| *SONCC-ShaR.27.1.38.2* | *Develop comprehensive PIT tagging and retrieval project that assesses habitat use and survival* | | | | | |
| SONCC-ShaR.27.1.39 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-ShaR.27.1.39.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-ShaR.27.1.47 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-ShaR.27.1.47.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-ShaR.27.1.49 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-ShaR.27.1.49.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-ShaR.27.1.49.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-ShaR.27.1.61 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-ShaR.27.1.61.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-ShaR.27.4.54 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-ShaR.27.4.54.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-ShaR.27.4.55 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-ShaR.27.4.55.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-ShaR.27.4.56 | Monitor | No | Track threat | Describe threat of hatcheries | Population wide | 3d |
| *SONCC-ShaR.27.4.56.1* | | *Describe status of development and implementation of applicable HGMPs at least one every five years* | | | | |
| SONCC-ShaR.27.4.59 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-ShaR.27.4.59.1* | | *Describe status and trend of abundance and distribution of invasive species annually* | | | | |

Table 5-40. Monitoring-related recovery actions for Smith River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-SmiR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-SmiR.27.2.28.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-SmiR.27.2.28.2* | | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | |
| SONCC-SmiR.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-SmiR.27.2.29.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-SmiR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-SmiR.27.2.30.1* | | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | |
| SONCC-SmiR.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | All IP habitat | 3d |
| *SONCC-SmiR.27.2.31.1* | | *Identify habitat condition of the estuary* | | | | |
| SONCC-SmiR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-SmiR.27.2.34.1* | | *Assess barriers limiting distribution of coho salmon* | | | | |
| SONCC-SmiR.27.2.36 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-SmiR.27.2.36.1* | | *Determine best indicators of estuarine condition* | | | | |
| SONCC-SmiR.27.2.43 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-SmiR.27.2.43.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-SmiR.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-SmiR.27.1.25.1* | | *Determine annual abundance of adult coho salmon* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-SmiR.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-SmiR.27.1.26.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-SmiR.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | BR |
| *SONCC-SmiR.27.1.27.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-SmiR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | BR |
| *SONCC-SmiR.27.1.33.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-SmiR.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | BR |
| *SONCC-SmiR.27.1.35.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-SmiR.27.1.35.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-SmiR.27.1.45 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-SmiR.27.1.45.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-SmiR.27.4.41 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-SmiR.27.4.41.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-SmiR.27.4.42 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-SmiR.27.4.42.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-SmiR.27.4.44 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-SmiR.27.4.44.1* | | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | |

Table 5-41. Monitoring-related recovery actions for South Fork Eel River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-SFER.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-SFER.27.2.37.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-SFER.27.2.37.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-SFER.27.2.38 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-SFER.27.2.38.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-SFER.27.2.39 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-SFER.27.2.39.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-SFER.27.2.40 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-SFER.27.2.40.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-SFER.27.2.41 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-SFER.27.2.41.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-SFER.27.2.42 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-SFER.27.2.42.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-SFER.27.2.42.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-SFER.27.2.56 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-SFER.27.2.56.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-SFER.27.2.57 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-SFER.27.2.57.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-SFER.27.2.59 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-SFER.27.2.59.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-SFER.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-SFER.27.1.32.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-SFER.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-SFER.27.1.33.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-SFER.27.1.34 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-SFER.27.1.34.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-SFER.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-SFER.27.1.35.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-SFER.27.1.36 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-SFER.27.1.36.1* | | *Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin* | | | | |
| *SONCC-SFER.27.1.36.2* | | *Identify the status and trend of invasive species* | | | | |
| SONCC-SFER.27.1.44 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-SFER.27.1.44.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-SFER.27.1.44.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-SFER.27.1.58 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-SFER.27.1.58.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-SFER.27.4.52 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-SFER.27.4.52.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-SFER.27.4.53 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-SFER.27.4.53.1* | | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | |
| SONCC-SFER.27.4.54 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-SFER.27.4.54.1* | | *Describe status and trend of abundance and distribution of invasive species annually* | | | | |
| SONCC-SFER.27.4.55 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | All IP habitat | 3d |
| *SONCC-SFER.27.4.55.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |
| SONCC-SFER.27.4.60 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-SFER.27.4.60.1* | | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | |

Table 5-42. Monitoring-related recovery actions for South Fork Trinity River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-SFTR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-SFTR.27.2.34.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-SFTR.27.2.34.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-SFTR.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-SFTR.27.2.35.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-SFTR.27.2.36 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-SFTR.27.2.36.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-SFTR.27.2.37 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-SFTR.27.2.37.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-SFTR.27.2.38 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-SFTR.27.2.38.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-SFTR.27.2.39 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-SFTR.27.2.39.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-SFTR.27.2.39.2* | *Identify instream flow needs* | | | | | |
| SONCC-SFTR.27.2.49 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-SFTR.27.2.49.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |
| SONCC-SFTR.27.2.53 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-SFTR.27.2.53.1* | *Measure water temperature continuously during the summer period* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-SFTR.27.1.31 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-SFTR.27.1.31.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-SFTR.27.1.32 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-SFTR.27.1.32.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-SFTR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-SFTR.27.1.33.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-SFTR.27.1.43 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-SFTR.27.1.43.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-SFTR.27.1.45 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-SFTR.27.1.45.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-SFTR.27.1.45.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-SFTR.27.1.50 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Hatchery Management' | All IP habitat | 3d |
| *SONCC-SFTR.27.1.50.1* | | *Annually determine the percent of hatchery origin spawners (PHOS), percent of natural origin spawners (PNOS), and the proportion of natural influence (PNI)* | | | | |
| SONCC-SFTR.27.4.51 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-SFTR.27.4.51.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-SFTR.27.4.52 | Monitor | No | Track threat | Describe threat of hatcheries | Population wide | 3d |
| *SONCC-SFTR.27.4.52.1* | | *Describe status of development and implementation of applicable HGMPs at least one every five years* | | | | |

Table 5-43. Monitoring-related recovery actions for Strawberry Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-StrC.27.2.11 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-StrC.27.2.11.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-StrC.27.2.11.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-StrC.27.2.17 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-StrC.27.2.17.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-StrC.27.2.20 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-StrC.27.2.20.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |
| SONCC-StrC.27.2.21 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-StrC.27.2.21.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-StrC.27.2.22 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-StrC.27.2.22.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-StrC.27.2.23 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-StrC.27.2.23.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-StrC.27.1.15 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-StrC.27.1.15.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-StrC.27.1.16 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-StrC.27.1.16.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-StrC.27.1.16.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-StrC.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-StrC.27.1.27.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-StrC.27.4.25 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-StrC.27.4.25.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-StrC.27.4.26 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-StrC.27.4.26.1* | | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | |

Table 5-44. Monitoring-related recovery actions for Upper Klamath River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-UKR.27.2.42 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-UKR.27.2.42.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-UKR.27.2.42.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-UKR.27.2.43 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-UKR.27.2.43.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-UKR.27.2.44 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-UKR.27.2.44.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-UKR.27.2.45 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-UKR.27.2.45.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-UKR.27.2.46 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-UKR.27.2.46.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-UKR.27.2.47 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-UKR.27.2.47.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-UKR.27.2.47.2* | *Identify instream flow needs* | | | | | |
| SONCC-UKR.27.2.56 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-UKR.27.2.56.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-UKR.27.2.57 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-UKR.27.2.57.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-UKR.27.2.59 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-UKR.27.2.59.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-UKR.27.1.34 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate survival of juvenile coho salmon | Population wide | 3d |
| *SONCC-UKR.27.1.34.1* | | *Develop comprehensive PIT tagging and retrieval project that assesses habitat use and survival* | | | | |
| SONCC-UKR.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-UKR.27.1.35.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-UKR.27.1.36 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-UKR.27.1.36.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-UKR.27.1.37 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-UKR.27.1.37.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-UKR.27.1.38 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track surrogate for genetic diversity | Iron Gate Hatchery | 3d |
| *SONCC-UKR.27.1.38.1* | | *Describe annual ratio of naturally-produced fish to hatchery-produced fish spawned for hatchery production* | | | | |
| SONCC-UKR.27.1.39 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-UKR.27.1.39.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-UKR.27.1.40 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Disease' | Population wide | 3d |
| *SONCC-UKR.27.1.40.1* | | *Annually estimate the infection and mortality rate of juvenile coho salmon from pathogens, such as Ceratonova shasta and Parvicapsula minibicornis* | | | | |
| SONCC-UKR.27.1.41 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Hatchery Management' | Population wide | 3d |
| *SONCC-UKR.27.1.41.1* | | *Annually determine the percent of hatchery origin spawners (PHOS), percent of natural origin spawners (PNOS), and the proportion of natural influence (PNI)* | | | | |
| SONCC-UKR.27.1.50 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-UKR.27.1.50.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-UKR.27.1.50.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-UKR.27.1.58 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-UKR.27.1.58.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-UKR.27.4.52 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-UKR.27.4.52.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-UKR.27.4.53 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-UKR.27.4.53.1* | | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | |
| SONCC-UKR.27.4.54 | Monitor | No | Track threat | Describe threat of hatcheries | Population wide | 3d |
| *SONCC-UKR.27.4.54.1* | | *Describe status of development and implementation of applicable HGMPs at least one every five years* | | | | |
| SONCC-UKR.27.4.55 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | All IP habitat | 3d |
| *SONCC-UKR.27.4.55.1* | | *Assess barriers limiting distribution of coho salmon* | | | | |

Table 5-45. Monitoring-related recovery actions for Upper Mainstem Eel River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-UMER.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-UMER.27.2.24.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-UMER.27.2.24.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-UMER.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-UMER.27.2.25.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-UMER.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-UMER.27.2.26.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-UMER.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-UMER.27.2.27.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-UMER.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-UMER.27.2.28.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-UMER.27.2.40 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-UMER.27.2.40.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |
| SONCC-UMER.27.2.41 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-UMER.27.2.41.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-UMER.27.2.42 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-UMER.27.2.42.1* | *Measure water temperature continuously during the summer period* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-UMER.27.2.43 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-UMER.27.2.43.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-UMER.27.2.43.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-UMER.27.2.48 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-UMER.27.2.48.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-UMER.27.2.49 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-UMER.27.2.49.1* | *Determine best indicators of estuarine condition* | | | | | |
| SONCC-UMER.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-UMER.27.1.21.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-UMER.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-UMER.27.1.22.1* | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | | |
| SONCC-UMER.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | Population wide | 3d |
| *SONCC-UMER.27.1.23.1* | *Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin* | | | | | |
| *SONCC-UMER.27.1.23.2* | *Identify the status and trend of invasive species* | | | | | |
| SONCC-UMER.27.1.31 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-UMER.27.1.31.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-UMER.27.1.31.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-UMER.27.4.44 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-UMER.27.4.44.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-UMER.27.4.45 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-UMER.27.4.45.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-UMER.27.4.46 | Monitor | No | Track threat | Describe threat of high intensity fire | Population wide | 3d |
| *SONCC-UMER.27.4.46.1* | | *Describe trends in occurrence of high intensity fire at least once every five years* | | | | |
| SONCC-UMER.27.4.47 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-UMER.27.4.47.1* | | *Describe status and trend of abundance and distribution of invasive species annually* | | | | |

Table 5-46. Monitoring-related recovery actions for Upper Rogue River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-URR.27.2.30 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-URR.27.2.30.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-URR.27.2.30.2* | | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | |
| SONCC-URR.27.2.31 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-URR.27.2.31.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-URR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-URR.27.2.32.1* | | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | |
| SONCC-URR.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-URR.27.2.33.1* | | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | |
| SONCC-URR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-URR.27.2.34.1* | | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | |
| SONCC-URR.27.2.35 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-URR.27.2.35.1* | | *Continuously measure the hydrograph* | | | | |
| SONCC-URR.27.2.55 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-URR.27.2.55.1* | | *Identify habitat condition of the estuary* | | | | |
| SONCC-URR.27.2.56 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-URR.27.2.56.1* | | *Determine best indicators of estuarine condition* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-URR.27.2.58 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-URR.27.2.58.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-URR.27.1.25 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-URR.27.1.25.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-URR.27.1.26 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-URR.27.1.26.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-URR.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track surrogate for genetic diversity | Cole Rivers Hatchery | 3d |
| *SONCC-URR.27.1.27.1* | | *Describe annual ratio of naturally-produced fish to hatchery-produced fish used to produce hatchery fish* | | | | |
| SONCC-URR.27.1.28 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-URR.27.1.28.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-URR.27.1.29 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Hatchery Management' | Population wide | 3d |
| *SONCC-URR.27.1.29.1* | | *Annually determine the percent of hatchery origin spawners (PHOS), percent of natural origin spawners (PNOS), and the proportion of natural influence (PNI)* | | | | |
| SONCC-URR.27.1.38 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-URR.27.1.38.1* | | *Conduct presence/absence surveys for juveniles* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-URR.27.1.41 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-URR.27.1.41.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-URR.27.1.41.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |
| SONCC-URR.27.1.60 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-URR.27.1.60.1* | *Install and annually operate a life cycle monitoring (LCM) station* | | | | | |
| SONCC-URR.27.4.51 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-URR.27.4.51.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-URR.27.4.52 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-URR.27.4.52.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-URR.27.4.53 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-URR.27.4.53.1* | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | | |
| SONCC-URR.27.4.54 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | All IP habitat | 3d |
| *SONCC-URR.27.4.54.1* | *Assess barriers limiting distribution of coho salmon* | | | | | |
| SONCC-URR.27.4.57 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-URR.27.4.57.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |
| SONCC-URR.27.4.59 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | All IP habitat | 3d |
| *SONCC-URR.27.4.59.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

Table 5-47. Monitoring-related recovery actions for Upper Trinity River.

| Action ID | Target | Key LF | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-UTR.27.2.32 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-UTR.27.2.32.1* | | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | |
| *SONCC-UTR.27.2.32.2* | | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | |
| SONCC-UTR.27.2.33 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-UTR.27.2.33.1* | | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | |
| SONCC-UTR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-UTR.27.2.34.1* | | *Continuously measure the hydrograph* | | | | |
| *SONCC-UTR.27.2.34.2* | | *Identify instream flow needs for coho salmon* | | | | |
| SONCC-UTR.27.2.46 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Barriers' | All IP habitat | 3d |
| *SONCC-UTR.27.2.46.1* | | *Assess barriers limiting distribution of coho salmon* | | | | |
| SONCC-UTR.27.1.27 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-UTR.27.1.27.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-UTR.27.1.28 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-UTR.27.1.28.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-UTR.27.1.29 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track surrogate for genetic diversity | Trinity River Hatchery | 3d |
| *SONCC-UTR.27.1.29.1* | | *Describe annual ratio of naturally-produced fish to hatchery-produced fish spawned for hatchery production* | | | | |

| Action ID | Target | Key LF | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-UTR.27.1.30 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-UTR.27.1.30.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-UTR.27.1.31 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Hatchery Management' | Population wide | 3d |
| *SONCC-UTR.27.1.31.1* | | *Annually determine the percent of hatchery origin spawners (PHOS), percent of natural origin spawners (PNOS), and the proportion of natural influence (PNI)* | | | | |
| SONCC-UTR.27.1.40 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-UTR.27.1.40.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-UTR.27.1.42 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-UTR.27.1.42.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-UTR.27.1.42.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-UTR.27.1.48 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the threat 'Invasive Species' | All IP habitat | 3d |
| *SONCC-UTR.27.1.48.1* | | *Identify the status and trend of invasive species* | | | | |
| SONCC-UTR.27.1.53 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Develop survival estimates | Site to be determined | 3d |
| *SONCC-UTR.27.1.53.1* | | *Install and annually operate a life cycle monitoring (LCM) station* | | | | |
| SONCC-UTR.27.4.49 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-UTR.27.4.49.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |

| Action ID | Target | Key LF | Strategy | Action Description | Area | Priority |
| --- | --- | --- | --- | --- | --- | --- |
| *Step ID* | *Step Description* | | | | | |
| SONCC-UTR.27.4.50 | Monitor | No | Track threat | Describe threat of road-stream crossing barriers | Population wide | 3d |
| *SONCC-UTR.27.4.50.1* | *Describe any new road-stream crossing barriers and any changes to existing road-stream crossing barriers at least once every five years* | | | | | |
| SONCC-UTR.27.4.51 | Monitor | No | Track threat | Describe threat of hatcheries | Population wide | 3d |
| *SONCC-UTR.27.4.51.1* | *Describe status of development and implementation of applicable HGMPs at least one every five years* | | | | | |
| SONCC-UTR.27.4.52 | Monitor | No | Track threat | Describe threat of invasive species | Population wide | 3d |
| *SONCC-UTR.27.4.52.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |

Table 5-48. Monitoring-related recovery actions for Wilson Creek.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-WilC.27.2.8 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-WilC.27.2.8.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-WilC.27.2.8.2* | *Measure indicators for spawning and rearing habitat once every 15 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-WilC.27.2.15 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-WilC.27.2.15.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-WilC.27.2.16 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-WilC.27.2.16.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-WilC.27.2.17 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-WilC.27.2.17.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-WilC.27.1.9 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Assess coho habitat use | Unnamed creeks south of Crescent City | 3d |
| *SONCC-WilC.27.1.9.1* | *Assess coho population use of tributaries and other small streams on RNSP lands* | | | | | |
| *SONCC-WilC.27.1.9.2* | *Assess coho population use of tributaries and other small streams on private lands* | | | | | |
| SONCC-WilC.27.1.12 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-WilC.27.1.12.1* | *Conduct presence/absence surveys for juveniles* | | | | | |
| SONCC-WilC.27.1.13 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-WilC.27.1.13.1* | *Develop supplemental or alternate means to set population types and targets* | | | | | |
| *SONCC-WilC.27.1.13.2* | *If appropriate, modify population types and targets using revised methodology* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-WilC.27.1.20 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-WilC.27.1.20.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-WilC.27.4.18 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-WilC.27.4.18.1* | | *Describe the status and trends of road treatments and road density at least once every five years* | | | | |
| SONCC-WilC.27.4.19 | Monitor | No | Track threat | Describe mining/gravel extraction threat | Population wide | 3d |
| *SONCC-WilC.27.4.19.1* | | *Describe any new mining or gravel extraction and any changes to existing mining and gravel extraction at least once every five years* | | | | |

Table 5-49. Monitoring-related recovery actions for Winchuck River.

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-WinR.27.2.24 | Monitor | No | Track habitat condition | Track habitat indicators related to spawning, rearing, and migration | Population wide | 3d |
| *SONCC-WinR.27.2.24.1* | *Measure indicators for spawning and rearing habitat. Conduct a comprehensive survey* | | | | | |
| *SONCC-WinR.27.2.24.2* | *Measure indicators for spawning and rearing habitat once every 10 years, sub-sampling using GRTS technique* | | | | | |
| SONCC-WinR.27.2.25 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Lack of Floodplain and Channel Structure' | All IP habitat | 3d |
| *SONCC-WinR.27.2.25.1* | *Measure the indicators, pool depth, pool frequency, D50, and LWD* | | | | | |
| SONCC-WinR.27.2.26 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Degraded Riparian Forest Condition' | All IP habitat | 3d |
| *SONCC-WinR.27.2.26.1* | *Measure the indicators, canopy cover, canopy type, and riparian condition* | | | | | |
| SONCC-WinR.27.2.27 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Altered Sediment Supply' | All IP habitat | 3d |
| *SONCC-WinR.27.2.27.1* | *Measure the indicators, % sand, % fines, V Star, silt/sand surface, turbidity, embeddedness* | | | | | |
| SONCC-WinR.27.2.28 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Water Quality' | All IP habitat | 3d |
| *SONCC-WinR.27.2.28.1* | *Measure the indicators, pH, D.O., temperature, and aquatic insects* | | | | | |
| SONCC-WinR.27.2.29 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Estuarine Function' | Estuary | 3d |
| *SONCC-WinR.27.2.29.1* | *Identify habitat condition of the estuary* | | | | | |
| SONCC-WinR.27.2.34 | Monitor | No | Track habitat condition | Track habitat indicators related to the stress 'Impaired Hydrologic Function' | All IP habitat | 3d |
| *SONCC-WinR.27.2.34.1* | *Continuously measure the hydrograph* | | | | | |
| *SONCC-WinR.27.2.34.2* | *Identify instream flow needs for coho salmon* | | | | | |
| SONCC-WinR.27.2.52 | Monitor | No | Track habitat condition | Determine best indicators of estuarine condition | Estuary | 3d |
| *SONCC-WinR.27.2.52.1* | *Determine best indicators of estuarine condition* | | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | | *Step Description* | | | | |
| SONCC-WinR.27.2.53 | Monitor | No | Track habitat condition | Track water temperature | All IP habitat | 3d |
| *SONCC-WinR.27.2.53.1* | | *Measure water temperature continuously during the summer period* | | | | |
| SONCC-WinR.27.1.21 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate abundance | Population wide | 3d |
| *SONCC-WinR.27.1.21.1* | | *Determine annual abundance of adult coho salmon* | | | | |
| SONCC-WinR.27.1.22 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Estimate juvenile spatial distribution | Population wide | 3d |
| *SONCC-WinR.27.1.22.1* | | *Conduct presence/absence surveys for juveniles* | | | | |
| SONCC-WinR.27.1.23 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track indicators related to the stress 'Fishing and Collecting' | Population wide | 3d |
| *SONCC-WinR.27.1.23.1* | | *Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon.* | | | | |
| SONCC-WinR.27.1.33 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Track life-history diversity | Population wide | 3d |
| *SONCC-WinR.27.1.33.1* | | *Describe annual variation in migration timing, age structure, habitat occupied, and behavior* | | | | |
| SONCC-WinR.27.1.35 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Refine methods for setting population types and targets | Population wide | 3d |
| *SONCC-WinR.27.1.35.1* | | *Develop supplemental or alternate means to set population types and targets* | | | | |
| *SONCC-WinR.27.1.35.2* | | *If appropriate, modify population types and targets using revised methodology* | | | | |
| SONCC-WinR.27.1.36 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Evaluate the potential to restore extirpated independent populations | Population wide | 3d |
| *SONCC-WinR.27.1.36.1* | | *Evaluate the potential to restore extirpated independent populations* | | | | |

| Action ID | Target | KLS/T | Strategy | Action Description | Area | Priority |
|---|---|---|---|---|---|---|
| *Step ID* | *Step Description* | | | | | |
| SONCC-WinR.27.1.51 | Monitor | No | Track population abundance, spatial structure, productivity, or diversity | Describe threat of invasive species | Population wide | 3d |
| *SONCC-WinR.27.1.51.1* | *Describe status and trend of abundance and distribution of invasive species annually* | | | | | |
| SONCC-WinR.27.4.48 | Monitor | No | Track threat | Describe road threat | Population wide | 3d |
| *SONCC-WinR.27.4.48.1* | *Describe the status and trends of road treatments and road density at least once every five years* | | | | | |
| SONCC-WinR.27.4.49 | Monitor | No | Track threat | Describe channelization/diking threat | Population wide | 3d |
| *SONCC-WinR.27.4.49.1* | *Describe new channelization/diking and changes to channelization/diking at least once every five years* | | | | | |
| SONCC-WinR.27.4.50 | Monitor | No | Track threat | Describe threat of development | Population wide | 3d |
| *SONCC-WinR.27.4.50.1* | *Describe new urban/residential/industrial development and changes to development at least once every five years* | | | | | |
| SONCC-WinR.27.4.54 | Monitor | No | Track threat | Track indicators related to the threat 'Barriers' | Population wide | 3d |
| *SONCC-WinR.27.4.54.1* | *Annually monitor the extent of barriers due to sediment or seasonally dry areas* | | | | | |

This page intentionally left blank.

# 6. Implementation Program

## 6.1 Phased Approach to Recovery

Recovery of the SONCC coho salmon ESU will occur by rebuilding each population so that it can eventually serve its needed role. The recovery strategy, to be applied on a population-by-population basis, has two phases. In Phase I, the goal for Core and Non-Core 1 populations is to prevent extinction by rebuilding spawner numbers to above depensation, and the goal for Dependent and Non-Core 2 populations is to build capacity to support strays by restoring habitat to support all life stages. Once a population achieves the goal for Phase I, its goal changes to that for Phase II. In Phase II, the goal for each independent population is to rebuild the number of spawners to those levels needed for a recovered ESU. The goal for each dependent and Non-Core 2 population in Phase II is to build juvenile occupancy to needed levels. **Table 6-1**shows each population's current phase of recovery and status relative to depensation or habitat.

Table 6-1. Current phase of recovery and status of each population.

| Population | Phase of Recovery | |
|---|---|---|
| | Current Phase of Recovery | Status |
| Elk River | Extinction prevention | Likely below depensation |
| Brush Creek | Building capacity | Insufficient habitat to support all life stages |
| Mussel Creek | Building capacity | Insufficient habitat to support all life stages |
| Lower Rogue River | Extinction prevention | Likely below depensation |
| Hunter Creek | Building capacity | Insufficient habitat to support all life stages |
| Pistol Creek | Building capacity | Insufficient habitat to support all life stages |
| Chetco River | Extinction prevention | Likely below depensation |
| Winchuck River | Extinction prevention | Likely below depensation |
| Smith River | Extinction prevention | Likely below depensation |
| Elk Creek | Building capacity | Insufficient habitat to support all life stages |
| Wilson Creek | Building capacity | Insufficient habitat to support all life stages |
| Lower Klamath River | Extinction prevention | Likely below depensation |
| Redwood Creek | Extinction prevention | Likely below depensation |
| Maple Creek/Big Lagoon | Building capacity | Insufficient habitat to support all life stages |
| Little River | Rebuilding | Likely above depensation |
| Strawberry Creek | Building capacity | Insufficient habitat to support all life stages |
| Norton/Widow White Creek | Building capacity | Insufficient habitat to support all life stages |
| Mad River | Extinction prevention | Likely below depensation |
| Humboldt Bay tributaries | Rebuilding | Likely above depensation |
| Lower Eel/Van Duzen Rivers | Extinction prevention | Likely below depensation |
| Guthrie Creek | Building capacity | Insufficient habitat to support all life stages |
| Bear River | Building capacity | Insufficient habitat to support all life stages |
| Mattole River | Extinction prevention | Likely below depensation |
| Illinois River | Rebuilding | Likely above depensation |
| Middle Rogue/Applegate Rivers | Rebuilding | Likely above depensation |
| Upper Rogue River | Rebuilding | Likely above depensation |
| Middle Klamath River | Rebuilding | Likely above depensation |

| Population | Phase of Recovery | |
|---|---|---|
| Upper Klamath River | Extinction prevention | Likely below depensation |
| Shasta River | Extinction prevention | Likely below depensation |
| Scott River | Rebuilding | Likely above depensation |
| Salmon River | Extinction prevention | Likely below depensation |
| Lower Trinity River | Extinction prevention | Likely below depensation |
| South Fork Trinity River | Extinction prevention | Likely below depensation |
| Upper Trinity River | Rebuilding | Likely above depensation |
| Mainstem Eel River | Extinction prevention | Likely below depensation |
| North Fork Eel River | Building capacity | Insufficient habitat to support all life stages |
| Middle Mainstem Eel River | Extinction prevention | Likely below depensation |
| Upper Mainstem Eel River | Building capacity | Insufficient habitat to support all life stages |
| Middle Fork Eel River | Building capacity | Insufficient habitat to support all life stages |
| South Fork Eel River | Rebuilding | Likely above depensation |

## 6.2 Recovery Action Themes

The seven diversity strata in the SONCC Coho Salmon ESU share stresses and threats which must be reduced to allow for SONCC coho salmon to recover. Many of the stresses and threats can be addressed with recovery actions. Recovery actions are designed to both address acute issues and restore processes which create and maintain coho salmon habitat. Recovery actions should focus on areas where coho salmon currently persist, and on unoccupied areas of suitable habitat, to maximize the chance of preserving existing coho salmon. The best available information on coho salmon distribution is described in Chapters 7 through 46. Recovery actions that are common to multiple coho salmon populations are organized into the following themes. See the recovery actions at the end of Chapters 7 through 46 to determine which themes apply to particular populations of interest.

### 6.2.1 Flow

Stream flow quantity, quality, and timing are insufficient across much of the ESU. Insufficient flows contribute to problems with water quality in many populations. Instream flow criteria should be established. Flows should be restored, through actions such as reducing the number of unpermitted diversions, encouraging water conservation, streamlining water leasing and instream dedication processes, and improving timber, grazing, and irrigation practices. The current timing and volume of flow should be assessed in the Eel, Klamath, Trinity, and Rogue Rivers, and dams and diversions should be operated so that the timing and volume of flow better approximates natural conditions.

### 6.2.2 Floodplain and Channel Structure

Floodplain and channel structure is insufficient for all populations. Habitat should be reconnected and restored. Large wood or other structure should be added to streams. Off-channel ponds, wetlands, and side channels should be restored or connected to the channel, possibly by reintroducing beavers. Levees and dikes should be removed, set back, or reconfigured and the natural channel form and floodplain connectivity re-established. Mature forests should be established along streams to increase the potential for large woody debris by improving timber harvest practices, planting conifers, releasing conifers from competition with hardwoods, and establishing a healthy fire regime.

### 6.2.3 Estuaries

In coastal basins, estuaries have been disconnected from their floodplains by major highways or levees, drained or filled, or converted to freshwater. Restoration of the hydrologic function of estuaries is necessary to provide tidal habitat used by rearing juvenile coho salmon, and to restore passage to needed habitat upstream of the estuary. The tidal exchange of water should be increased by setting back or removing levees and improving or removing tide gates. Tidal channels, wetlands, sloughs, and the estuary should be connected. Channelized reaches should be restored by restoring passage and habitat complexity. Remaining estuarine habitat needed for recovery should be protected from development, dredging, or filling.

### 6.2.4 Dams

In the Klamath and Trinity rivers, dams block access to large amounts of habitat needed to produce coho salmon. Dams also disrupt ecosystem functions in these rivers by impeding sediment transport and degrading water quality. For the Upper Klamath River, the recovery strategy and actions include removing four Klamath Hydroelectric Project (Project) dams on the mainstem of the Klamath River as provided in the Klamath Hydroelectric Settlement Agreement or constructing and operating fishways prescribed by NMFS for Project relicensing. On the Trinity River, recovery actions include studying the feasibility of fish passage at Lewiston and Trinity dams and providing fish passage accordingly. If habitat above dams becomes accessible, it should be restored.

### 6.2.5 Hatcheries

The ecological and genetic impacts of fish produced by the Trinity River Hatchery and Iron Gate Hatchery should be reduced. Hatchery and genetic management plans should be developed for every hatchery in the ESU.

Some populations of coho salmon are so small that they suffer from effects of low population size which increase the possibility of population extirpation. Enhancement programs such as captive broodstock, rescue rearing, or conservation hatcheries should be considered and, if appropriate, employed to support coho salmon populations in the Mainstem Eel River, Middle Mainstem Eel River, Mattole River, and Shasta River.

### 6.2.6 Disease and Non-Native Species

An assessment of all means possible to disrupt the life cycle of the *C. shasta* parasite should be completed and a plan developed and implemented in the Upper Klamath River based on the results of the assessment. A plan should be developed and implemented to reduce the number of warm-water non-native fish in the Interior Rogue and Interior Klamath basins. In the Interior Trinity stratum, brown trout should be eradicated. Throughout the Eel River, Sacramento pikeminnow abundance should be substantially reduced.

### 6.2.7 Fishing

Fisheries should be managed such that they do not limit attainment of population-specific viability criteria for the SONCC coho salmon ESU.

### 6.2.8 Altered Sediment Supply

To reduce fine sediment delivery to streams, roads should be upgraded, maintained, or decommissioned, slopes stabilized, and timber harvest and grazing practices improved.

## 6.3 Benefits of Recovery

Healthy salmon and steelhead populations provide significant economic, societal, and environmental benefits. Communities, businesses, jobs, and cultures have been built around salmonids on the West Coast.

Monetary investments in watershed restoration projects can promote the economic vitality in a myriad of ways. The largest economic returns resulting from recovered salmon and steelhead populations are associated with sport and commercial fishing. For example, the California commercial and recreational salmon fisheries are estimated to generate a total of $118-279 million in income annually (University of the Pacific 2010), and provide roughly two to three thousand jobs. These figures will increase as salmon runs increase, providing both economic gains and more commercial and recreational fishing opportunities. With a revived sport and commercial fishery, these substantial economic gains and the creation of jobs would be realized across the SONCC coho salmon ESU range, most notably for river communities and coastal counties.

The economy also will be stimulated through the employment of workers needed to implement recovery projects. Habitat restoration projects stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects (Nielsen-Pincus and Moseley 2010). Every dollar invested in watershed restoration projects travels through the state's economy. Design, implementation, and maintenance of habitat restoration projects require hiring consultants, contractors, employees, and field crews, and purchasing equipment, goods and services. People hired to carry out such projects spend their wages on goods and services in their local communities. In Oregon, 90% of investments in habitat restoration have been shown to stay in the state (Nielsen-Pincus and Moseley 2010).

Based on studies that examined streams in Colorado and salmonid restoration in the Columbia River Basin (Washington, Oregon and Idaho), the San Joaquin River (California), and the Elwha River (Washington), the value of salmonid recovery could be significantly larger than the fiscal or socioeconomic costs of recovery (CDFG 2004a). Importantly, the general model for viewing cost versus benefits should be viewed in terms of long-term benefits derived from short-term costs. Recovery actions taken for a particular listed salmonid are likely to also benefit other listed salmonids that occur in the same area, thus increasing the cost effectiveness of the actions.

Habitats restored to properly functioning conditions offer enhanced resource values and provide substantial non-monetary benefits for human communities. These benefits include: improving and protecting the quality of important surface and ground water supplies, reducing damage from flooding resulting from floodplain development, reducing expenditures on bank stabilization and flood control actions, and reducing the incidence of high severity fire. Restoring and maintaining healthy watersheds also enhances important human uses of aquatic habitats, including outdoor recreation, ecological education, field-based research, aesthetic benefits, and the preservation of tribal and cultural heritage.

Salmonid recovery is an investment and opportunity to diversify and strengthen the economy while enhancing the quality of life for present and future generations. The dollars necessary to recover salmonids should be made available without delay such that the suite of benefits can begin to accrue as soon as possible.

## 6.4 Achieving Recovery

Even with NMFS and other Federal agencies doing all within their authority and resources to achieve recovery of SONCC coho salmon, recovery will likely not occur without involvement by other entities. Federal agencies have neither the funds nor the authority to bring about all the actions necessary to sufficiently improve the condition of this species. Partnerships are a critical component of SONCC coho salmon recovery: partnerships between private landowners, tribes, and local, state, and federal government agencies; between non-governmental organizations and landowners; and between federal, state, and local agencies. A recovered ESU can provide ecosystem, recreation, and economic benefits to communities. All of these entities have a common interest in bringing healthy coho salmon populations and their ecosystems back to California and Oregon's coasts. Anyone who has an interest in the recovery of a listed species is a conservation partner. Conservation Partners Conservation partners are essential to the implementation and success of the recovery plan. NMFS looks forward to working with our conservation partners to recover the SONCC coho salmon ESU. Conservation partners may be individuals, groups, government or non-government organizations, industry, or tribes. A list of known conservation partners can be found in Appendix E.

## 6.5 Implementation Schedule

The last tables in Chapters 7 through 46 list the population-specific recovery actions that make up the SONCC coho salmon Recovery Program, including the recovery action number, recovery action step number, target, strategy, recovery action, action step, area, priority, and whether the action addresses a key limiting stress or threat. Appendix F lists the recovery action step number, potential lead agency and estimated cost for each action. Together, the tables in Chapters 7 through 46 and Appendix F make up the implementation schedule. A portion of an example implementation schedule is shown in Figure 6-1.

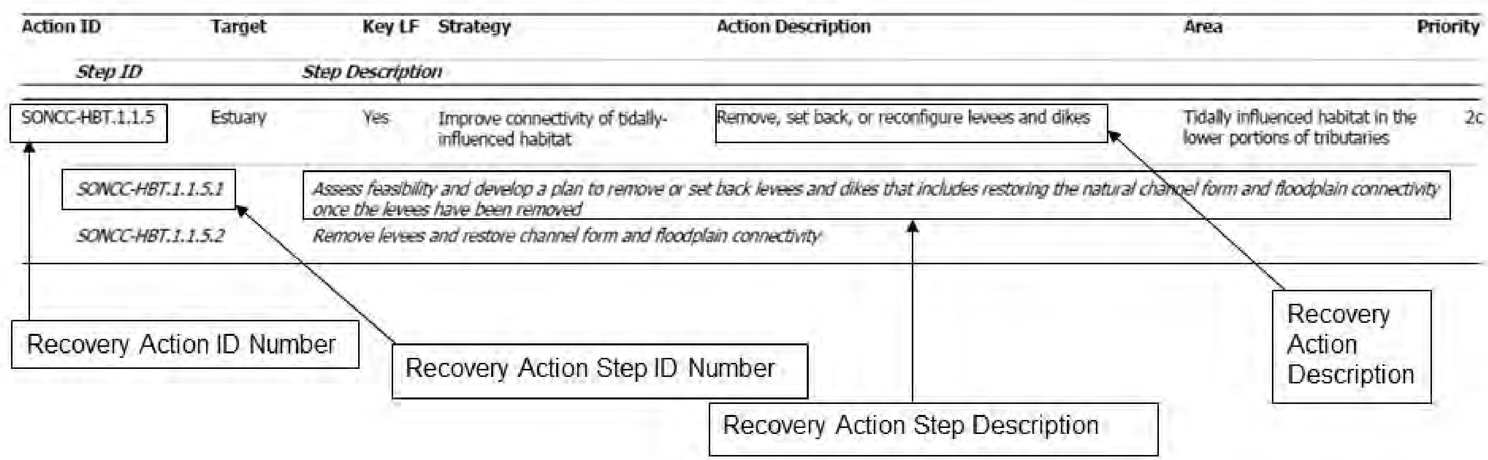



Figure 6-1. Example implementation schedule with selected elements labeled.

The fields in the recovery action tables found at the end of each population profile (Chapters 7 to 46) provides a unique ID number for each recovery action and recovery action step, information about which stress or threat each is meant to address, the purpose of the action, the particular action to be completed and the steps needed to complete it, the location where the action should be completed, the priority assigned to each action, and whether the action addresses a key limiting stress or threat. Additional fields, including cost and potential lead, are shown in Appendix F.

### 6.5.1 Recovery Action ID Number

A unique recovery action number is assigned to every recovery action to facilitate reference to the recovery action. For example, in the recovery action number SONCC-HBT.2.2, “SONCC” refers to the ESU, “HBT” refers to the population (in this case "Humboldt Bay Tributaries"), the first “2” is the strategy ID number (see Table 6-2), and the second “2” refers to the recovery action.

### 6.5.2 Recovery Action Step ID Number

The recovery action step ID number is a unique identifier assigned to each step of a particular recovery action to facilitate reference to a particular recovery action step number. It consists of the Recovery Action Number, with an additional number which refers to the sequential order of the action step (i.e., 1, 2, 3, or 4). For example, in SONCC-HBT.2.2.1, the “1” refers to the action step, in this case the first in a sequence of steps.

### 6.5.3 Target

The target is the primary stress or threat the recovery action is designed to address (e.g., the strategy “Sediment” is meant to address the stress “Altered sediment supply”).

shows the target ID number, the target, and the stress or threat addressed by that target. For example, in SONCC-HBT-2.2.1, the target is Floodplain and Channel Structure. Note that a recovery action may address more than one stress or threat, and therefore more than one target. However, only one target is associated with each recovery action in the implementation schedule.

Table 6-2. Stress or threat addressed by each target.

| Strategy ID Number* | Target | Stress or Threat Addressed |
|---|---|---|
| 1 | Estuary | Impaired Estuarine Function |
| 2 | Floodplain and Channel Structure | Lack of Floodplain and Channel Structure |
| 3 | Hydrology | Impaired Hydrologic Function |
| 5 | Passage | Barriers |
| 7 | Riparian | Degraded Riparian Forest Conditions |
| 8 | Sediment | Altered Sediment Supply |
| 10 | Water Quality | Impaired Water Quality |
| 12 | Agricultural Practices | Agricultural Practices |
| 13 | Channelization/Diking | Channelization/Diking |
| 14 | Invasive, Non-native Species | Invasive, Non-native Species |
| 16 | Fishing/Collecting | Adverse Fishery-Related Effects |
| 17 | Hatcheries | Adverse Hatchery-Related Effects |
| 19 | Timber Harvest | Timber Harvest |
| 22 | Urban, Residential, Industrial Development | Urban, Residential, Industrial Development |
| 23 | Road-Stream Crossing Barriers | Road-Stream Crossing Barriers |
| 26 | Low Population Dynamics | Not applicable |
| 27 | Monitor | Not applicable |
| 28 | Roads | Roads |
| 29 | Research | Not applicable |
| 30 | Disease, Predation, Competition | Disease, Predation, Competition |
| *Gaps in strategy ID numbers reflect categories not used for SONCC plan but used for other recovery plans in California. | | |

### 6.5.4 Strategy

The strategy describes the purpose of the recovery action: To increase, reduce, or maintain particular characteristics of the stress (e.g., reduce delivery of sediment to streams).

### 6.5.5 Recovery Action

Action to be completed (e.g., reduce road-stream hydrologic connection).

### 6.5.6 Action Step

Steps to accomplish action (e.g., assess and prioritize road-stream connection, and identify appropriate treatments to meet strategy; decommission roads, guided by assessment). The action steps describe the actions to be taken to accomplish the recovery action and strategy.

### 6.5.7 Area

Location where action should be completed (e.g., all tributaries of the alluvial coastal plain downstream of Rock Creek, Indian Creek, and Bagley Creek, especially the Butler Creek watershed). Complementary actions were often created for recovery actions that had area identified as "population wide." The complementary actions will describe the area as, "area where fish would benefit immediately." Complementary actions that benefit fish immediately will have a higher priority than those described as population wide.

### 6.5.8 Priority

Each recovery action has been assigned a priority number, which is explained in Section 6.7.

### 6.5.9 Key Limiting Stress or Key Limiting Threat

Some recovery actions address key limiting stresses or key limiting threats - those stresses and threats that have the greatest impact on current population viability. Key limiting stresses and threats are explained in Section 6.5.9, and are identified for each population in its respective population profile (Chapters 7 through 46). If a recovery action addresses a key limiting stress or key limiting threat for a given population, this field will read "Yes". If not, it will read "No". Whether or not an action addresses a key limiting stress or threat factors in to the priority assigned to that action.

## 6.6 Developing Conservation Plans for Recovery Action Implementation

In general, the SONCC Coho Recovery Plan avoids describing overly prescriptive actions within individual watersheds so that conservation partners can develop the best strategies to obtain the associated objectives. Typically, a multi-stepped process is described to help managers achieve these goals. First, a proper assessment will help identify and prioritize locations for restoration. Second, an implementation or conservation plan will determine a strategy for abating the stress or threat through recovery actions. Third, actions can be implemented under the guidance of the plan. In some cases, a simplified assessment or plan may suffice in instances where effects and treatment are obvious (e.g., cows are walking in the stream, action is to build fences).

Below is an example of a multi-stepped action found in the Smith River population profile:

Strategy: Improve wood recruitment, bank stability, shading, and food subsidies
Action: Improve grazing practices

Action Steps:

| | |
|---|---|
| SONCC-SmiR.7.1.7.1 | Assess grazing impact on sediment delivery and riparian condition, identifying opportunities for improvement |
| SONCC-SmiR.7.1.7.2 | Develop grazing management plan to meet objective |
| SONCC-SmiR.7.1.7.3 | Plant vegetation to stabilize stream bank |
| SONCC-SmiR.7.1.7.4 | Fence livestock out of riparian zones |
| SONCC-SmiR.7.1.7.5 | Remove instream livestock watering sources |

The development of a conservation plan or restoration strategy is a critical phase of restoration and when done correctly, will help ensure goals are met and desired conditions are attained. The following provides guidelines for developing conservation/restoration plans for some of the most frequently described recovery actions:

**Strategy: Reduce delivery of sediment to streams**
**Action: Reduce road-stream hydrologic connection**

A road assessment for a watershed should identify which roads are primary sources for sediment in the stream network. Assessments should include the identification of road surfaces (native material, gravel, paved, etc.), condition of the road and drainage features, and potential for sediment delivery (distance to the stream, eroding cut slopes, etc.).

If possible, the treatment plan should first prioritize the restoration of those roads delivering the most sediment to streams, and identify the actions necessary to reduce sediment delivery. Roads may need to be decommissioned by pulling out culverts or locking gates, or could be completely removed by re-contouring the hill slope to mimic a natural state. In other cases, roads may only need to be upgraded to solve the majority of sediment delivery problems. Roads surfaced with native materials typically contribute the majority of fines (USFS 2004). An assessment may find that it is only necessary to surface native roads with gravel, crown the road surfaces to discourage erosion of the surface, or improve drainage features. Treatment plans should include a long term maintenance schedule and monitoring plan if necessary. The California Department of Fish and Game's California Salmonid Stream Habitat Restoration Manual (CDFG 2010a) includes instructions for how to carry out an upslope erosion inventory and how to control sediment inputs.

**Strategy: Improve wood recruitment, bank stability, shading, and food subsidies**
**(or) Reduce sediment delivery to streams**
**Action: Improve grazing practices**

After an assessment is completed, which evaluates the contribution of livestock to sediment delivery and riparian degradation, a grazing management plan can be developed to reduce the stresses to SONCC coho salmon. Actions included in a plan may include fencing livestock outside of the riparian corridor, moving water sources upslope so animals are not in the stream, and planting new vegetation alongside the stream. The Natural Resources Conservation Service (NRCS) can provide resources for plan development including appropriate BMPs. For example, NRCS (2013) describes specifications for sustainable grazing practices, how to improve conditions of riparian forests and water resources, and how to develop a monitoring plan.

**Strategy: Increase channel complexity**
**Action: Increase LWD, boulders, or other instream structure**
**(or) Construct off-channel ponds, alcoves, backwater habitat, or old stream oxbows**

*Instream structure*

An assessment of channel complexity may consider such factors as amount and size of LWD present, depth of pools, and frequency of pools. A plan to increase instream structure may describe locations where addition of instream structure/habitat would be most beneficial, and ideally would prioritize those locations. The plan could also describe, for each location, how the instream structure would be added and the type and size of structural material (e.g., wood, boulders). For coastal California, the preferred wood type is redwood or Douglas fir which have a life expectancy of 25-50 years once fallen from the tree. Deciduous trees have a higher rate of decay and may only last 5-10 years. A LWD plan should consider adding wood with a root wad attached to add stability and complexity to the structure. Log structures may range from a single log to very complex engineered log structures. Log structures may be unanchored and allowed to move with high stream flows or be anchored in place. Consideration should be given to downstream infrastructure such as roads and homes. In addition, the plan should consider opportunities for obtaining wood or other structural material, and whether the available wood or other structural material is sized appropriately for the watershed. "Section 5.1.2 Side Channel/Off Channel Habitat Restoration" in the Washington Department of Fish and Wildlife Stream Habitat Restoration Guidelines 2004 (Saldi-Caromile et al. 2004) provides additional details regarding large wood construction projects.

*Off-channel habitat*

An assessment of a watershed may note opportunities for improved connection of the channel to the floodplain. A preliminary look at aerial photographs will help identify old or abandoned channel features such as oxbows and side channels that can be reconnected. Types of side-channel or off-channel restoration may include:

- Connection of abandoned side channel or pond habitats to restore fish access.
- Connection of adjacent ponds, remnants from aggregate excavation.
- Connection of oxbow lakes on floodplains that have been isolated from the meandering channel by river management schemes, or channel incision.
- Creation or re-connection of side channel or off-channel habitat with self-sustaining channels.
- Improvement of hydrologic connection between floodplains and main channels.

Restoration projects in this category may require removal or breaching of levees and dikes, channel and pond excavation, creating temporary access roads, constructing wood or rock tailwater control structures, and construction of LWD habitat features.

A plan for creating off channel habitat may consider water supply (channel flow/overland flow/groundwater), water quality and reliability, risk of channel change, and channel and hydraulic grade. Ideally, a project will not require regular maintenance. Anticipated maintenance should be described and planned for. The use of appropriately designed LWD structures may function as water level control structures or could redirect flow to help maintain channel features. Additionally, a plan may consider details such as site constraints and project limits, risk to infrastructure or other properties due to increased flow through a project channel, and descriptions of how the off-channel feature is anticipated to change and adjust over time. Saldi-Caromile et al. 2004 is a good reference document for designing off channel habitat features.

**Strategy: Improve flow timing or volume**
**Action: Improve irrigation practices**

**(or) Improve water management techniques**
**(or) Increase instream flows**
**(or) Reduce diversions**
**(or) Store water under a forbearance agreement for flow augmentation**

An assessment of flow may consider factors such as the extent of current illegal diversions, an evaluation of current instream flows, and a description of current water management techniques. An assessment should also consider the coho salmon life stage that will benefit from additional flow and how it will benefit (e.g., lower temperature for rearing, improve spawning habitat, improve migration corridor) as well as what length of stream reach will be affected by the increased flow. A plan to increase instream flows or reduce diversions would identify the means by which such changes would be accomplished, possibly with a prioritized list of the areas most in need of increased flow, or the illegal diversions having the most impact on flow. Water conservation projects should provide for a more efficient use of water extracted from the stream and result in increased flows that benefit aquatic species. Water conservation measures may include off-channel water storage, changes in the timing or source of water supply, moving points of diversion, irrigation ditch lining, piping, stock-water systems, and agricultural tailwater recovery/management systems.

Water conservation projects that use water storage tanks may consider filling them through rainwater catchment or by surface or groundwater flow. A project plan may consider establishment of water storage tanks using a forbearance agreement for at least 10 years, which will provide temporal and quantitative assurances for pumping activities that result in less water withdrawal during the summer low flow period. Water storage capacity for the water diversion forbearance period should be of sufficient capacity to provide for all water needs during that time period. For example, if the no-pump period is 105 days (August to November), the diverters must have enough storage to cover any domestic, irrigation, or livestock needs during that time.

**Strategy: Improve access**
**Action: Remove structural barrier**

Structural barriers may include permanent, flash board, or seasonal push up dams. An assessment of a structural barrier should identify the life stages of coho salmon which are blocked by the barrier and characteristics of the barrier (e.g., height, size of jump pool, gradient). An assessment may also include amount and characteristics of the sediment that will be released by removing the dam.

A small dam removal plan may include engineered designs for the upstream channel that minimizes negative effects (e.g., scour, down cutting) to downstream habitat. The plan may include excavation of sediment, diversion of water during dam removal, and seasonal timing windows for construction. CDFW's Habitat Restoration Manual (CDFG 2010a) provides additional information about how to remove small dams.

**Strategy: Improve wood recruitment, bank stability, shading, and food subsidies**
**Action: Increase conifer riparian vegetation**

An assessment of riparian forests should identify regions where the most degraded conditions occur such as those areas with little or no vegetation, limited conifer abundance, and regions of small sized or crowded conifers. A silvicultural prescription should prioritize regions with the most degraded forests conditions and those immediately adjacent to fish habitat. Prescriptions may include planting conifers, protecting riparian zones with the use of buffers, thinning small conifers to encourage faster growth in others, or removing exotic species such as Himalayan blackberries that prevent the establishment of new conifers. The NRCS can provide resources about how to manage riparian forests, including suggestions for buffer sizes which may be variable depending on the size of the stream (NRCS 2013). Additionally, NRCS and other resources such as Fischer and Fischenich (2000)'s Design Recommendations for Riparian Corridors and Vegetated Buffer Strips can provide information about how to successfully plant vegetation, exclude foraging animals, and control competing vegetation. CDFG (2010a) describes how to manage forests to improve wood recruitment, stabilize banks, and manage for shade.

**Strategy: Increase channel complexity**
**Action: Increase beaver abundance**

A beaver conservation plan could significantly enhance coho habitat in watersheds, but must consider issues associated with relocation of beavers and landowner conflicts. It is preferable for a plan to follow an "Educate-Mitigate-Relocate" type strategy. A conservation plan should first focus on education and outreach to landowners, detailing the benefits of beaver to the health of our ecosystems (see Chapter 3, Lack of Floodplain and Channel Structure and Climate Change). Because it is preferable to encourage beavers to stay in their chosen habitats, mitigation and technical assistance to landowners dealing with beavers should be a strong focus in any conservation plan. Tools such as tree cages, sand painting for trees, piping through dams to control flooding, and culvert exclusion devices such as beaver deceivers can help restoration groups assist landowners in beaver conflicts prior to removal of the beaver. Finally, relocation or reintroduction of beaver may be considered as a last resort. If no beavers are currently present in a watershed, a feasibility study should be carried out to determine whether beavers could be successful. A ranking scheme for watersheds and stream reaches should be developed to guide relocation efforts and may include factors such as stream gradient, food resources, protective cover, and landownership. Strong guidelines and methods should be developed prior to relocating or reintroducing beaver to an area. The Methow Beaver Project in Washington State provides extensive detail regarding relocation methods for beavers and meeting restoration objectives (Woodruff 2013), while Swales and Pollock (in review) provides a review of California regulations for trapping and relocating beaver.

Conservation plans may also include restoration projects that utilize beaver engineering skills to create coho salmon habitat and restore hydrologic function to streams. A restoration project may include techniques for construction of beaver dam analogues that will simulate the effects of beaver dams both for the purposes of creating habitat suitable for beaver and for creating the beneficial effects of beaver dams in locations that beaver are unlikely to occupy in the near future. Pollock et al. (2012) details methods and monitoring protocols in one example of this type of restoration.

**Strategy: Improve water quality**
**Action: Reduce contaminants**

When developing a watershed scale pesticide management plan, it's important to start with an inventory of potential pesticide use in the watershed. Determine if pesticides come from urban development such as lawn care and gardening, if they are associated with agriculture, or both. Pesticide use and selection often differs depending upon the area treated, although similar pesticide classes (e.g. pyrethroid insecticides) or active ingredients (e.g. glyphosate) may be used in both urban and agricultural uses. After areas of potential pesticide use and discharge into local waterbodies have been identified, management objectives can be defined. Pesticide management plans should have an educational and technical assistance component that assists landowners in preventing or minimizing their chemical input to streams.

There are numerous resources available on-line for use when developing a watershed scale or site specific pesticide management plan. For urban areas or rural developments (e.g. housing or infrastructure development in a rural area), a manual that gives development techniques and practices considered to be “low impact development” for storm water quality should also be consulted. Typical best management practices for these urban areas, in addition to careful pesticide selection and application techniques, include installation of vegetated filter strips and grassy swales for filtering storm water that may carry pesticide residues from a site. Maintaining, improving or expanding buffer zones between pesticide application areas and streams is also a common practice. Infiltration of storm water or site drainage is often useful for preventing the discharge of non-mobile products to water bodies. More developed areas can often use detention basins to settle out sediments contaminated with pesticide residues, or infrastructure-specific areas such as inlet filters or wet vaults.

NMFS encourages the development of smaller scale pesticide management plans at the stream reach or even individual ownership level. In many cases, it may be impracticable to wait for or to rely upon the development of a watershed-wide plan. The principals and most BMPs expressed in the preceding paragraphs are valid for site-specific planning. Many municipalities in California are covered under State-issued discharge permits which require the organizations to work with their citizens to reduce pesticide discharges. Local jurisdictions (e.g. cities, counties) should be consulted to see if they have developed, or can access, programs or materials that will aid in this process. There are also many existing programs for agricultural landowners. The University of California Cooperative Extension system has organized and conducts many programs targeted to reducing nonpoint source pollution from agriculture, including pesticide pollution, with many geared toward particular cropping systems. There are additional, non-profit based programs freely available as well, such as Fish Friendly Farming and Fish Friendly Ranching programs.

## 6.7 Recovery Action Priority

Conservation partners should consider the priority of a recovery action when choosing recovery actions to implement. Table 6-3 describes the prioritization system NMFS used to assign priorities to recovery actions for Core and Non-Core 1 populations. Table 6-4 is the system used for recovery actions for Dependent and Non-Core 2 populations. The numeric parts of the priorities (i.e., 1, 2, and 3) are defined by Conditions 1, 2, and 3 in Table 6-3 and Conditions 1 and 2 in Table 6-4. These conditions are based on language from NMFS guidelines (NMFS 1990), which is designed to prioritize those actions that are necessary to prevent extinction of the ESU, or to prevent a significant negative impact to the ESU short of extinction, over all other actions needed to achieve ESU recovery. Condition 7 in Table 6.3, and Condition 5 in Table 6-4, are based on Oregon's "broad-sense recovery goals". Actions meeting either of these conditions would contribute to broad-sense recovery goals but are not necessary to provide for ESA recovery of the ESU. The a, b, c and d parts of the priorities are defined by Conditions 6, 5, and 4, respectively, in Table 6-3 and Conditions 3 and 4 in Table 6-4. Priorities with the letter d are defined by meeting Condition 2 or 3 but not 4, 5 and 6 in Table 6-2 or meeting Condition 1 or 2 but not 3 or 4 in Table 6-3. NMFS used these conditions to consider several important factors: 1. If an action addresses a key limiting stress or threat and so would help resolve an identified population bottleneck; 2. If an action will benefit coho salmon immediately because they are already present in or near the action area; and 3. If the number of spawners in a population is below the depensation threshold.

Table 6-3. Prioritization system for Core and Non-Core 1 populations.

| Condition | | Priority[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2a | 2b | 2c | 2d | 3a | 3b | 3c | 3d | BR |
| 1 | Action needed to prevent extinction of ESU by 1. Preventing extirpation of one or more independent populations or 2. Making a significant difference to multiple limiting factors in many of the populations in the ESU, meaningfully decreasing the extinction risk for much of the ESU. | x | | | | | | | | | |
| 2 | Action needed to prevent significant decline[2] in habitat or population in any population. | | x | x | x | x | | | | | |
| 3 | Action needed to achieve recovery of the ESU but does not meet Condition 1 or 2. | | | | | | x | x | x | x | |
| 4 | Action addresses key limiting stress or key limiting threat OR benefits[3] coho salmon immediately[4]. | | | x | x | | | x | x | | |
| 5 | Population below depensation based on the lowest three consecutive years from 2001 to 2012. | | x | x | | | x | x | | | |
| 6 | Action addresses key limiting stress or key limiting threat AND benefits[3] coho immediately[4]. | | x | | | | x | | | | |
| 7 | Action not needed to achieve ESA recovery but would contribute to broad-sense recovery (BR) goals. | | | | | | | | | | x |

[1]To qualify for a priority, an action must meet all the conditions marked for the priority.
[2]Examples of "prevent significant decline": Prevent loss of one or more year classes; prevent abundance from falling below the depensation threshold; prevent direct mortality of coho salmon; make habitat available which is necessary for population to build above depensation threshold; prevent loss of a critical life-history requirement (e.g., summer rearing habitat, migratory habitat); and prevent the loss of occupied habitat.
[3] "Benefit" means the action will significantly improve likelihood of survival of coho salmon. Improvement in likelihood in survival may occur at any life-history stage (e.g., increased growth leads to fish being larger when enters ocean, improving likelihood of survival in ocean).
[4] "Immediately" means coho salmon from the subject population will benefit from the action within three years of completing the action. Three years accounts for all three year classes of coho salmon.

Table 6-4. Prioritization system for Dependent and Non-Core 2 populations.

| | Condition | Priority[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2b | 2c | 2d | 3b | 3c | 3d | BR |
| 1 | Action needed to prevent significant decline[2] in habitat or population in any population. | x | x | x | | | | |
| 2 | Action needed to achieve recovery of the ESU but does not meet Criterion 1. | | | | x | x | x | |
| 3 | Action addresses key limiting stress or threat OR benefits[3] coho salmon immediately[4]. | | x | | | x | | |
| 4 | Action addresses key limiting stress or threat AND benefits[3] coho immediately[4]. | x | | | x | | | |
| 5 | Action not needed to achieve ESA recovery but would contribute to broad-sense recovery goals (BR). | | | | | | | x |

[1]To qualify for a given priority, an action must meet all the conditions marked for that priority.
[2]Examples of "prevent significant decline": Prevent loss of one or more year classes; prevent abundance from falling below the depensation threshold; prevent direct take of coho salmon; make habitat available which is necessary for population to build above depensation threshold; prevent loss of a critical life-history requirement (e.g., summer rearing habitat, migratory habitat); and prevent the loss of occupied habitat.
[3] "Benefit" means the action will significantly improve likelihood of survival of coho salmon. Improvement in likelihood in survival may occur at any life-history stage (e.g., increased growth leads to fish being larger when enters ocean, improving likelihood of survival in ocean).
[4] "Immediately" means coho salmon from the subject population will benefit from the action within three years of completing the action. Three years accounts for all three year classes of coho salmon.

## 6.8 Time to Achieve Phase I of Recovery for Any Population

In order for a population to be at moderate (not high) risk of extinction, it needs to consistently support more adults than the depensation threshold – usually in the tens to hundreds of adults, depending on the size of the population area. Phase I of recovery for independent populations, is to prevent extinction (Section 6.1) by rebuilding to above the depensation threshold and so achieve a moderate risk of extinction. Recovery actions which increase the amount of summer or winter rearing habitat by adding in-channel structure or off-channel ponds, or by ensuring enough water remains in the river in the summer months, can be effective almost immediately in increasing production and survival of the juveniles which will come back as adults. Barrier removal can provide access to dozens of kilometers of habitat in very little time. When these types of actions are implemented, fish response can be very rapid. Phase I of recovery, could therefore be accomplished in less than 10 years in some cases. The priority NMFS has assigned to each recovery action, which is described in Section 6.7, helps conservation partners identify which actions would most benefit coho salmon, either by benefiting them immediately or by addressing the key limiting stresses or key limiting threats which are causing bottlenecks in a population. If conservation partners focus on implementing the highest priority recovery actions, they have the greatest likelihood of helping the population avoid extinction by building to a level above the depensation threshold.

## 6.9 Time to Achieve Phase II of Recovery for All Populations

The minimum time to recover all populations in the SONCC coho salmon ESU and delist the species is determined by the following: 1) the time to complete all recovery actions, 2) the time for the habitat to respond to the recovery actions, 3) the time for the salmon populations to respond to the habitat improvements by attaining target levels; and 4) continued attainment of recovery criteria objectives described in Chapter 4 (i.e., population recovery targets, habitat condition) for at least 12 years (the time needed for determination of status of population (Williams et al. 2011) (Table 4-1).

Most actions consist of multiple steps and require time for planning and implementation; therefore, under ideal circumstances (e.g., assuming unlimited funding for recovery actions, planning is comprehensive and fast, and implementation is unimpeded) all actions could be completed in ten years. The environmental response to those actions will take in some cases many additional years. Actions such as increasing stream flows will result in an immediate positive benefit for coho salmon. However, other actions such as those associated with tree planting and the maturation of a riparian forest may take up to 80 years to reach the desired condition (Beschta et al. 1987, Keeton et al. 2007, Meleason et al. 2002). Because all recovery actions are necessary for the recovery of the species, and assuming actions will be implemented within ten years, 90 years will be the minimum time required for the improvement of environmental conditions necessary to rebuild coho populations and meet recovery criteria.

Coho salmon populations will likely start to recover immediately as a result of recovery action implementation. However, because that habitat is not expected to be fully recovered until 90 years have passed, and that habitat is expected to be needed to support target population sizes, the population targets cannot be fully realized until after that time. It is expected that another four generations (12 years) must pass before the population can build to a level consistent with final recovery after the habitat is fully restored (Bryant et al. 1999, Kiffney et al. 2007, Pess et al. 2008). At approximately year 102, populations may reach levels of viability. The final monitoring phase will take a minimum of 12 years (Williams et al. 2008; Table 4-1), resulting in delisting as early as year 114 if all recovery criteria are met and maintained during that final phase of monitoring.

The assumption that all recovery actions will be implemented within the first 10 years is likely unrealistic due to available funding, but it is used as a basis for recovery under ideal circumstances. If the actions are not completely implemented until year 30, delisting may not occur until year 134. Other assumptions used for this estimate may also be unrealistic. The time to recovery may be many times greater if any of the following occurs: 1) freshwater habitat conditions degrade further, 2) poor ocean conditions limit adult population size, 3) populations continue to decline, 4) recovery actions are not implemented immediately, or 5) adequate monitoring has not occurred to document improved conditions and populations.

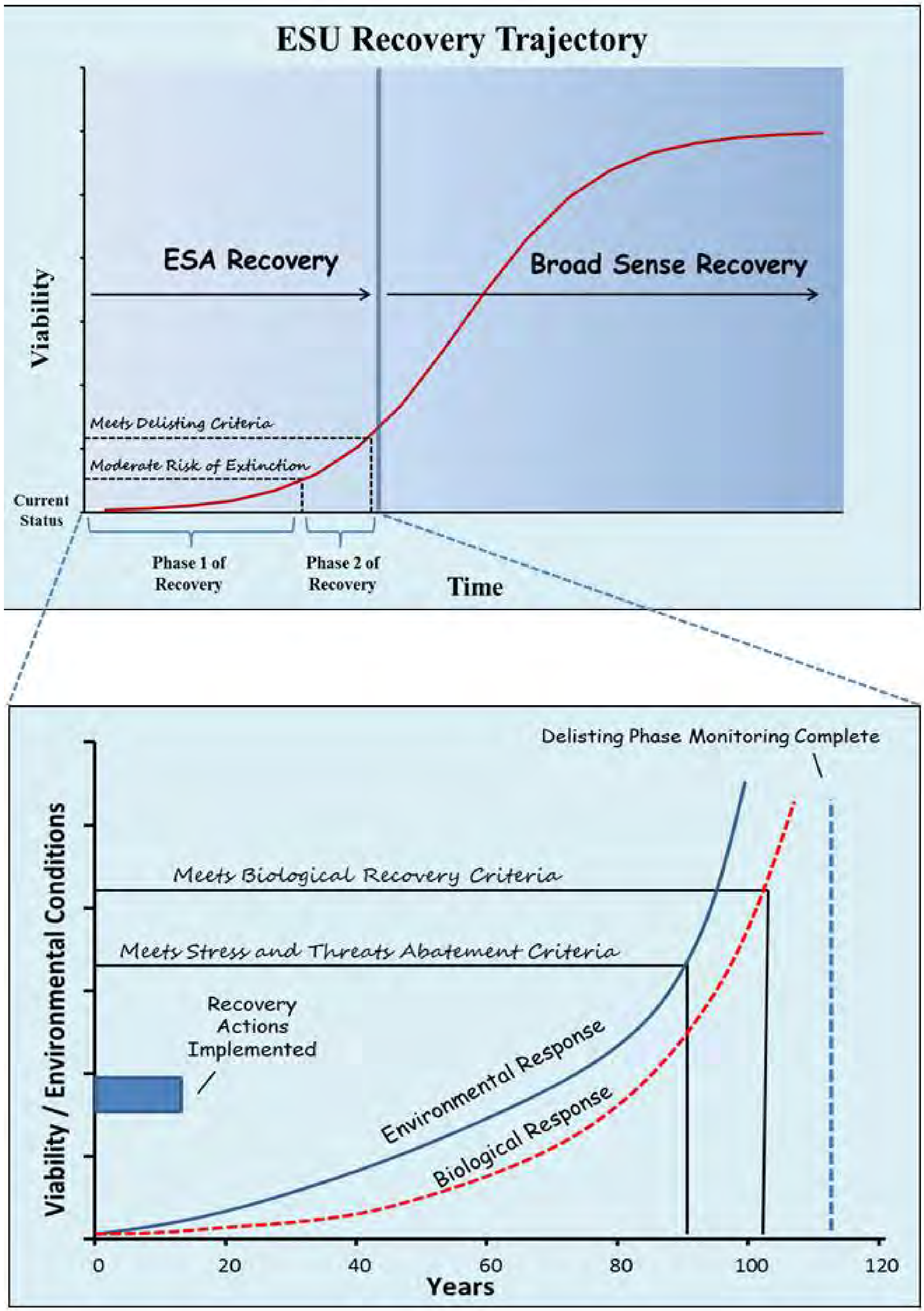



Figure 6-2. Minimum time to recovery displayed in context of long term trajectory and immediate goals.

## 6.10 Tracking Recovery

NMFS will track implementation of SONCC coho salmon recovery actions using an online database and associated mapping tool. This database and mapping tool, which is currently in final development, will track the implementation of recovery actions for Pacific salmon and steelhead listed under the Endangered Species Act. It is a web application that provides the following functions:

- Maps actions in a Geographic Information System (GIS);
- Tracks recovery action implementation;
- Fulfills NMFS' reporting requirements, specifically related to the Government Performance and Results Act; and
- Enables the public and stakeholders to access real-time data on recovery actions via an interactive web tool.

The Recovery Action Mapping Tool will be available here: www.westcoast.fisheries.noaa.gov/

### 6.10.1 Review of Recovery Progress

NMFS will regularly review the recovery actions accomplished and actions still in need of implementation, in order to track implementation status and identify any additional recovery needs. NMFS is required to review the status of listed species at least once every five years (ESA Section 4(c)(2)(A)). As part of each status review, NMFS will compare the status of the ESU, stresses, and threats to the delisting criteria. All available monitoring data will be used to determine the status of the ESU, describe progress made toward delisting, and identify any needed changes to the recovery program.

## 6.11 Changing the Recovery Plan

The recovery plan may be changed at any time. There are three types of plan modifications: update, revision, and addendum.

### 6.11.1 Update

An update to a recovery plan involves relatively minor changes. An update may identify specific actions that have been initiated since the plan was completed, as well as changes in species status or background information that do not alter the overall direction of the recovery effort. An update cannot suffice if substantive changes are made in the recovery criteria or if any changes in the recovery strategy, criteria, or recovery actions indicate a shift in the overall direction of planned recovery. In this case, a revision would be required.

### 6.11.2 Addendum

An addendum can be added to a plan after a recovery plan has been finalized. Types of addenda can range from implementation strategies or participation plans, to minor information updates. Addenda that represent significant additions to the recovery plan should undergo public review and comment before being attached to the recovery plan. An example of a significant addendum is one that adds a species to a plan.

### 6.11.3 Revision

A revision is a substantial rewrite of at least a portion of a recovery plan and is usually required if major changes are required in the recovery strategy, objectives, criteria, or actions. A revision may be required when new threats to the species are identified, when research identifies new life-history traits or threats that have significant recovery ramifications, or when the current plan is not achieving its objectives.

#### Notification, Review, and Approval of Plan Modifications

Updates to recovery plans and minor addenda represent minor changes and do not require formal public comment. These changes will be made to the latest recovery plan posted on NMFS regional and national internet sites.

Because plan revisions represent a significant change to the recovery plan, they go through the same review and clearance procedures as a draft and final recovery plan. If plan revisions or major addenda are planned, NMFS will publish a Federal Register Notice of Intent at the beginning of the process. This Notice will solicit data, provide information about public review and comment, and state the purpose of the revision.

## 6.12 How to Recommend Changes to the Recovery Plan

NMFS will accept suggestions for changes to the plan, or new information to be considered in the plan, at any time. Such changes or information can be provided by emailing the following address: SONCC.recovery@noaa.gov.

This page intentionally left blank.

## Literature Cited for Chapters 1 to 6


Abbott, J. C., R. L. Dunbrack, and C. D. Orr. 1985. The interaction of size and experience in dominance relationships of juvenile steelhead trout (*Salmo gairdneri*). Behaviour 92:241–253.

Ackerman, N.K. and S. Cramer. 2006. Simulating Fall Redistribution and Overwinter Survival of Klamath River Coho – Review Draft. Technical Memorandum #2 of 8. Klamath Coho Integrated Modeling Framework Technical Memorandum Series. Submitted to the Bureau of Reclamation Klamath Basin Area Office on November 22, 2006.

Ackerman, N.K., B. Pyper, S. Cramer, and I. Courter. 2006. Estimation of Returns of Naturally Produced Coho to the Klamath River – Review Draft Technical Memorandum #1 of 8 Klamath Coho Integrated Modeling Framework Technical Memorandum Series.

Adams, P.B., L.B. Boydstun, S.P. Gallagher, M.K. Lacy, T. McDonald, and K.E. Shaffer. 2011. California coastal salmonid population monitoring: Strategy, design, and methods. Fish Bulletin 180. State of California, The Natural Resources Agency, Department of Fish and Game. 80 p.

Ad Hoc Supplementation Monitoring and Evaluation Workgroup (AHSWG). Recommendations for broad scale monitoring to evaluate the effects of hatchery supplementation on the fitness of natural salmon and steelhead populations. Final Report of the Ad Hoc Supplementation Monitoring and Evaluation Workgroup (AHSWG). October 9, 2008. 82 p.

Agee, J. K. 1998. The landscape ecology of western forest fire regimes. Northwest Science, 72(17), 24-34.

Agrawal, A., R. Schick, E. Bjorkstedt, R.G. Szerlong, M. Goslin, B. Spence, T. Williams, and K. Burnett. 2005. Predicting the potential for historical coho, Chinook and steelhead habitat in northern California. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-379.

Aitken J.K. 1998. The importance of estuarine habitats to anadromous salmonids of the Pacific Northwest: a literature review. US Fish and Wildlife Service, Lacey, WA.

Al-Humaidhi, A.W., M.A. Bellman, J. Jannot, and J. Majewski. 2012. Observed and estimated total bycatch of salmon in the 2002-2010 U.S. west coast fisheries. West Coast Groundfish Observer Program. National Marine Fisheries Service, NWFSC, 2725 Montlake Blvd. E, Seattle, WA 98112.

Allee, W.C. 1938. The Social Life of Animals. AMS Press, New York. 1976 reprint of 1938 edition, originally published by Norton, New York.

Allen, D.M. 2008. Development and application of a process-based, basin-scale stream temperature model. Ph.D. dissertation, University of California, Berkeley. 168 pp. Available from: http://www.stillwatersci.com/resources/2008allen.pdf.

Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11:140-152.

Anderson J. 2008. Wood Creek Tidal Marsh Design Report for the Wood Creek Tidal Marsh Enhancement Project. Prepared for the Northcoast Regional Land Trust by Jeff Anderson & Associates, Arcata, CA. Available from: http://naturalresourcesservices.org/assets/files/FINAL_Wood_Creek_Tidal_Marsh_Design_Report.pdf

Andonaegui, C. 2000. Salmon, steelhead and bull trout habitat limiting factors. Water Resource Inventory Area 48. Washington State Conservation Commission, Olympia, Washington.

Araki, H., W.R. Ardren, E. Olsen, B. Cooper, and M.S. Blouin. 2007a. Reproductive success of captive-bred steelhead trout in the wild: evaluation of three hatchery programs in the Hood River. Conservation Biology **21**: 181–190. doi:10.1111/j.1523-1739. 2006.00564.x. PMID:17298524.

Araki, H., B. Cooper, and M.S. Blouin. 2007b. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science (Washington, D.C.) 318: 100–103. doi:10.1126/ science.1145621. PMID:17916734.

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery-reared salmonids in the wild. Evolutionary Applications 1: 342–355. doi: 10.1111/j.1752-4571.2008.00026.x

Araki, H., B. Cooper and M.S. Blouin. 2009. Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild. Biological Letters 5: 621-624.

Araki, H., and C. Schmidt. 2010. Is hatchery stocking a help or harm? Evidence, limitations and future directions in ecological and genetic surveys. Aquaculture 308:S2–S11.

Arauho, H. A. 2011. Population responses of coho and Chinook salmon to sedimentation associated with forest roads in a coastal watershed of the Lower Fraser River. Master's thesis, Simon Fraser University, British Columbia, Canada.

Armentrout, S., H. Brown, S. Chappell, M. Everett-Brown, J. Fites, J. Forbes, M. McFarland, J. Riley, K. Roby, A. Villalovos, R. Walden, D. Watts, and M.R. Williams. 1998. Watershed Analysis for Mill, Deer, and Antelope Creeks. U.S. Department of Agriculture. Lassen National Forest. Almanor Ranger District. Chester, CA. 299 pp.

Asarian, E. 2014. Assessment of altered hydrologic function, dams, and diversions within the Southern Oregon/Northern California Coast evolutionarily significant unit of coho salmon. Prepared for the NOAA Fisheries, Arcata Office. 72 p. plus appendices.

Atwood, K., and D. J. Gray. 2002. As long as the world goes around: the land and people of southwestern Oregon. The Oregon History Project, Oregon Historical Society Accessed on 26 April 2008.

Au, D.W.K. 1972. Population dynamics of the coho salmon and its response to logging in three coastal streams. Doctoral dissertation. Oregon State University, Corvallis.

Barnett, T. P., D. W. Pierce, K. M. AchutaRao, P. J. Gleckler, B. D. Santer, J. M. Gregory, and W. M. Washington. 2005. Penetration of human-induced warming into the world's oceans. Science 309:284-287.

Barr, B.R., M.E. Koopman, C.D. Williams, S. Vynne, R. Hamilton, and B. Doppelt. 2010. Preparing for Climate Change in the Klamath Basin. National Center for Conservation Science and Policy and The Climate Leadership Initiative. 36 pp Available from: https://scholarsbank.uoregon.edu/xmlui/handle/1794/10722

Barrowman, N.J., R.A. Myers, R. Hilborn, D.G. Kehler, and C.A. Field. 2003. The variability among populations of coho salmon in the maximum reproductive rate and depensation. Ecological Applications 13(3): 784-793.

Bartholomew, J.L. 2008. *Ceratomyxa shasta* 2007 Study summary, Oregon State University Final Report to Bureau of Reclamation http://www.fws.gov/arcata/fisheries/projectupdates.html

Bartholomew, J.L. 2012. Annual Report. Fiscal year 2012, 2011 supplement. Long-term fish disease monitoring program in the lower Klamath River. Oregon State University.

Bartholomew, J. L., Atkinson, S. D. and Hallett, S. L. 2006. Involvement of *Manayunkia speciosa* (Annelida: Polychaeta: Sabellidae) in the life cycle of *Parvicapsula minibicornis*, a myxozoan parasite of Pacific salmon. *Journal of Parasitology*. 92:742-748.

Bartholomew, J.L., H.V. Lorz, S.A. Sollid and D.G. Stevens. 2003. Susceptibility of juvenile and yearling bull trout to *Myxobolus cerebralis*, and effects of sustained parasite challenges. Journal of Aquatic Animal Health.15:248-255.

Bartholow, J.M. 2005. Recent water temperature trends in the Lower Klamath River, CA. N. American Journal of Fisheries Management. 25:152-162.

Bartley, D.M., B. Bentley, P.G. Olin, and G.A.E. Gall. 1992. Population genetic structure of coho salmon (*Oncorhynchus kisutch*). California Department of Fish and Game 78:88–104.

Bash, J., C. Berman, and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Center for Streamside Studies, University of Washington. 74 pages.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences 104:6720–6725

Bauer, S. 2013a. Personal communication. California Department of Fish and Wildlife, Eureka, California. January 17.

Bauer, S. 2013b. Personal communication. California Department of Fish and Wildlife, Eureka, California. February 5.

Beacham, T.D. 1982. Fecundity of coho salmon (*Oncorhynchus kisutch*) and chum salmon (*O. keta*) in the northeast Pacific Ocean. Can. J. Zool. 60:1463- 1469.

Beamish, R.J., C. Neville, and A.J. Cass. 1997a. Production of Fraser River sockeye salmon (*Oncorhynchus nerka*) in relation to decadal-scale changes in the climate and the ocean. Canadian Journal of Fisheries and Aquatic Sciences 54: 543-554.

Beamish R.J., C. Mahnken, and C.M. Neville. 1997b. Hatchery and wild production of Pacific salmon in relation to large-scale, natural shifts in the productivity of the marine environment. ICES Journal of Marine Science 54:1200–1215.

Beamish R.J., D.J. Noakes, G.A. McFarlane, L. Klyashtorin, V.V. Ivanov, and V. Kurashov. 1999. The regime concept and natural trends in the production of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 56:516-526

Beamish, R. J., D. J. Noakes, G. A. McFarlane, W. Pinnix, R. Sweeting, and J. King. 2000. Trends in coho marine survival in relation to the regime concept. Fisheries Oceanography 9:114-119.

Beamish, R.J., C. Mahnken, and C.M. Neville. (2004) Evidence that reduced early marine growth is associated with lower marine survival of Coho salmon. *Transactions of the American Fisheries Society*,133, 26-33.

Beamish, R.J. and C. Mahnken. 2001. A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change, *Progress in Oceanography* 49 pp. 423–437.

Beamish, R. J., Noakes, D. J., McFarlane, G. A., Pinnix, W., Sweeting, R., & King, J. 2000. Trends in coho marine survival in relation to the regime concept. Fisheries Oceanography, 9(1), 114-119.

Beecher H.A., B.A. Caldwell, S.B. DeMond, D. Seiler, and S.N. Boessow. 2010. An Empirical Assessment of PHABSIM Using Long-Term Monitoring of Coho Salmon Smolt

Production in Bingham Creek, Washington. North American Journal of Fisheries Management 30: 1529–1543.

Beechie, T., G. R. Pess, P. Kennard, R. Bilby, and S. Bolton. 2000. Modeling Recovery Rates and Pathways for Woody Debris Recruitment in Northwestern Washington Streams. North American Journal of Fisheries Management **20**:436-452.

Beechie T.J., D.A. Sear, J.D. Olden, G.R. Pess, J.M. Buffington, H. Moir, P. Roni, and M.M. Pollock. 2010. Process-Based Principles for Restoring River Ecosystems. BioScience 60: 209–222.

Beechie, T.J., E.A. Steel, P. Roni, and E. Quimby (editors). 2003. Ecosystem recovery planning for listed salmon: an integrated assessment approach for salmon habitat. U.S. Department of Commerce, NOAA Technical memorandum. NMFS-NWFSC-58. 183p.

Beechie T, Imaki H, Greene J, Wade A, Wu H, Pess G, Roni P, Kimball J, Stanford J, Kiffney P. 2012. Restoring salmon habitat for a changing climate. River Research and Applications. doi: 10.1002/rra.2590

Bell, E. and W.G. Duffy. 2007. Previously undocumented two-year freshwater residency of juvenile coho salmon in Prairie Creek, California. Transactions of the American Fisheries Society 136: 966-970.

Bellows, B.C. 2003. Managed Grazing in Riparian Areas. Appropriate technology Transfer for Rural Areas (ATTRA). 28 Pp

Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54(1): 419-431.

Benda, L. and P. Bigelow. 2014. On the patterns and processes of wood in northern California streams. Geomorphology 209: 79-97.

Benda, L., D. Miller, P. Bigelow, K. Andrus. 2003. Effects of post-fire erosion on channel environments, Boise River, Idaho. Forest Ecology and Management 178:105-119.

Bennett, T. R., P. Roni, K. Denton, M. McHenry, and R. Moses. 2014. Nomads no more: early juveniles coho salmon migrants contribute to the adult return. Ecology of Freshwater Fish. doi: 10.1111/eff.12144.

Bennett, T. R., R. C. Wissmar, and P. Roni. 2011. Fall and spring emigration timing of juvenile coho salmon from the East Twin River, Washington. Northwest Science 85: 562–570.

Benson, K. 2010. Personal communication. Biologist. Redwood National and State Parks.

Berejikian, B. A. 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (*Oncorhynchus mykiss*) to avoid a benthic predator. Canadian Journal of Fisheries and Aquatic Sciences 52: 2476-2482.

Berejikian, B.A., Mathews, S.B., and Quinn, T.P. 1996. The effects of hatchery and wild ancestry on the development of agonistic behavior in steelhead trout fry (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences. **53**: 2004–2014.

Berg, L. 1982. The effect of exposure to short-term pulses of suspended sediment on the behavior of juvenile salmonids. P. 177-196 in G.F. Hartman et al. [eds.] Proceedings of the Carnation Creek workshop: a ten-year review. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, Canada.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill- flaring, and feeding behaviour in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Berggren, T. J. and M. J. Filardo. 1993. An analysis of variables influencing the migration of juvenile salmonids in the Columbia River basin. North American Journal of Fisheries Management 13:48-63.

Beschta, R. L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Streamside Management: Forestry and Fishery Interactions 57: 191-232.

Beschta, R. L., & Taylor, R. L. 1988. Stream temperature increases and land use in a forested watershed. JAWRA Journal of American Water Resources Association. 24(1), 19-25.

Bi, H., Peterson, W.T., Lamb, J. and Casillas, E. (2011) Copepods and salmon: characterizing the spatial distribution of juvenile salmon along the Washington and Oregon coast, U.S.A. Fisheries Oceanography, 20: 125-138.

Bilby, R.E., B.R. Fransen, and P.A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: Evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53: 164–73.

Bilby, R.E., B.R. Fransen, J.K. Walter, C.J. Cederholm, and W.J. Scarlett. 2001. Preliminary evaluation of the use of nitrogen stable isotope ratios to establish escapement levels for Pacific salmon. Fisheries 26: 6–14.

Bilton, H. T. , D. F. Alderdice, and J. T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity. Canadian Journal of Fisheries and Aquatic Sciences 39: 426-447.

Bilton, H. T., R. B. Morley, A. S. Colburn, and J. Van Tyne. 1984. The influence of time and size and release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity and results from releases from Quinsam River Hatchery, B,C,, in 1980. Canadian Technical Report of Fisheries and Aquatic Sciences 1306: 1-98.

Birtwell, I.K. 1999. The effects of sediment on fish and their habitat. Canadian Stock Assessment Secretariat Research Document 99/139,West Vancouver, British Columbia.

Bisson, P.A., B.E Rieman, C. Luce, P.F. Hessburg, D.C. Lee, J.F. Kershner, G.H. Reeves, and R.E. Gresswell. 2003. Fire and aquatic ecosystems of the western USA: current knowledge and key questions. Forest Ecology and Management 178:213-229.

Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 4: 371-374.

Bisson, P.A., Reeves, G.H., Bilby, R.E., Naiman, R.J. 1997. Watershed management and Pacific salmon: desired future conditions. In: Stouder, D.J., Bisson, P.A., Naiman, R.J. (Eds.), Pacific Salmon and their Ecosystems: Status and Future Options. Chapman & Hall, New York, pp. 447– 474.

Bisson, P.A. and S.M. Wondzell. 2009. Olympic Experimental State Forest Synthesis of Riparian Research and Monitoring. 63 p.

Bjorkstedt, E.P, B.C. Spence, J.C. Garza, D.G. Hankin, D. Fuller, W.E. Jones, J.J. Smith, and R. Macedo. 2005. An analysis of historic population structure for evolutionarily significant units of Chinook salmon, coho salmon, and steelhead in the North-Central California Coast recovery domain. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-382. 231 p.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. In: Meehan, W.R. Influences of forest and rangeland management of salmonid fishes and their habitats. Bethesda, MD: American Fisheries Society: 83-138.

Blanchard, T. 2002. Draft 2002 technical report AQU 16: Summary of information available to assess potential aquatic species interactions in the Lewis River Basin. PacifiCorp/Cowlitz PUD Lewis River Hydroelectric Projects. FERC Project Nos. 935, 2071, 2111, and 2213.

Blanchet, S., G. Loot, L. Bernatchez, and J.J. Dodson. 2007. The disruption of dominance hierarchies by a non-native species: an individual based analysis. Oecologia 152:569–581

Bliesner, A., D. Halligan, M. Miles, and K. Sullivan. 2006. Bear River watershed analysis. Fish habitat assessment. Appendix E. HCP Signatory Review Team Draft. June 21.106p.

Booth, D.B and C.R. Jackson. 1997. Urbanization of Aquatic Systems--Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation. Journal of the American Water Res. Assoc. 22(5). 20 p.

Booth, D.B., B. Visitacion and A.C. Steinemann. 2006. Damages and Costs of Stormwater Runoff in the Puget Sound Region. Project sponsored by the Puget Sound Action Team and the WA Governor's Office. The Water Center, Department of Civil and Environmental Engineering, University of Washington, Seattle, WA. 42 p.

Botkin, D.B., K. Cummins, T. Dunne, H. Regier, M. J. Sobel, and L. M. Talbot. 1995. Status and Future of Anadromous Fish of Western Oregon and Northern California: Findings and Options, Center for the Study of the Environment, Santa Barbara, CA.

Bottom, D.L., T.E. Nickelson, and Johnson, S.L. 1986. Research and development of Oregon's coastal salmon stocks. Oregon Department of Fish and Wildlife, Fishery Research Project NA-85-ABD-00111. Annual Progress Report, Portland, OR.

Bottom, D., C. Simenstad, J. Burke, A. Baptista, D. Jay, K. Jone, E. Casillas, and M. Schiewe. 2005. Salmon at River's End: the Role of the Estuary in the Decline and Recovery of Columbia River Salmon. U.S. Department of Commerce, NOAA Tech Memo. NMFS-NWFSC-68, 246 p.

Bottom, D., K. Jones, C. Simenstad, and C. Smith. 2009. Reconnecting Social and Ecological Resilience in Salmon Ecosystems. Ecology and Society 14(1):5.

Bourque, R. 2013. Personal Communication. Aquatic Monitoring Supervisor. Green Diamond Resource Company. Korbel, CA.

Bowen, J.L., and I. Valiela. 2001. The ecological effects of urbanization of coastal watersheds: Historical increases in nitrogen loads and eutrophication of Waquoit Bay estuaries. Canadian Journal of Fisheries and Aquatic Sciences 58:1489-1500.

Bowers, J. 2013. Oregon Fish Habitat Distribution - Current and Historical Coho. Natural Resources Information Management Program. Oregon Department of Fish and Wildlife. Portland, OR.

Boydstun, L.B. and T. McDonald (Editors). 2005. Actions plan for monitoring California's coastal salmonids. Report for NOAA Fisheries Santa Cruz Laboratory, Contract number WASC-3-1295. 68 pp plus appendices.

Bradford, M. J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences 52:1327-1338.Bradford, M. J., R.A. Myers, & J.R. Irvine. 2000. Reference points for coho salmon (Oncorhynchus kisutch) harvest rates and escapement goals based on freshwater production. Canadian Journal of Fisheries and Aquatic Sciences, 57(4), 677-686.

Brannon, E. L., M. S. Powell, T. P. Quinn, and A. Talbot. 2004. Population structure of Columbia River Basin chinook salmon and steelhead trout. Reviews in Fisheries Science 12:99-232.

Branton, M. 2011. Can conservation strategies for a single species be used to inform and guide restoration of ecological structure and function in floodplain ponds? Doctor of Philosophy in the Faculty of Graduate Studies (Forestry), University of British Columbia. Vancouver. 233 p.

Briggs, J. C. 1953. The behavior and reproduction of salmonid fishes in a coastal stream. Fish Bulletin 94. California Department of Fish and Game.

Brodeur, R.D., J.P. Fisher, D.J. Teel, R.L. Emmett, E. Casillas, and T.W. Miller. 2004. Juvenile salmonid distribution, growth, condition, origin, and environmental and species associations in the Northern California Current. Fisheries Bulletin 102: 25-46.

Brown, T. G., & G. F. Hartman. 1988. Contribution of seasonally flooded lands and minor tributaries to the production of coho salmon in Carnation Creek, British Columbia. Transactions of the American Fisheries Society, 117(6), 546-551.

Brown, A.V., M.M. Lyttle, and K.B. Brown. 1998. Impacts of gravel mining on gravel bed streams. Transactions of the American Fisheries Society 127: 979-994.

Brown, J.S. 1999. Vigilance, patch use and habitat selection: Foraging under predation risk. Evolutionary Ecology Research 1:49-71.

Brown, P.M. 2007. What Was the Role of Fire in Coast Redwood Forests? In: Proceedings of the Redwood Region Forest Science Symposium. 15-17 March 2004. P. 215

Brown, G.W. and J.T. Krygier. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resources Research 7(5): 1189-1198.

Brown, A.V., M.M. Lyttle, and K.B. Brown. 1998. Impacts of Gravel Mining on Gravel Bed Streams. Transactions of the American Fisheries Society 127(6): 981-996.

Brown, L.R. and P.B. Moyle. 1991. Eel River survey: final report. Report to California Department of Fish and Game, Contract: F-46-R-2.

Brown, L.R., and P.B. Moyle. 1994. Distribution, ecology, and status of the fishes of the San Joaquin River drainage, California. California Fish and Game, 79: 96-1 14.

Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical Decline and Current Status of Coho Salmon in California. North American Journal of Fisheries Management 14(2): 237-261.

Brown, R.F. and B.R. Mate. 1983. Abundance, movements and feeding habits of harbor seals *(Phoca vitulina)* at Netarts and Tillamook bays, Oregon. NOAA Fishery Bulletin 81(2): 291–301.

Bryant, M. D., B. J. Frenette, and S. J. McCurdy. 1999. Colonization of a watershed by anadromous salmonids following the installation of a fish ladder in Margaret Creek, southeast Alaska. North American Journal of Fisheries Management 19:1129-1136

Buffington J.M., T.E. Lisle, R.D. Woodsmith, S. Hilton. 2002. Controls on the size and occurrence of pools in coarse‐grained forest rivers. River Research and Applications 18:507-531.

Bugert R.M. and T.C. Bjornn. 1991. Habitat Use by Steelhead and Coho Salmon and Their Responses to Predators and Cover in Laboratory Streams, Trans. Amer. Fish. Soc. 120: 486-493.

Burke, M., K. Jorde, & J.M. Buffington. 2009. Application of a hierarchical framework for assessing environmental impacts of dam operation: changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. Journal of environmental management, 90, S224-S236.

Burnett, K., G. Reeves, D. Miller, S. Clarke, K. Christiansen, and K. Vance-Borland. 2003. A first step toward broad-scale identification of freshwater protected areas for Pacific salmon and trout in Oregon, USA. Pages 144-154 in J. P. Beumer, A. Grant, and D. C. Smith, editors. Aquatic protected areas: what works best and how do we know? Proceedings of the World Congress on Aquatic Protected Areas, Cairns, Australia, August 2002.

Burnett, K.M., G.H. Reeves, D.J. Miller, S. Clarke, K. Vance-Borland, and K. Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications 17(1): 66-80.

Bustard, D. R., & Narver, D. W. (1975). Preferences of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Board of Canada, 32(5), 681-687.

Čada, C. F., M. D. Deacon, S. V. Mitz, and M. S. Bevelhimer. 1997. Effects of water velocity on the survival of downstream-migrating juvenile salmon and steelhead: A review with emphasis on the Columbia river basin. Reviews in Fisheries Science 5(2): 131-183.

Cafferata P. and L. Reid. 2013. Applications of Long-Term Watershed Research to Forest Management in California: 50 Years of Learning from the Caspar Creek Experimental Watersheds. California Department of Forestry & Fire Protection, Sacramento, CA. 110p.

CALFIRE. 2013. California Forest Practice Rules. Title 14, California Code of Regulations Chapters 4, 4.5, and 10, with the Z'berg-Nejedly Forest Practice Act; pertinent excerpts from Protection of Forest, Range, and Forage Lands-Prohibited Activities and the Wild and Scenic Rivers Act; the Professional Foresters Law and Registration of Professional Foresters Rules, and with information related to Forest Roadbed Materials. Prepared for: California Licensed Timber Operators and California Registered Professional Foresters. Compiled by: The California Department of Forestry and Fire Protection, Resource Management, Forest Practice Program, P.O. Box 944246, Sacramento, CA 94244-2460. 356 p. Downloaded from http:\\www.fire.ca.gov on 3/11/14.

CalFish. 2009. California Fish Passage Assessment Database (CFPAD). State-wide inventory of known and potential barriers to fish passage. Accessed 9/30/2009 from:http://www.calfish.org/ProgramsandProjects/FishPassageAssessment/tabid/97/Default.aspxNMFS-NWFSC-27, 261 p

California Advisory Committee on Salmon and Steelhead Trout. 1988. Restoring the balance. 1988 Annual Report. A report to the Legislature and the Department of Fish and Game. 84 pp.

California Department of Fish and Game (CDFG). 1994. Petition to the Board of Forestry to list coho salmon (*Oncorhynchus kisutch*) as a sensitive species. Redding, CA. 109p.

California Department of Fish and Game (CDFG). 1997. A Biological Needs Assessment for Anadromous Fish in the Shasta River Siskiyou County, California. Northern California-North Coast Region. Redding, CA. 29p.

California Department of Fish and Game (CDFG). 2002a. Status review of California coho salmon north of San Francisco. Report to the California Fish and Game Commission. Candidate Species Status Review Report 2002-3.

California Department of Fish and Game (CDFG). 2002b. Department of Fish and Game Annual Report: Shasta and Shasta River Juvenile Salmonid Outmigration Study, 2003. Northern California, North Coast Region.

California Department of Fish and Game (CDFG). 2004a. Recovery strategy for California coho salmon. Report to the California Fish and Game Commission. 594pp. Copies/CD available upon request from California Department of Fish and Game, Native Anadromous Fish and Watershed Branch, 1419 9th Street, Sacramento, CA 95814, or on-line: http:www.dfg.ca.gov/fish/Resources/Coho/SAL_CohoRecoveryRpt.asp

California Department of Fish and Game (CDFG). 2004b. September 2002 Klamath River fish-kill: final analysis of contributing factors and impacts. July.

California Department of Fish and Game (CDFG). 2009. Trinity River Basin Salmon and Steelhead Monitoring Project 2005-2006 Season. Northern California-North Coast Region, Redding, California.

California Department of Fish and Game (CDFG). 2010. California salmonid stream habitat restoration manual. State of California Resources Agency. Fourth Edition.

California Department of Fish and Game (CDFG). 2011. Freshwater Sport Fishing Regulations. Effective March 1, 2011 through February 29, 2012. 75 p.

California Department of Fish and Game (CDFG). 2012. A "Growing" Issue. Environmental Impacts of Medical Marijuana in Northern California. Draft Briefing. July.

California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS). 2001. Joint Hatchery Review Committee final report on anadromous salmonid fish hatcheries in California. 93 p.

California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS). 2002. Guidelines for maintaining instream flows to protect fisheries resources downstream of water diversions in mid-California coastal streams. June 17.

California Department of Fish and Wildlife. 2013. Hatchery and Genetic Management Plan for Mad River Hatchery Winter-Run Steelhead. Co-Manager Draft Review Copy.

California Division of Water Rights (CDWR). 2001. *A Guide to California Water Right Appropriations*. State of California.

California Environmental Protection Agency (CEPA). 2011. State Water Resources Control Board, Division of Water Rights, Website. http://www.waterboards.ca.gov/waterrights/

California State Lands Commission. 1993. California's rivers-A public trust report. Second Edition. Sacramento, California.

Campton, D. E. 1995. Genetic effects of hatchery fish on wild populations of Pacific salmon and steelhead: What do we really know? Pp. 337–353 in H. L. Schramm Jr. and R. G. Piper (Eds.), American Fisheries Society, Bethesda, MD.

Cannata, S., R. Henly, J. Erler, J. Falls, D. McGuire and J. Sunahara. 2006. Redwood Creek watershed assessment report. Coastal Watershed Planning and Assessment Program and North Coast Watershed Assessment Program. California Resources Agency and California Environmental Protection Agency, Sacramento, California.

Carrasco, K. 2000. Coho pre-spawn mortalities in a flooded reed canary grass habitat. Reed Canary grass Working Group Conference, Washington State Department of Transportation, USDA Natural Resources Conservation Service, and Society for Ecological Restoration – Northwest Chapter, March 15, 2000, Olympia, Washington.

Carter, K. 2005. The effects of dissolved oxygen on steelhead trout, coho salmon, and Chinook salmon biology and function by life stage. Prepared as staff to the California Regional Water Quality Control Board, North Coast Region.

Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63(2): 215-244.

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2010. Climate Change Scenarios and Sea Level Rise Estimates for the California 2009 Climate Change Scenarios Assessment. PEIR Report CEC-500-2009-014-F. 64 p.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations of the Clearwater River, Jefferson County, Washington. Pages 38-74 in Proceedings of Conference on Salmon Spawning Gravel: A Renewable Resource in the Pacific Northwest? Report 19. Wash. State University, Water Research Center, Pullman, WA.

Cederholm, C.J., R.E. Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett and J.W. Ward. 1997. Response of Juvenile Coho Salmon and Steelhead to Placement of Large Woody Debris in a Coastal Washington Stream. North American Journal of Fisheries Management. 17:947-963.

Cederholm, C.J., Kunze, M.D., Murota, T. and Sibatani, A. 1999. Pacific salmon carcasses: Essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24: 6-15.

Chamberlin, T.W., R.D. Harr, F.H. Everest. 1991. Timber harvesting, silviculture, and watershed processes. In: W.R. Meehan (ed.), Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society, Special Publication Number 19. Bethesda, Maryland.

Chapman, D. W. 1961. Factors determining production of coho salmon, Oncorhynchus kisutch, in three Oregon streams. Doctor of Philosophy, Oregon State University. 223 p.

Chapman, D. W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada 19: 1047-1080.

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Transactions of the American Fisheries Society 109:357-363.

Chapman, D. W., J. F. Corliss, R. W. Phillips, and R. L. Demory. 1961. Summary report, Alsea watershed study. Oregon State University, Agriculture Experimental Station, Miscellaneous Paper 110, Corvallis.

Chesney, W. R., C.C. Adams, W. B. Crombie, H. D. Langendorf, S.A. Stenhouse and K. M. Kirkby. 2009. Shasta River Juvenile Coho Habitat & Migration Study. Report prepared for U. S. Bureau of Reclamation, Klamath Area Office. Funded by U.S. Bureau of Reclamation, National Oceanic and Atmospheric Administration and California Department of Fish and Game. California Department of Fish and Game, Yreka, California. Accessed 12/13/2011 from: http://www.klamathriver.org/Documents/CDFG-Juvenile-Coho-2009.pdf

Chesney, D. and M. Knechtle. 2010. Shasta River Chinook and coho salmon observations in 2009-2010. California Department of Fish and Game. Siskiyou County, California.

Chesney, D. and M. Knechtle. 2011a. Recovery of fall-run Chinook and coho salmon at Iron Gate Hatchery, September 24, 2010 to December 15, 2010. California Department of Fish and Game, Klamath River Project, Yreka, CA. 20 p.

Chesney, D. and M. Knechtle. 2011b. Shasta River Chinook and coho salmon observations in 2010-2011, Siskiyou County, CA. California Department of Fish and Game, Klamath River Project, Yreka, CA. 30 p.

Chesney, D. and M. Knechtle. 2013a. Shasta River Chinook and coho salmon observations in 2013, Siskiyou County, CA. Final Report. California Department of Fish and Wildlife, Klamath River Project, Yreka, CA. 27 p.

Chesney, D. and M. Knechtle. 2013b. Recovery of fall-run Chinook and coho salmon at Iron Gate Hatchery, September 26, 2012 to December 6, 2012. California Department of Fish and Wildlife. Klamath River Project. Yreka, CA. 22 p.

Chilcote, M.W. 1999. Conservation status of Lower Columbia River coho salmon. Oregon Department of Fish and Wildlife Information Report Number 99-3. 45 p.

Chilcote, M.W. 2003. Relationship between natural productivity and the frequency of wild fish in mixed spawning populations of wild and hatchery steelhead (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 60:1057-1067.

Chilcote, M.W., K.W. Goodson, and M.R. Falcy. 2011. Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Canadian Journal of Fisheries and Aquatic Sciences 68: 511-522.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society 115(5): 726– 735.

Claeson, S.M., J.L. Li, J.E. Compton, and P.A. Bisson. 2006. Response of nutrients, biofilm, and benthic insects to salmon carcass addition. Canadian Journal of Fisheries and Aquatic Sciences 63: 1230–41.

Clark, C.W. 1985. Bioeconomic Modelling and Fisheries Management. John Wiley & Sons, New York, NY.

Clements S, T. Stahl, C. B. Schreck. 2012. A comparison of the behavior and survival of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) in a small estuary system. Aquaculture. 362–363:148–157.

**Code of Federal Regulations (CFR):**

Title 50 Code of Federal Regulations, Part 424. Listing Endangered and Threatened Species and Designating Critical Habitat.

Title 50 Code of Federal Regulations, Part 223. Threatened Marine and Anadromous Species, Subpart B Restrictions Applicable to Threatened Marine and Anadromous Species – 203.

Cohen, R. 1997. Fact Sheets: Functions and Values of Riparian Areas. Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement. http://www.douglasma.org/cdd/concom/regs/wetlands/rivfstoc.html

Cole, J. 2000. Coastal sea surface temperature and coho salmon production off the north-west United States. Fisheries Oceanography 9: 1–16.

Collins, A. L., P. S. Naden, D. A. Sear, J. I. Jones, I. D. L. Foster, and K. Morrow. 2011. Sediment Targets for Informing River Catchment Management: International Experience and Prospects. Hydrological Processes 25:2112-2129.

Collins, B.D. and D.R. Montgomery. 2002. Forest development, wood jams, and restoration of floodplain rivers in the Puget Lowland, Washington. Restoration Ecology 10(2): 237-247.

Compton, J.E., C.P. Andersen, D.L. Phillips, J.R. Brooks, M.G. Johnson, M.R. Church, W.E. Hogsett, M.A. Cairns, P.T. Rygiewicz, B. C. McComb, and C. D. Shaff. 2006. Ecological and water quality consequences of nutrient additions for salmon restoration in the Pacific Northwest. Frontiers in Ecology and the Environment. 4: 18-26.

Cone, J. and S. Ridlington, editors. 1996. The Northwest Salmon Crisis: A Documented History. Oregon State University Press, Corvallis, Oregon, 374 pp.

Cordone, A.J. and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. Reprint from California Fish and Game. Vol. 47, No. 2. California Department of Fish and Game, Inland Fisheries Branch. Sacramento, CA. 41 pp.

Cornwell, T.J., Bottom, D.L., and Jones, K.K. 2001. Rearing of juvenile salmon in recovering wetlands of the Salmon River Estuary. Information Reports 2001-05. Oregon Department of Fish and Wildlife, Portland, Oregon.

Coutant, C. C. 1998. What is ''normative'' for fish pathogens? A perspective on the controversy over interactions between wild and cultured fish. Journal of Aquatic Animal Health 10:101–106.

Cover, M.R., C.C. May, W.E. Dietrich, and V.H. Resh. 2008. Quantitative linkages among sediment supply, streambed fine sediment, and benthic macroinvertebrates in northern California streams. Journal of the North American Benthological Society 27, 135–149.

Craig, B. 2010. Life-history Patterns and Ecology of Juvenile Coho Salmon (*Oncorhynchus kisutch*) within a Tidal Freshwater Estuary. Master's thesis, University of Washington. 85 pp.

Crawford, B.A. and S. Rumsey. 2011. Guidance for monitoring recovery of salmon and steelhead listed under the federal Endangered Species Act (Idaho, Oregon, and Washington). Northwest Region, NOAA Fisheries Service. 125 p.

Crisp T.M., E.D. Clegg, R.L. Cooper, W.P. Wood, D.G. Anderson, and K.P. Baetcke. 1998. Environmental endocrine disruption: an effect assessment and analysis. Environ Health Perspectives 106: 11–56.

Crispin, V., R. House, and D. Roberts. 1993. Changes in instream habitat, large woody debris, and salmon habitat after the restructuring of a coastal Oregon stream. North American Journal of Fisheries Management 13: 96-102.

Crone, R. A., and C. E. Bond. 1976. Life-history of coho salmon, *Oncorhynchus kisutch,* in Sashin Creek, southeastern Alaska. *U.S. Fisheries Bulletin* 74:897-923.

Crossin, G.T., Hinch, S.G., Farrell, A.P., Higgs, D.A. and Healey, M.C. (2004) Somatic energy of sockeye salmon *Oncorhynchus nerka* at the onset of upriver migration: a comparison among ocean climate regimes. Fisheries Oceanography 13: 345-349.

Crozier LG, Hendry AP, Lawson PW, Quinn TP, Mantua NJ, Battin J, Shaw RG, Huey RB. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications 1:252–270.

Daly, E.A., C.E. Benkwitt, R.D. Brodeur, M.N.C. Litz and L. A. Copeman. 2010 Fatty acid profiles of juvenile salmon indicate prey selection strategies in coastal marine waters. Marine Biology 157: 1975-1987.

Daniels AE, Morrison JF, Joyce LA, Crookston NL, Chen S-C, McNulty SG. 2012. Climate projections FAQ. US Department of Agriculture, Forest Service, Rocky Mountain Research Station. Available from: http://www.fs.fed.us/rm/pubs/rmrs_gtr277.pdf

Davidson, R.S., B.H. Letcher, and K. H. Nislow. 2010. Drivers of growth variation in juvenile Atlantic salmon: an elasticity analysis approach. Journal of Animal Ecology 79: 1113–1121.

Davis, G. E., J. Foster, C. E. Warren, and P. Doudoroff. 1963. The influence of oxygen concentration on the swimming performance of juvenile Pacific salmon at various temperatures. Transactions of the American Fisheries Society 92: 111-124.

Dawley, E. M., R. D. Ledgerwood, T. H. Blahm, C. W. Sims, J. T. Durkin, R. A. Kirn, A. E. Rankis, G. E. Monan, and F. J. Ossiander. 1986. Migrational characteristics, biological observations, and relative survival of juvenile salmonids entering the Columbia River estuary, 1966-1983. Final Report to Bonneville Power Administration, 256 p. Available Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.

Deitch, M.J., G.M. Kondolf, and A.M. Merenlender. 2009. Hydrologic impacts of small-scale instream diversions for frost and heat protection in the California wine country. River Research and Applications 25:118–134.

Deitch, M.J., A.M. Merenlender, S. Feirer. 2013. Cumulative Effects of Small Reservoirs on Streamflow in Northern Coastal California Catchments. Water Resource Management: 1–18.

DeVries, P., K.L. Fetherston, A. Vitale, & S. Madsen. 2012. Emulating riverine landscape controls of beaver in stream restoration. Fisheries, 37(6), 246-255.

DeWald, L., and M. A. Wilzbach. 1992. Interactions between native brook trout and hatchery brown trout: effects on habitat use, feeding, and growth. Transactions of the American Fisheries Society 121(3):287-296.

Dietrich, W. E., and F. K. Ligon. 2009. RIPPLE: a digital terrain-based model for linking salmon population dynamics to channel networks. Prepared by UC Berkeley and Stillwater Sciences, Berkeley, California.

Dittman, A., and T. Quinn. 1996. Homing in Pacific salmon: mechanisms and ecological basis. *Journal of Experimental Biology*, *199*(1), 83-91.

Doppelt, B., R. Hamilton, C. Williams, and M. Koopman. 2008. Preparing for Climate Change in the Rogue River Basin of Southwest Oregon. Report available from the Institute for Sustainable Environment, University of Oregon, Eugene

Driscoll, J. 2009. Miners Blast back at Karuk Tribe. Times Standard Newspaper. March 4, 2009.

Duffy, W. 2011. Prairie Creek life cycle monitoring project. Final project report. Humboldt State University, Sponsored Programs Foundation Agreement No. PO810315. March 1. 12 p.

Dunham, J. B. M. K. Young, R. E. Gresswell, B. E. Riemana. 2003. The effect of wildland fire on aquatic ecosystems in the western USA. Forest Ecology and Management 178: 183-196.

Dutra, B.L. and S.A. Thomas. 1999. 1998-99 Chinook and coho spawning report. Lower Trinity Ranger District, Six Rivers National Forest, Willow Creek, California. April 1999. Online at: http://www.krisweb.com/biblio/trinity_usdafs_dutraetal_1999.pdf

Dwire, K.A. and J.B. Kauffman. 2003. Fire and riparian ecosystems in landscapes of the western USA. Forest Ecology and Management 178: 61-74.

Eames, M., T. Quinn, K. Reidinger, and D. Haring. 1981. Northern Puget Sound 1976 adult coho and chum tagging studies. Wash. Dep. Fish. Tech. Rep. 64, 136 p.

Eaton, J.G., J.H. McCormick, B.E. Goodno, D.G. O'Brien, H.G. Stefany, M. Hondzo, and R.M. Scheller. 1995. A field information-based system for estimating fish temperature tolerances. Fisheries 20(4): 10-18.

Eaton, C. 2010. Resource Partitioning, Habitat Connectivity, and Resulting Foraging Activity Among Salmonids in the Estuarine Habitat Mosaic. Master's thesis, University of Washington. 105 pp.

Ebersole, J.L., M.E. Colvin, P.J. Wigington Jr., S.G. Leibowitz, J.P. Baker, M.R. Church, J.E. Compton, B.A. Miller, M.A. Cairns, B.P. Hansen, and H.R. LaVigne. 2009. Modeling stream network-scale variation in coho salmon overwinter survival and smolt size. Transactions of the American Fisheries Society 138: 564-580.

Ebersole, J.L., P.J. Wigington Jr., J.P. Baker, M.A. Cairns, M.R. Church, B.P. Hansen, B.A. Miller, H.R. LaVigne, J.E. Compton, and S.G. Leibowitz. 2006. Juvenile coho salmon growth and survival across stream network seasonal habitats. Transactions of the American Fisheries Society 135: 1681-1697.

Elder, D., B. Olson, A. Olson, J. Villeponteaux, and P. Brucker. 2002. Salmon River Subbasin Restoration Strategy: Steps to Recovery and Conservation of Aquatic Resources. Report prepared for the Klamath River Basin Fisheries Restoration Task Force and U.S. Fish and Wildlife Service, Yreka, California. 53 pp.

Elliott, J.M. 1981. Some aspects of thermal stress on freshwater teleosts. Pages 209-245 *In* A. D. Pickering editor, Stress and Fish. Academic Press, London.

Emmett, R.L. and Krutzikowsky, G.K. (2008) Nocturnal feeding of Pacific hake and jack mackerel off the mouth of the Columbia River, 1998-2004: Implications for juvenile salmon predation. Transactions of the American Fisheries Society 137: 657-676.

Emmett, R.L. and Sampson, D.B. 2007. The relationship between predatory fish, forage fishes, and juvenile salmonid marine survival off the Columbia River: a simple trophic model analysis. CALCOFI Report 48: 96-105.

Emmett, R. L., G.K. Krutzikowsky and P. Bentley. 2006. Abundance and distribution of pelagic piscivorous fishes in the Columbia River plume during spring/early summer 1998–2003: relationship to oceanographic conditions, forage fishes, and juvenile salmonids. Progress in Oceanography 68(1): 1-26.

Engber, E.A., J.M. Varner III, L.A. Arguello, and N.G. Sugihara. 2011. The Effects of Conifer Encroachment and Overstory Structure on Fuels and Fire in an Oak Woodland Landscape. Fire Ecology 7:32–50.

Engen, S., R. Lande, and B. E. Saether. 2003. Demographic stochasticity and Allee effects in populations with two sexes. Ecology 84: 2378-2386.

Everest, F. H., & Reeves, G. H. 2007. Riparian and aquatic habitats of the Pacific Northwest and southeast Alaska: ecology, management history, and potential management strategies.

Ewers, R. M. and R. K. Didham. 2005. Confounding factors in the detection of species response to habitat fragmentation. Biological Reviews 81: 117-142.

Ewing, R.D. 1999. Diminishing returns: Salmon decline and pesticides. Funded by the Oregon Pesticide Education Network, Biotech Research and Consulting, Inc., Corvallis, OR. 55 pp.

Fagan, W. F. and E. E. Holmes. 2006. Quantifying the extinction vortex. Ecology Letters 9: 51-60.

Ferguson, J.A., J. Romer, J.C. Sifneos, L. Madsen, C.B. Schreck, M. Glynn, and M.L. Kent. 2012. Impacts of multispecies parasitism on juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon. Aquaculture 362-363: 184-192.

Firman, J. C., E. A. Steel, D. W. Jensen, K. M. Burnett, K. Christiansen, B. E. Feist, D. P. Larsen, and K. Anlauf. 2011. Landscape Models of Adult Coho Salmon Density Examined at Four Spatial Extents. Transactions of the American Fisheries Society 140(2):440-455.

Fisher, J.P. and Pearcy, W.G. 1990. Spacing of scale circuli versus growth rate in young coho salmon. Fishery Bulletin 88: 637-643.

Federal Energy Regulatory Commission (FERC). 2007. Final Environmental Impact Statement for Relicensing of the Klamath Hydroelectric Project No. 2082-027. November 16.

Feely, R. A., C.L. Sabine, J.M. Hernandez-Ayon, D. Ianson, & B. Hales. 2008. Evidence for upwelling of corrosive" acidified" water onto the continental shelf. Science, *320*(5882), 1490-1492.

Fischer, R. A., & J.C. Fischenich. 2000. Design Recommendations for Riparian Corridors and Vegetated Buffer Strips. No. ERDC-TN-EMRRP-SR-24). Army Engineer Waterways Experiment Station Vicksburg MS Engineer Research and Development Center

Five Counties Salmonid Conservation Program. 2010. Water Quality and Stream Habitat protection manuals for County Road Maintenance in Northwestern California Watersheds. Prepared for the Five Counties Salmon Conservation Program Available at: http://www.5counties.org/docs.htm

Flagg, T.A., B.A. Berejikia, J.E. Colt, W.W. Dickhoff, L.W. Harrell, et al., eds. 2000. Ecological and behavioral impacts of artificial production strategies on the abundance of wild salmon populations—a review of practices in the Pacific Northwest. NOAA Tech. Memo. NMFS-NWFSC-4, Northwest Fish. Sci. Cent., Seattle, WA

Flaherty, C.M. and Dodson, S.I. 2005. Effects of pharmaceuticals on Daphnia survival, growth, and reproduction: Chemosphere, v. 61, p. 200-207.

Fleming, I. A. 1994. Captive breeding and the conservation of wild salmon populations. Conservation Biology 8:886–888.

Fleming, I. A. 1996. Reproductive strategies of Atlantic salmon: ecology and evolution. Reviews in Fish Biology and Fisheries 6: 379–416.

Fleming I. A., and M.R. Gross. 1989. Evolution of adult female life-history and morphology in a Pacific Salmon (Coho: Oncorhynchus kisutch). Evolution. 43: 141–157.

Fleming, I. A., and M. R. Gross. 1990. Latitudinal clines: a trade-off between egg number and size in Pacific salmon. Ecology 71: 1-11.

Fleming, I. A. and M.R. Gross. 1994. Breeding competition in a Pacific salmon (Coho: *Oncorhynchus kisutch*): Measures of natural and sexual selection. Evolution 48: 637-657.

Fleming, I. A., and Petersson, E. 2001. The ability of released, hatchery salmonids to breed and contribute to the natural productivity of wild populations. Nordic Journal of Freshwater Research, 75: 71e98.

Fleming, I. A., B. Jonsson, M. R. Gross, and A. Lamberg. 1996. An experimental study of the reproductive behavior and success of farmed and wild Atlantic Salmon (*Salmo salar*). Journal of Applied Ecology 33:893-905.

Flitcroft, R, K. Burnett, and K. Christiansen 2013. A simple model that identifies potential effects of sea-level rise on estuarine and estuary-ecotone habitat locations for salmonids in Oregon, USA. Environmental Management: 1–13.

Flitcroft, R., K. Burnett, J Snyder, G. Reeves, L. Ganio. Riverscape patterns among years of juvenile coho salmon in midcoastal Oregon: Implications for conservation. Transactions of the American Fisheries Society. 143:26-38.

Foott, S. 1995. Preliminary results of Spring 1995 Klamath R. chinook smolt study (95-FP-01), Iron Gate Hatchery June release group. U.S. Fish and Wildlife Service California-Nevada Fish Health Center, Anderson, CA. 6 p.

Foott, J.S, G. Stutzer, R. Fogerty, H.C. Hansel, S.D. Juhnke, and J.W. Beeman. 2010. Pilot study to access the role of *Ceratomyxa shasta* infection in mortality of fall-run Chinook smolts migration through the lower Klamath River in 2008. US Fish and Wildlife Service-US Geological Survey Technical report, US Fish and Wildlife Service, CA-NV Fish Health Center, Anderson, CA.

Ford, M. J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. Conservation Biology 16:815-825.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. Forest Ecosystem Management: an ecological, economic and social assessment. Report of the Forest Ecosystem Management Assessment Team. 1993-793-071. U.S. Govt. Printing Office.

Foster, S.C., C.H. Stein, and K.K. Jones. 2001. A guide to interpreting stream survey reports. Oregon Department of Fish and Wildlife, Aquatic Inventories Project, Portland, OR. 55 p.

Fouty, S.C. 2003. Current and historic stream channel response to changes in cattle and elk grazing pressure and beaver activity. PhD thesis. University of Oregon, Eugene, Ore.

Fowler, C. W. and Baker, J. D. 1991. A review of animal population dynamics at extremely reduced population levels. Report of the International Whaling Commission 41: 545–554.

Frankham, R. 2005. Genetics and Extinction. Biological Conservation 126: 131–140.

Fraser, F. J., E. A. Perry, and D. T. Lightly. 1983. Big Qualicum River salmon development project. Volume 1: a biological assessment 1959-1972. Canadian Technical Report of Fisheries and Aquatic Sciences 1189. Department of Fisheries and Oceans, Fisheries Research Branch, Pacific Biological Station, Nanaimo, British Columbia.

Freedman, J. A., R. A. Carline, and J. R. Stauffer. 2013. Gravel Dredging Alters Diversity and Structure of Riverine Fish Assemblages. Freshwater Biology 58:261-274.

Fresh, K.L. 1997. The role of competition and predation in the decline of Pacific salmon and steelhead. In Pacific salmon and their ecosystems: status and future options. Edited by D.J. Stouder, P.A. Bisson, and R.J. Naiman. Chapman Hall, New York. pp. 245–275.

Fried, J.S, M.S. Torn, and E. Mills. 2004. The impact of climate change on wildfire severity: A regional forecast for Northern California. Climate Change 64:169–191

Frissell, C.A. 1992. Cumulative effects of land use on salmonid habitat on southwest Oregon streams. Ph.D. thesis, Oregon State University, Corvalis, OR.

Fruit Grower Supply Company (FGSC). 2012 Fruit Growers Supply Company's multi-species habitat conservation plan. 526 pp.

Furniss, M. J., B. P. Staab, S. Hazelhurst, C. F. Clifton, K. B. Roby, B. L. Ilhadrt, E. B. Larry, A. H. Todd, L. M. Reid, S. J. Hines, K. A. Bennett, C. H. Luce, P. J. Edwards. 2010. Water, climate change, and forests: watershed stewardship for a changing climate. Gen. Tech. Rep. PNW-GTR-812. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 75 p

Galbraith, H., R. Jones, R. Park, J. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2005. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. In: Ralph, C. John; Rich, Terrell D., editors 2005. Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20-24; Asilomar, California, Volume 2 Gen. Tech. Rep. PSW-GTR-191. Albany, CA: U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Research Station: p. 1119-1122.

Gallagher, S.P., S. Thompson, and D.W. Wright. 2012. Identifying factors limiting coho salmon to inform stream restoration in coastal Northern California. California Department of Fish and Game 98(4): 185-201.

Garwood, J.M. 2012. Historic and recent occurrence of coho salmon (Oncorhynchus kisutch) in California streams within the Southern Oregon/ Northern California Evolutionarily Significant Unit. California Department of Fish and Game, Arcata, CA 78 p.

Gilbert, C.H. 1912. Age at maturity of the Pacific coast salmon of the genus *Oncorhynchus*. Fish Bull., U.S. 32:3-22.

Giorgi, A.E. 1993. Flow augmentation and reservoir drawdown: Strategies for recovery of threatened and endangered stocks of salmon in the Snake River Basin Recovery issues for threatened and endangered Snake River salmon: Technical report 2. Bonneville Power Administration, Portland, OR. 50 p.

Gleason, M., S. Newkirk, M. Merrifiled, J. Howard, R. Cox, M. Webb, J. Koepcke, B. Stranko, B. Taylor, M. Beck, R. Fuller, P. Dye, D. Vander Schaaf, and J. Carter. 2011. A Conservation Assessment of West Coast (USA) Estuaries. The Nature Conservancy, Arlington VA. 65pp.

Godfrey, H. 1965. Coho salmon in offshore waters, p. 1-39. *In*: Salmon of the North Pacific Ocean. Part IX. Coho, chinook and masu salmon in offshore waters. International North Pacific Fisheries Commission Bulletin 16.

Gleick, P. H., 1987. The Development and Testing of a Water Balance Model for Climate Impact Assessment: Modeling the Sacramento Basin. Water Resources Research 23: 1049-1061.

Goede, R. W. 1986. Management considerations in stocking of diseased or carrier fish. Pages 349–355 in R. H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Bethesda, Maryland.

Goldman, C.R. and A.J. Horne. 1983. Limnology. McGraw-Hill, Inc. New York. 464 pp.

Goley, D. and A. Gemmer. 2000. Pinniped/salmonid interactions on the Smith, Mad and Eel rivers in northern California between 31 August and 15 December 1999. Unpublished report, Humboldt State University Marine Mammal Education and Research Program, Arcata, California.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-66, 598 p.

Goode, J., J. Buffington, D. Tonina, D. Isaak, R. Thurow, S. Wenger, D. Nagel, C. Luce, D. Tetzlaff, and C. Soulsby. 2013. Potential Effects of Climate Change on Streambed Scour and Risks to Salmonid Survival in Snow-dominated Mountain Basins. Hydrological Processes 27: 750-765.

Goodman, D. 2005. Selection equilibrium for hatchery and wild spawning fitness in integrated breeding programs. Canadian Journal of Fisheries and Aquatic Sciences 62: 374-389.

Graf, W.L. 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology 79:336–360.

Grant, W.S. (Ed.) 1997. Genetic effects of straying of non-native hatchery fish into natural populations: Proceedings of the workshop. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-30, 130 p.

Grant, G.E., Lewis, S.L., Swanson, F.J., Cissel, J.H., McDonnell, J.J. 2008. Effects of forest practices on peak flows and consequent channel response: a state-of-science report for western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-760. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 p.

Grantham, T.E,, D.A. Newburn, M.A. McCarthy, and A.M. Merenlender. 2012. The Role of Streamflow and Land Use in Limiting Oversummer Survival of Juvenile Steelhead in California Streams. Transactions of the American Fisheries Society 141: 585–598.

Graybill, M.R. 1981. Haul-out patterns and diet of harbor seals, *Phoca vitulina*, in Coos County, Oregon. M.S. thesis. University of Oregon.

Greig, S.M., D.A. Sear, and P.A. Carling. 2005. The impact of fine sediment accumulation on the survival of incubating salmon progeny: Implications for sediment management. Science of The Total Environment 344: 241-258.

Green Diamond Resource Company (GDRC). 2006. Aquatic habitat conservation plan and candidate conservation agreement with assurances. Final. Volume 1-2 plus appendices.

Prepared for National Marine Fisheries Service and U.S. Fish and Wildlife Service, October 2006. 568 p.

Green Diamond Resource Company (GDRC). 2009. First Biennial Report. Submitted to National Marine Fisheries Service and U.S. Fish and Wildlife Service. 242 pp.

Green Diamond Resource Company (GDRC). 2013. Summary of Green Diamond Resource Company spawner survey results for the Little River watershed, Humboldt County. September 2013. 4 p.

Gresswell, R.E. 1999. Fire and Aquatic Ecosystems in Forested Biomes of North America Transactions of the American Fisheries Society 128(2): 193-221.

Griffith, J. S., Jr. 1972. Comparative behavior and habitat utilization of brook trout (*Salvelinus fontinalis*) and cutthroat trout (*Salmo clarki*) in small streams in northern Idaho. Journal of the Fisheries Research Board of Canada 29:265-273.

Griffith, J.S., and D.A. Andrews. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. North American Journal of Fisheries Management 1:21-28.

Guillen, G. 2003. Klamath River fish die-off, September 2002: Report on estimate of mortality. Report number AFWO-01-03 . U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office. Arcata, CA. 35 pp.

Gustafson, R.G., R.S. Waples, J.M. Myers, L.A. Weitkamp, G.J. Bryant, O.W. Johnson, and J.J. Hard. 2007. Pacific salmon extinctions: quantifying lost and remaining diversity. Conservation Biology 21(4):1009-1020.

Guyette, M.Q., C.S. Loftin, J. Zydlewski, and B. Jonsson. 2013. Carcass analog addition enhances juvenile Atlantic salmon (*Salmo salar*) growth and condition. Canadian Journal of Fisheries and Aquatic Sciences 70: 860–70.

Hanson, L.C. 1993. The foraging ecology of harbor seals, *Phoca vitulina*, and California sea lions, *Zalophus californianus*, at the mouth of the Russian River, California. Master's thesis, Sonoma State University, California.

Hard, J.J., B.A. Berejikian, E.P. Tezak, S.L. Schroder, C.M. Knudsen, and L.T. Parker. 2000. Evidence for morphometric differentiation of wild an captively reared adult coho salmon: a geometric analysis. Environmental Biology of Fishes 58:61–73.

Hare, S.R. and R.C. Francis. 1995. Climate change and salmon production in the northeast Pacific Ocean. Pages 357-372 in: R.J. Beamish, Editor, *Climate Change and Northern Fish Populations.* Canadian Special Publication of Fisheries and Aquatic Sciences 121.

Harris, R.R., C.M. Olson, S.D. Kocher, J.M. Gerstein, W. Stockard and W.E. Weaver. 2005. Procedures for Monitoring the Implementation and Effectiveness of Fisheries Habitat Restoration Projects. Center for Forestry, University of California, Berkeley. 24pp.

Hartman, G.F., B.C. Anderson, and J.C. Scrivener. 1982. Seaward movement of coho salmon (*Oncorhynchus kisutch*) fry in Carnation Creek, an unstable coastal stream in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 39:588–597.

Hartman, G.F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and Steelhead trout (*Salmo gairdneri*). Journal Fisheries Research Board of Canada 22:1035-1081.

Harvey, B.C. and T.E. Lisle. 1999. Scour of Chinook Salmon Redds on Suction Dredge Tailings. North American Journal of Fisheries Management 19:613-617.

Harvey B.C., R.J. Nakamoto, and J.L. White. 2006. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. Transactions of the American Fisheries Society 135:998–1005.

Hatchery Scientific Review Group (HSRG)– L. Mobrand (chair), J. Barr, L. Blankenship, D. Campton, T. Evelyn, T. Flagg, C. Mahnken, R. Piper, P. Seidel, L. Seeb and B. Smoker. 2004. Hatchery Reform: Principles and Recommendations of the HSRG. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA 98101 (available from www.hatcheryreform.org).

Hauer, J. 2013. Overwinter survival and growth of juvenile coho salmon, *Oncorhynchus kisutch*, in Freshwater Creek, California. Available from: http://humboldt-dspace.calstate.edu/handle/2148/1490

Hawkins, C. P., K. L. Bartz, and C. M. U. Neale. 1997. Vulnerability of Riparian Vegetation to Catastrophic Flooding: Implications for Riparian Restoration. Restoration Ecology 5(4S):75-84.

Hawkins, S.W. and J.M. Tipping. 1999. Predation by juvenile hatchery salmonids on wild fall Chinook salmon fry in the Lewis River, Washington. California Fish and Game 85(3): 124-129.

Hearn, W. E. 1987. Interspecific competition and habitat segregation among stream dwelling trout and salmon: A review. Fisheries 12:24–31.

Heinimaa, S. and P. Heinimaa. 2004. Effect of the female size on egg quality and fecundity of the wild Atlantic salmon in the sub-arctic River Teno. Boreal Environment Research 9, 55–62.

Hemmer, H. 1990. Domestication: The decline of environmental appreciation. Cambridge University Press, Cambridge, MA.

Henderson, M. A. and A.J. Cass. 1991. Effects of smolt size on smolt-to-adult survival for Chilko Lake sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 48: 988-994.

Herrmann, R.B., Warren, C.E., Doudoroff, P., 1962. Influence of oxygen concentration on the growth of juvenile coho salmon. Transactions of the American Fisheries Society 91: 155–167.

Hillemeier, D., T. Soto, S. Silloway, A. Corum, M. Kleeman, and L. Lestelle. 2009. The Role of the Klamath River Mainstem Corridor in the Life-History and Performance of Juvenile Coho Salmon (*Oncorhynchus kisutch*). Period Covered: May 2007–May 2008. Report submitted to the United States Bureau of Reclamation. Klamath Falls, Oregon, 97603.

Hillman, T.W. and J.W. Mullan. 1989. Effect of hatchery releases on the abundance and behavior of wild juvenile salmonids. Pages 265-285 in Don Chapman Consultants, Inc. Summer and winter ecology of juvenile Chinook salmon and steelhead trout in the Wenatchee River, Washington. Final report submitted to Chelan County Public Utility District, Wenatchee, Washington.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Canadian Journal of Fisheries and Aquatic Sciences 48:945–957.

Hjort, R.C., and C.B. Schreck. 1982. Phenotypic differences among stocks of hatchery and wild coho salmon, *Oncorhynchus kisutch*, in Oregon, Washington, and California. Fish. Bull., U.S. 80:105-119.

Hobday A.J. and G.W. Boehlert. 2001. The role of coastal ocean variation in spatial and temporal patterns in survival and size of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 58(10):2021–2036.

Hogarth, W. T. 2005. Final National Marine Fisheries Service (NMFS) national gravel extraction guidance. United States Department of Commerce, National Oceanographic and Atmospheric Administration.

Holt, R.A., J.E. Sanders, J.L. Zim, J.L. Fryer, and K.S. Pilcher. 1975. Relation of water temperature to Flexibacter columnaris infection in steel head trout (*Salmo gairdneri*), coho (*Oncorhynchus kisutch*), and chinook *(O. tshawytscha*) salmon. Journal Fisheries Research Board of Canada 32:1553-1559.

Holtby, L.B. and M. C. Healey. 1990. Sex-specific life history tactics and risk-taking in coho salmon. Ecology 71(2): 678-690.

Holtby, L.B., and J.C. Scrivener. 1989. Observed and simulated effects of climatic variability, clear-cut logging, and fishing on the numbers of chum salmon (*Oncorhynchus keta*) and coho salmon (*O. kisutch*) returning to Carnation Creek, British Columbia. In C. D. Levings, L. B. Holtby, and M. A. Henderson (editors), Proceedings of the national workshop on effects of habitat alteration on salmonid stocks, p. 62-81. Canadian Special Publication Fisheries and Aquatic Sciences 105.

Hood, W.G. 2005. Sea Level Rise in the Skagit Delta. Skagit River Tidings. Skagit Watershed Council, Mount Vernon, Washington.

Hooff, R.C. and Peterson, W.T. (2006) Copepod biodiversity as an indicator of changes in ocean and climate conditions of the northern California current ecosystem. Limnology and Oceanography 51: 2607-2620

Hoopa Valley Tribe Environmental Protection Agency (HVTEPA). 2008. Water Quality Control Plan Hoopa Valley Indian Reservation. Approved September 11, 2002, Amendments Approved February 14, 2008. Hoopa Tribal EPA. Hoopa, CA. 285p.

Hopelain, J.S. 2001. Lower Klamath River angler creel census with emphasis on upstream migrating fall chinook salmon, coho salmon, and steelhead trout during July through October, 1983 through 1987.

Humboldt Redwoods Company (HRC). Undated. Class I Stream Aquatic Habitat Trend Monitoring. 2012 Annual Report. Scotia, CA.

Hurst, T.P. (2007) Causes and consequences of winter mortality in fishes. J. Fish Biol. 71: 315-345.

ICF/ Jones & Stokes. 2010. Hatchery and Stocking Program Environmental Impact Report/Environmental Impact Statement. Final. January.(ICF J&S 00264.08) (SCH #2008082025). Sacramento, CA. Prepared for the California Department of Fish and Game and U.S. Fish and Wildlife Service, Sacramento, CA. Available at: http://www.dfg.ca.gov/news/pubnotice/hatchery/

Independent Multidisciplinary Science Team (IMST). 1999. Recovery of wild salmonids in western Oregon forests: Oregon Forest Practices Act rules and the measures in the Oregon plan for salmon and watersheds Technical report. IMST (OR), v 1999-1

Independent Multidisciplinary Science Team (IMST). 2002. Recovery of Wild Salmonids in Western Oregon Lowlands. Technical Report 2002-01. July 15, 2002. Oregon Watershed Enhancement Board Office. Salem, Oregon. Available on the Internet at: http://www.fsl.orst.edu/imst/reports/2002-01.doc

Independent Scientific Advisory Board (ISAB). 2002. Hatchery surpluses in the Pacific Northwest. Fisheries 27(12): 16-27.

Intergovernmental Panel on Climate Change (IPCC). 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Isaak, D., S. Wollrab, D. Horan, and G. Chandler. 2012. Climate Change Effects on Stream and River Temperatures Across the Northwest U.S. from 1980-2009 and Implications for Salmonid Fishes. Climatic Change 113:499-524.

Isaak, D.J., C. Luce, B.E. Rieman, D. Nagel, E. Peterson, D. Horan, S. Parkes, and G. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications: Vol. 20, No. 5, pp. 1350-1371. doi: 10.1890/09-0822.1. http://www.treesearch.fs.fed.us/pubs/35471

Iwata, M. and Komatsu, S. 1984. Importance of estuarine residence for adaptation of chum salmon (*Oncorhynchus keta*) fry to seawater. Canadian Journal of Fisheries and Aquatic Sciences 41(5): 744-749.

Izagirre O, A. Serra, H. Guasch, A. Elosegi. 2009. Effects of sediment deposition on periphytic biomass, photosynthetic activity and algal community structure. Science of the Total Environment 407: 5694–5700.

Jacobs, S.E. 1988. Oregon coastal salmon spawning surveys, 1985. Oregon Department of Fish and Wildlife Fish Division, 56 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Jacobson, K., B. Peterson, M. Trudel, J. Ferguson, C. Morgan, D. Welch, A. Baptista, B. Beckman, R. Brodeur, E. Casillas, R. Emmett, J. Miller, D. Teel, T. Wainwright, L. Weitkamp, J. Zamon, and K. Fresh. The Marine Ecology of Juvenile Columbia River Basin Salmonids: A Synthesis of Research 1998-2011. Report of the US National Marine Fisheries Service, National Oceanic and Atmospheric Administration Fisheries and Oceans Canada, Kintama Research Services, Ltd. And Oregon State University to Northwest Power and Conservation Council. January 2012. 168 p..

Jacobson, K.C., D. Teel, D.M. van Doornik, and E. Casillas. 2008. Parasite-associated mortality of juvenile Pacific salmon caused by the trematode *Nanophyetus salmincola* during early marine residence. Marine Ecology Progress Series 354: 235-244.

Jahn, J. 2010. Personal communication. Fisheries Biologist. National Marine Fisheries Service. Santa Rosa, CA.

Jameson, R.J. and K.W. Kenyon. 1977. Prey of sea lions in the Rogue River, Oregon. Journal of Mammalogy 58(4): 672.

Janetski, D.J., D.T. Chaloner, S.D Tiegs, and G.A. Lamberti. 2009. Pacific salmon effects on stream ecosystems: A quantitative synthesis. Oecologia 159: 583–95.

Jassal R.S., T.A. Black, D.L. Spittlehouse, C. Brümmer, and Z. Nesic. 2009. Evapotranspiration and water use efficiency in different-aged Pacific Northwest Douglas-fir stands. Agricultural and Forest Meteorology 149:1168–1178.

Jenkins, T. M. 1969. Social structure, position choice and microdistribution of two trout species (*Salmo trutta* and *Salmo gairdneri)* resident in mountain streams. Animal Behavior Monographs 1(2): 57–123.

Jensen, P. T. and J. Hyde. 1971. Sex Ratios and Survival Estimates Among Salmon Populations. Transactions of the Western Section of the Wildlife Society, 7, 20-27.

Johnson, C. 2010. Personal communication. Biologist. National Marine Fisheries Service. La Jolla, CA.

Johnson, S.L. 1988. The effects of the 1983 El Niño on Oregon's coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon. Fisheries Research 6: 105-123.

Johnson, S.L., M.F. Solazzi, and J.D. Rogers. 1993. Development and evaluation of techniques to rehabilitate Oregon's wild salmonids. Oregon Department of Fish and Wildlife Fish Research Project F-125-R-5. Annual report. 12 p.

Johnstone, J.A. and T.E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. Proceedings of the National Academy of Sciences 107(10): 4533-4538.

Jokikokko, E., I. Kallio-Nyberg, I. Saloniemi, and E. Jutila. 2006. The survival of semiwild, wild and hatchery-reared Atlantic salmon smolts of the Simojoki River in the Baltic Sea. Journal of Fish Biology 68: 430-442.

Jones, K. K., T. J. Cornwell., D. L. Bottom, L. A. Campbell, and S. Stein. 2014. The contribution of estuary-resident life histories to the return of adult *Oncorhynchus kisutch*. Journal of Fish Biology. Doi:10.1111/jfb.12380.

Jong, W.H. and T. Mills. 1992. Anadromous salmonid escapement studies, South Fork Trinity River, 1984 through 1990. Klamath-Trinity Program, Inland Fisheries Division. Unpublished Administrative Report No. 92-XX. 26 p.

Jong, B., L. Preston, and M. Gilroy. 2008. Status of coho salmon (*Oncorhynchus kisutch*) in California as measured by changes in temporal and spatial historic occurrence Part I: California coastal watersheds north of Punta Gorda. Draft for NMFS. Northern Region Fisheries Program for Fisheries Restoration Grant Program. California Department of Fish and Game. Sacramento, California. September 2.

Jonsson, B., N. Jonsson, and L.P. Hansen. 2003. Atlantic salmon straying from the River Imsa. Journal of Fish Biology. 62:641–657.

Jordahl, D.M., and A. Benson. 1987. Effect of low pH on survival of brook trout embryos and yolk-sac larvae in West Virginia streams. Transactions of the American Fisheries Society 116: 807–816.

Joseph, L.N., S.A. Field, C. Wilcox, and H.P. Possingham. 2006. Presence-absence versus abundance data for monitoring threatened species. Conservation biology 20(6):1679-1687.

Kahler, T.H., P. Roni, and T.P. Quinn. 2001. Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1947–1956.

Kanehl, P., and Lyons, J. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin.

Karuk Tribe of California. 2002. Water Quality Control Plan. Karuk Tribe Department of Natural Resources, Orleans, CA. 36 p.

Katz, J., P. Moyle, R. Quinones, J. Israel, and S. Purdy. 2012. Impending Extinction of Salmon, Steelhead, and Trout (Salmonidae) in California. Environmental Biology of Fishes. DOI 10.1007/s10641-012-9974-8

Kaufmann, P.R., Larsen, D.P., Faustini, J.M., 2009. Bed Stability and Sedimentation Associated With Human Disturbances in Pacific Northwest Streams. Journal of the American Water Resources Association 45:434-459.

Kaushal, S.S., G.E. Likens, N.A. Jaworski, M.L Pace, A.M. Sides, D. Seekell, K.T. Belt, D.H. Secor, and R. L. Wingate. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment 8:461-6.

Keeley, J.E., 2009. Fire intensity, fire severity and burn severity: a brief review and suggested usage. International Journal of Wildland Fire 18:116-126.

Keeton, W.S., C.E. Kraft, D.R. Warren. 2007. Mature and old-growth riparian forests: structure, dynamics, and effects on Adirondack stream habitats. Ecological Applications 17(3): 852-868.

Keister, J.E., E. Di Lorenzo, C.A. Morgan, V. Combes, and W.T. Peterson. 2011. Zooplankton species composition is linked to ocean transport in the Northern California Current. Global Change Biology 17:2498-2511.

Kelsey, H.M. 1980. A sediment budget and an analysis of geomorphic process in the Van Duzen River basin, north coastal California, 1941-1975: Geological Society of America Bulletin 91(41 pt 2): 1119-1216.

Kemp, P., D. Sear, A. Collins, P. Naden, and I Jones. 2011. The Impacts of fine sediment on riverine fish. Hydrological Processes 25:1800-1821.

Kendall, B.E. and G.A. Fox. 2003. Unstructured individual variation and demographic stochasticity. Conservation Biology 17: 1170-1172.

Keppeler, E., Lewis, J., Lisle, T., 2003. Effects of forest management on streamflow, sediment yield, and erosion, Caspar Creek Experimental Watersheds. The First Interagency Conference on Research in the Watersheds, Benson, AZ. USDA Forest Service, Pacific Southwest Research Station, Arcata, CA.

Kier Associates and National Marine Fisheries Service (NMFS). 2008. Updated guide to the reference values used in the Southern Oregon/Northern California coho salmon recovery conservation action planning (CAP) workbooks. July. Arcata, CA.

Kiffney, P.M., R.E. Bilby, and B. Sanderson. 2005. Monitoring the effects of nutrient enrichment on freshwater ecosystems. *In* Monitoring stream and watershed restoration, P. Roni, editor. American Fisheries Society, Bethesda, MD.

Kiffney, P., G. Pess, K. Kloehn, J. Cram, R. Klett, and J. Anderson. 2007. Recolonization of the Cedar River above Landsburg by anadromous fish: ecological patterns and effects. Final report to Seattle Public Utilities, Contract #DA00-003C. Seattle, WA

Kiffney, P.M., E.R. Buhle, S.M. Naman, G.R. Pess, & R.S. Klett. 2014. Linking resource availability and habitat structure to stream organisms: an experimental and observational assessment. Ecosphere, 5(4), art39.

Kinnison, M.T., M.J. Unwin, A.P. Hendry, and T.P. Quinn. 2001. Migratory costs and the evolution of egg size and number in introduced and indigenous salmon populations. Evolution 55:1656-1667.

Kiparsky, M. and P.H. Gleick. 2003. Climate change and California water resources: a survey and summary of the literature. Pacific Institute for Studies in Development, Environment, and Security, Oakland, California. California Energy Commission. Report 500-04-073, Sacramento, CA

Klein, R.D. 1979. Urbanization and stream water quality impairment. Water Resources Bulletin 15: 948-963.

Klein, R.D. 2012. Hydrologic Assessment of Low Flows in the Mattole River Basin, 2004-2011. Prepared for Sanctuary Forest Inc. Mattole Flow Program, February 2012. 22 p.

Klein, R.D., W.J. Trush, M. Buffleben, 2008. Watershed condition, turbidity, and implications for anadromous salmonids in north coastal California streams. Report to North Coast Regional Water Quality Control Board, Santa Rosa, CA.

Knechtle, M. 2014. Personal communication. Associate Fisheries Biologist, California Department of Fish and Wildlife. January.

Knechtle, M. and D. Chesney. 2013a. 2012 Scott River salmon studies – Final Report. California Department of Fish and Wildlife Northern Region, Klamath River Project, Yreka, California. 23 p.

Knechtle, M. and D. Chesney. 2013b. Bogus Creek salmon studies – Final Report. California Department of Fish and Wildlife Northern Region, Klamath River Project, Yreka, California. 22 p.

Knighton, A.D. 1991. Channel bed adjustment along mine-affected rivers of northeast Tasmania. Geomorphology 4:205–19.

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. J. Climatology:4545–4559.

Kock, T.J., T.L. Liedtke, D.W. Rondorf, J.D. Serl, M. Kohn, and K.A. Bumbaco. 2012. Elevated streamflows increase dam passage by juvenile coho salmon during winter: Implications of climate change in the Pacific Northwest. North American Journal of Fisheries Management 32: 1070-1079.

Koenings, J.P., H.J. Geiger, and J.J. Hasbrouck. 1993. Smolt-to-adult survival patterns of sockeye salmon (*Oncorhynchus nerka*): Effects of smolt length and geographic latitude when entering the sea. Canadian Journal of Fisheries and Aquatic Sciences 50:600-611.

Kohane, M. J. & Parsons, P. A. 1988. Domestication. Evolutionary change under stress. Evolutionary Biology 23: 31–48.

Kohler, A.E, T.N. Pearsons, J.S. Zendt, M.G. Mesa, C.L. Johnson, and P.J. Connolly. 2012. Nutrient enrichment with salmon carcass analogs in the Columbia River basin, USA: A stream food web analysis. Transactions of the American Fisheries Society 141: 802–24.

Koller, M. 2010. Passage Assessment Database (PAD). California Cooperative Fish and Habitat Data Program (CalFish). Retrieved December 09, 2010 from www.calfish.org.

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. *Environmental Management* 21(4):533-551.

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society 129: 262-281.

Kondolf, G.M., and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29: 2275-2285.

Kondolf, G.M., and M.L. Swanson. 1993. Channel adjustments to reservoir construction and instream gravel mining, Stony Creek, California. Environmental Geology and Water Science 21:256-269.

Koski, K.V. 1966. The survival of coho salmon (Oncorhynchus kisutch) from egg deposition to emergence in three Oregon coastal streams. Master's thesis, Oregon State University. 98 pp.

Koski, K. 2009. The Fate of Coho Salmon Nomads: the Story of an Estuarine-Rearing Strategy Promoting Resilience. Ecology and Society 14(1):4.

Koslow, J.A., A. Hobday and G. Boehlert. 2002. Climate variability and marine survival of coho salmon (*Oncorhynchus kisutch*) off the coast of California, Oregon and Washington, USA. Fisheries Oceanography 11: 65-77.

Kostow, K.E. 2004. Differences in juvenile phenotypes and survival between hatchery stocks and a natural population provide evidence for modified selection due to captive breeding. Canadian Journal of Fisheries and Aquatic Sciences 61:577–589.

Kostow K.E. 2009. Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Rev. Fish Biol. Fish., 19(1): 9-31.

Kostow, K.E. and S.J. Zhou. 2006. The effect of an introduced summer steelhead hatchery stock on the productivity of a wild winter steelhead population. Transactions of the American Fisheries Society 135:825-841.

Kostow, K.E, Marshall AR, Phelps S.R. 2003. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society 132:780–790.

Kruzic, L. 2011. Personal communication. Fishery Biologist. National Marine Fisheries Service. Salmon Recovery Division. Roseburg, Oregon.

Kubicek, P. 2013. Personal communication. Senior Consulting Scientist, Pacific Gas & Electric Company San Ramon, California.

Kukulka, T., D.A. Jay. 2003. Impacts of Columbia River discharge on water surface elevation and salmonid habitat I. A non-stationary fluvial tide model, Journal of Geophysical Research 108(C9), 10.1029/2002JC001382

Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov, 2007: Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.

Kruzic, L. 2011. Fishery Biologist. National Marine Fisheries Service. Salmon Recovery Division. Roseburg, Oregon.

Labelle, M. 1992. Straying patterns of coho salmon (*Oncorhynchus kisutch*) stocks from southeast Vancouver Island, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 49:1843-1855.

Laetz, C.A., D.H. Baldwin, T.K. Collier, V. Herbert, J.D. Stark and N. L. Scholz. 2009. The Synergistic Toxicity of Pesticide Mixtures: Implications for Risk Assessment and the Conservation of Endangered Pacific Salmon. Environmental Health Perspectives, Volume 117, No. 3 | March 2009, 348-353.

Laird, A., B. Powell, and J. Anderson. 2013. Humboldt Bay Shoreline Inventory, Mapping and Sea Level Rise Vulnerability Assessment. Report to State Coastal Conservancy. 158 p.

Lancaster, M. 2013. Climate, Cumulative Effects and Conditions to Counter Them. Presentation at the Salmonid Restoration Federation annual conference in Fortuna, CA, March 15, 2013.

Lande, R. 1993. Risks of population extinction from demographic and environmental stochasticity and random catastrophes. American Naturalist. 142:911-927.

Landgridge, R.  2002.  Changing legal regimes and the allocation of water between two California Rivers.  Natural Resources Journal 42:  283-330.

Landsberg, J.H. 2002. The effects of harmful algal blooms on aquatic organisms.  Reviews of Fisheries Science 10, 113–390.

Langridge, R. 2002. Changing legal regimes and the allocation of water between two northern California rivers. Natural Resources Journal 42 (2):283–330.

Lanigan, S.H., S.N. Gordon, P.  Eldred, M. Isley, S. Wilcox, C. Moyer, and H.Andersen.  2012. Northwest Forest Plan – the first 15 years (1994-2008): status and trend of watershed condition. Gen. Tech. Rep. PNW-GTR-856. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Lanman, C.W., K. Lundquist, H. Perryman, J.E. Asarian, B. Dolman, R.B. Lanman, and M.M. Pollock.  2013.  The historical range of beaver (*Castor canadensis*) in coastal California: an updated review of the evidence.  California Fish and Game 99:  193-221.

Larkin, P.A.  1977. Pacific salmon. Pages 156-186 in J. A. Gulland, editor. Fish population dynamics.

Larson, Z.S.  2012.  Mill Creek fisheries restoration monitoring program final report, 2010-2012.  Prepared by Zachary S. Larson for Rowdy Creek Fish Hatchery, California Department of Fish and Wildlife.  82 p.

Lathrop R.C., S.R. Carpenter, J.C. Panuska, P.A. Soranno, and CF.A. Stow.  1998. Phosphorus Loading Reductions Needed to Control Blue-green Algal Blooms in Lake  Mendota. Canadian Journal of Fisheries and Aquatic Sciences 55:1169-1178.

Lawson, P.W.  1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries 18(8):6-10.

Lawson, P., E. A. Logerwell, N. J. Mantua, R. C. Francis, and V. N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*).  Canadian Journal of Fisheries and Aquatic Sciences. Vol. 61:360-373.

Learn, S.  2011.  Gold miner Cliff Tracy agrees to stop mining on Galice Creek in southwest Oregon.  The Oregonian, Friday, June 24, 2011.  1 p.

Lee, K.N.  1993.  Compass and gyroscope:  integrating science and politics for the environment. Island Press, Washington D.C.

Leider, S.A., Hulett, P.L., Loch, J.J., and Chilcote, M.W. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture, 88(3-4): 239–252.

Leidy, R.A., and G.R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River Basin, northwestern California. U.S. Fish and Wildlife Service, Sacramento, California, 38 p. (Available U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento Field Office, 2800 Cottage Way, Rm. 1803, Sacramento, CA 95825.)

Leopold, L.B. 1968, Hydrology for Urban Land Planning A Guidebook on the Hydrologic Effects of Urban Land Use, U.S. Geological Survey Circular 554, 18p.

Lestelle, L. C. 2007. Coho salmon (Oncorhynchus kisutch) life history patterns in the Pacific Northwest and California. Prepared for US Bureau of Reclamation, Klamath Area Office. Final Report, March.

Lettenmaier, D. P. and T. Y. Gan. 1990. Hydrologic Sensitivities of the Sacramento-San Joaquin River Basin, California, to Global Warming, Water Resources Research. 26(1): 69-86.

Levin P.S, R.W. Zabel, and J.G. Williams. 2001. The road to extinction is paved with good intentions: negative association of fish hatcheries with threatened salmon. Proceedings of the Royal Society of London 268: 1153–1158.

Levin, P.S. and N. Tolimieri. 2001. Differences in the impacts of dams on the dynamics of salmon populations. Animal Conservation, 4(4): 291-299.

Liermann, M. and R. Hilborn. 2001. Depensation: evidence, models, and implications. Fish and Fisheries 2: 33-58.

Ligon, F.K., W.E. Dietrich and W.J. Trush. 1995. Downstream Ecological Effects of Dams. Bioscience 45(3): 183-192.

Ligon, F.K., A. Rich, G. Rynearson, D. Thornburgh, and W. Trush. 1999. Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat. Prepared for the Resources Agency of California and the National Marine Fisheries Service; Sacramento, CA.

Lindley, S.T., R.S. Schick, E. Mora, P.B. Adams, J.J. Anderson, S. Greene, C. Hanson, B. May, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science 5: Article 4.

Lisle, T.E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California. Water Resources Research 18(6):1643-1651.

Lisle, T.E. 1989. Sediment transport and resulting deposition in spawning gravels, North Coast California. Water Resource Research 25: 1303-1319.

Lister, D.B., L.M. Thorson, and I. Wallace. 1981. Chinook and coho salmon escapements and coded-wire tag returns to the Cowichan-Koksilah river system, 1976-1979. Can. Manuscript Rep. Fish. Aquat. Sci. 1608, 168 p.

Litz, M.N.C., R.D. Brodeur, R.L. Emmett, S.S. Heppell, R.S. Rasmussen, L. O'Higgins and M.S. Morris. 2010. Effects of variable oceanographic conditions on forage fish lipid content and fatty acid composition in the northern California Current. Marine Ecology Progress Series 405: 71-85.

Loeffel, R.E., and H.O. Wendler. 1968. Review of the Pacific coast chinook and coho salmon resources with special emphasis on the troll fishery. Prepared by the U.S. working group of the Informal Committee on Chinook and Coho, 107 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Logerwell, E.A., Mantua, N.J., Lawson, P.W., Francis, R.C., and Agostini, V.N. 2003. Tracking environmental processes in the coastal zone for understanding and predicting Oregon coho (Oncorhynchus kisutch) marine survival. Fisheries Oceanography 12: 554–568.

Lorenz, J.M., and J.H. Eiler. 1989. Spawning Habitat and Redd Characteristics of Sockeye Salmon in the Glacial Taku River, British Columbia and Alaska. Transactions of the American Fisheries Society 118:495-502.

Love, M. 2012. Restoring Salmon Creeks Tidal Processes to Create a Diversity of Estuarine Habitats. Presentation to the Salmonid Restoration Federation's November 15, 2012, Coastal Off-channel and Tidal Habitat Restoration Symposium. Arcata, CA. Available online at: http://www.calsalmon.org/files/documents/tools/field-schools/CoastalSymposium2012_Love_RestoringSalmonCreeks.pdf

Luers, A.L., P.C. Frumhoff, K. Hayhoe, and M.D. Mastrandrea. 2007. How to avoid dangerous climate change: a target for U.S. emissions reductions. Union of Concerned Scientists (UCS), Cambridge, MA

Lum, J.L. 2003. Effects of smolt length and emigration timing on marine survival and age at maturity of wild coho salmon (*Oncorhynchus kisutch*) at Auke Creek, Juneau, Alaska. M.S. thesis, University of Alaska Fairbanks, Fairbanks, Alaska.

Lynch, D. D. and J.C. Risley. 2003, Klamath River Basin hydrologic conditions prior to the September 2002 die-off of salmon and steelhead: U.S. Geological Survey Water-Resources Investigations Report 03–4099, 10 p.

Macdonald, J.S., C.D. Levings, C.D. McAllister, U.H.M. Fagerlund, and J.R. McBride. 1988. A field experiment to test the importance of estuaries for chinook salmon (*Oncorhynchus tshawytscha*) survival: Short-term results. Canadian Journal of Fisheries and Aquatic Sciences 45(8): 1366-1377.

MacDonald, L., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects for forestry activities on streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, Region 10, NPS Section, WD-139, Seattle, Washington.

MacFarlane, R.B., S. Hayes, and B. Wells. 2008. Coho and Chinook Salmon Decline in California during the Spawning Seasons of 2007/'08. Unpublished memo.

Madej, M.A., Sutherland, D.G., Lisle, T.E., Pryor, B., 2009. Channel responses to varying sediment input: A flume experiment modeled after Redwood Creek, California. Geomorphology 103, 507–519.

Magilligan F.J. and K.H. Nislow. 2005. Changes in hydrologic regime by dams. Geomorphology 71: 61–78.

Magoulick, D.D. and R.M. Kobza. 2003. The role of refugia for fishes during drought: a review and synthesis. Freshwater biology 48:1186–1198.

Mantua, N., S. Hare, Y. Zhang, J. Wallace, and R. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production, Bulletin of the American Meteorological Society 78: 1069–1079.

Marine, K.R. and J.J. Cech Jr. 2004. Effects of High Water Temperature on Growth, Smoltification, and Predator Avoidance in juvenile Sacramento River Chinook Salmon. N. Amer. J. Fish. Man. 24:198-210

Marine Fish Conservation Network. 2007. Taking Stock: The Cure for Chronic Overfishing. www.conservefish.org/index.php?option=com_content&task=view&id=185&Itemid=228

Martin, A. 2009. Personal Communication. Fisheries Biologist, Yurok Tribal Fisheries Program.

Mason, J.C., and D.W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. Journal of the Fisheries Research Board of Canada 22(1): 172-190.

Mathews, S.B., and R. Buckley. 1976. Marine mortality of Puget Sound coho salmon (*Oncorhynchus kisutch*). Journal of the Fisheries Research Board of Canada 33: 1677-1684.

Mathews, S. B. and F. W. Olson. 1980. Factors affecting Puget Sound coho salmon (*Oncorhynchus kisutch*) runs. Canadian Journal of Fisheries and Aquatic Sciences 37(9):1373-1378.

Matthews, G.M., D.L. Park, S. Achord, and T.E. Ruehle. 1986. Static seawater challenge test to measure relative stress levels in spring Chinook salmon smolts. Transactions of the American Fisheries Society 115:236-244.

Mattole River and Range Partnership (MRRP). 2009. Mattole Integrated Coastal Watershed Management Plan, Foresight 2020. Mattole Restoration Council, Mattole Salmon Group, and Sanctuary Forest. 178 p.

Maule, A.G., C.B. Schreck, C.S. Bradford, and B.A. Barton. 1988. Physiological effects of collecting and transporting emigrating juvenile chinook salmon past dams on the Columbia River. Transactions of the American Fisheries Society 117:245-261.

May C.L. and D.C. Lee. 2004. The relationships among in-channel sediment storage, pool depth, and summer survival of juvenile salmonids in Oregon Coast Range streams. North American Journal of Fisheries Management 24:761–774.

May, C.W., E.B. Welch, R.R. Horner, J.R. Karr, and B.W. Mar. 1997. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams. Washington Department of Ecology, Olympia, WA.

May, R.M. 1973. Stability in randomly fluctuating versus deterministic environments. American Naturalist 107: 621-650.

McBain & Trush, Inc. 2012. Streamflow Thresholds for Juvenile Salmonid Rearing and Adult Spawning Habitat in the Mattole Headwaters Southern Sub-Basin. Prepared for Trout Unlimited by McBain & Trush, Inc., Arcata, CA. 45pp.

McCormick, S.D., R.L. Saunders, L.P. Hansen, and T.P. Quinn. 1998. Movement, migration, and smolting in Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 55(Suppl.1): 77–92.

McCullough, D. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Columbia Intertribal Fisheries Commission, Portland, OR. Prepared for the U.S. Environmental Protection Agency Region 10. Published as EPA 910-R-99-010.

McElhany P., T. Backman, C. Busack, S. Heppell, S. Kolmes, A. Maule, J. Myers, D. Rawding, D. Shively, A. Steel, C. Steward, and T. Whitesel. 2003. Interim report on viability criteria for Willamette and Lower Columbia Basin Pacific salmonids. Willamette/Lower Columbia Technical Recovery Team report, 31 March 2003. NOAA Fisheries, Seattle, Washington. Available at: www.nwfsc.noaa.gov/trt/wlc_viabrpt/complete.pdf.

McElhany, P., M. Ruckelshaus, M. Ford, T. Wainwright, and E. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42, 158p.

McGinnity, P.,P. Prodohl, A. Ferguson, R. Hynes, N. O'Maoi-le´idigh, N. Baker, D. Cotter, B. O'Hea, D. Cooke, G. Rogan, J. Taggart, and T. Cross. 2003. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as result of interactions with escaped farmed salmon. Proceedings of the Royal Society of London Series B 270: 2443-2450.

McGurk, M.D. 1996. Allometry of marine mortality of Pacific Salmon. Fish Bulletin 94:77-88

McHugh P. and P. Budy. 2006. Experimental effects of nonnative brown trout (*Salmo trutta*) on the individual- and population-level performance of native Bonneville cutthroat trout (*Oncorhynchus clarkii utah*). Transactions of the American Fisheries Society 135:1441–1455.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves, and L.A. Brown. 1994. Management history of eastside ecosystems: Change in fish habitat over 50 years, 1935 to 1992. 1994. Forest Service, U.S. Department of Agriculture.

McLean, J.E., P. Bentzen, and T.P. Quinn. 2003. Differential reproductive success of Sympatric, naturally spawning hatchery and wild steelhead trout (*Oncorhynchus mykiss*) through the adult stage. Canadian Journal of Fisheries and Aquatic Sciences 60(4): 433–440. doi:10.1139/f03-040.

McMichael, G.A., C.S. Sharpe, and T.N. Pearson. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society 126: 230–239.

McMichael, G.A., T.N. Pearsons, and S.A. Leider. 1999. Behavioral interactions among hatchery reared steelhead smolts and wild (*Oncorhynchus mykiss*) in natural streams. North American Journal of Fisheries Management 19:948-956.

Meengs, C.C. and R.T. Lackey. 2005. Estimating the size of historical Oregon salmon runs. Reviews in Fisheries Science 13:51-66.

Melbourne, B.A. and A. Hastings. 2008. Extinction risk depends strongly on factors contributing to stochasticity. Nature 454: 100-103.

Meleason, M.A., S.V. Gregory, and J. Bolte. 2002. Simulation of stream wood source distance for small streams in the western cascades, Oregon. Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests, W.F. Laudenslayer, Jr., P.J. Shea, B.E. Valentive, C.P. Weatherspoon, and T.E. Lisle (Editors). General Technical Report PSWGTR-181, USDA Forest Service, Pacific Southwest Research Station, Albany, California. 2002.

Mellina, E. and S. G. Hinch. 2009. Influences of Riparian Logging and In-Stream Large Wood Removal on Pool Habitat and Salmonid Density and Biomass: a Meta-Analysis. Canadian Journal of Forest Resources 39:1280-1301.

Merrell, T.R., Jr., and K.V. Koski. 1978. Habitat values of coastal wetlands for pacific coast salmonids. Pages 256–266 *in* P. E. Greeson, and J. R. Clark, editors. Wetland functions and values: the state of our understanding: proceedings of the national symposium on wetlands. American Water Resources Association, Minneapolis, Maryland.

Moffitt, C. M., B. C. Stewart, S. E. LaPatra, R. D. Brunson, J. L. Bartholomew, J. E. Peterson, and K. H. Amos. 1998. Pathogens and diseases of fish in aquatic ecosystems:

implications for fisheries and management. Journal of Aquatic Animal Health 10: 95–100.

Miller, B. and S. Sadro. 2003. Residence Time and Seasonal Movements of Juvenile Coho Salmon in the Ecotone and Lower Estuary of Winchester Creek, South Slough, Oregon. Transactions of the American Fisheries Society 132:546–559.

Miller, B., K. Nordholm, and R.J. Constable, Jr. 2008. West Fork Smith River Salmonid Life Cycle Monitoring Project, Draft Report 2007-2008, Oregon Department of Fish and Wildlife, Western Oregon Research and Monitoring Program.

Minshall, G.W. 2003. Responses of stream benthic macroinvertebrates to fire. Forest Ecology and Management 178: 155-161.

Mobrand, L., J. Barr, D. Campton, T. Evelyn, T. Flagg, C. Mahnken, L. Seeb, P. Seidel, and W. Smoker. 2005 . Hatchery Reform in Washington State: Principles and Emerging Issues. Fisheries, 30(6):11-23.

Montgomery D.R., B.D. Collins, J.M. Buffington, T.B. Abbe. 2003. Geomorphic effects of wood in rivers. In: Gregory, Stan V.; Boyer, Kathryn L.; Gurnell, Angela M., eds. The ecology and management of wood in world rivers. American Fisheries Society Symposium 37: 21-47.

Montgomery, D.R., K.M. Schmidt, H.M. Greenberg, W.E. Dietrich. 2000. Forest clearing and regional landsliding. Geology 28: 311-314.

Moore, T.L. and S.J. Ricker. 2012. Escapement, spawning distribution and migration patterns of adult salmonids in Freshwater Creek, 2011-2012. Anadromous Fisheries Resource Assessment and Monitoring Program, California Department of Fish and Game, Northern California – North Coast Region. December. 22 p.

Moring, J.R. and R.L. Lantz. 1975. The Alsea watershed study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I—Biological studies. Fishery Research Report 9. Oregon Department of Fish and Wildlife, Portland, Oregon.

Moore, K.M.S., K.K. Jones, J.M. Dambacher. 1997. Methods for stream habitat surveys. Oregon Department of Fish and Wildlife Information Reports 97-4, Fish Division, Portland.

Moore G.W., B.J. Bond, J.A. Jones, N. Phillips, and F.C. Meinzer. 2004. Structural and compositional controls on transpiration in 40-and 450-year-old riparian forests in western Oregon, USA. Tree Physiology 24:481–491.

Moring, J.R. and R.L. Lantz. 1975. The Alsea watershed study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I – Biological studies. Oregon Department of Fish and Wildlife, Fisheries Technical Report 9, 66 p.

Moseley, M., R.D. Harmel, R. Blackwell, and T. Bidwell. 1998. Grazing and riparian area management. p. 47-53. In: M.S. Cooper (ed.) Riparian Area Management Handbook. Oklahoma Cooperative Extension Service, Division of Agricultural Services and Natural Resources, Oklahoma State University and the Oklahoma Conservation Commission. www.okstate.edu/OSU_Ag/e-952.pdf

Mote, P.W. and 18 co-authors. 1999. Impacts of climate variability and change: Pacific Northwest. A report of the Pacific Northwest Regional Assessment Group for the U.S. Global Change Research Program. JISAO/SMA Climate Impacts Group, University of Washington, Seattle.

Moyle, P.B. 2002. Inland fishes of California. Revised and expanded. University of California Press, Berkeley, CA.

Moyle, P.B., J.A. Israel, and S.E. Purdy. 2008. Salmon, steelhead, and trout in California: status of an emblematic fauna. University of California, Davis. Available: www. caltrout.org/SOS-Californias-Native-Fish-Crisis-Final-Report.pdf.

Moyle, P., J. Kiernan, P. Crain, and R. Quinones. 2013. Climate Change Vulnerability of Native and Alien Freshwater fishes of California: A Systematic Assessment Approach. PLoS ONE 8(5): e63883.

Muir, W. D., D. M. Marsh, B. P. Sandford, S. G. Smith, and J. G. Williams. 2006. Post-Hydropower system delayed mortality of transported Snake River stream-type Chinook salmon: Unraveling the mystery. Transactions of the American Fisheries Society: Vol. 135(6) pp. 1523–1534.

Mullen, R.E. 1981. Oregon's Commercial Harvest of Coho Salmon, *Oncorhynchus kisutch* (Walbaum), 1892 – 1960. Information Report Series, Fisheries Number 81-3. Research and Development Section. Oregon Department of Fish and Wildlife. Corvalis, Oregon. 167 p.

Müller-Schwarze, D., & L. Sun. 2003. The beaver: natural history of a wetlands engineer. Cornell University Press.

Mulvey, M., R. Leferink, and A. Borisenko. 2009. Willamette Basin rivers and streams assessment. DEQ 09-LAB-016. Oregon Department of Environmental Quality, Portland, Oregon.

Mundy, P.R. 1997. The role of harvest management in the future of Pacific salmon populations: shaping human behavior to enable the persistence of salmon. In: Stouder, Deanna J., Peter A. Bisson, and Robert J. Naiman, editors. Pacific Salmon and Their Ecosystems: Status and Future Options. Chapman and Hall, Inc., New York, NY, p. 315-329.

Murphy, G.I. 1952. An analysis of silver salmon counts at Benbow Dam, South Fork Eel River California. California Fish Game 38(1):105-112.

Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska-requirements for protection and restoration. U.S. Department of Commerce (NOAA) Coastal Ocean Program. Decision Analysis Series No. 7.

Murphy, M.L., J.F. Thedinga, K.V. Koski, and G.B. Grette. 1984. A stream ecosystem in an old-growth forest in southeastern Alaska. Part V: seasonal changes in habitat utilization by juvenile salmonids. Pages 89–98 in W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley, editors. Symposium proceedings on fish and wildlife relationships in old-growth forests. American Institute of Fisheries Research Biologists, Auke Bay, Alaska.

Murray, C.A., and C.D. Ziebell. 1984. Acclimation of rainbow trout to high pH to prevent stocking mortality in summer. Progressive Fish-Culturist 46:176-179.

Murray, C.B., T.D. Beacham, and J.D. McPhail. 1990. Influence of parental stock and incubation on the early development of coho salmon (*Oncorhynchus kisutch*) in British Columbia. Canadian Journal of Zoology 68: 347-358.

Naiman, R.J., Johnston, C.A. & Kelley, J.C. 1988. Alteration of North American streams by beaver. Bio-science 38: 753–762.

Naiman, R. J., J. S. Bechtold, T. J. Beechie, J. L. Latterell, and R. V. Pelt. 2010. A Process-Based View of Floodplain Forest Patterns in Coastal River Valleys of the Pacific Northwest. Ecosystems 13: 1-31.

Naiman, R. J. and Henri Decamps. 1997. The Ecology of Interfaces: Riparian Zones. Annual Review of Ecology and Systematics 28: 621-658.

Nakamoto, R.J. 1998. Effects of timber harvest on aquatic vertebrates and habitat in the North Fork Caspar Creek. Pages 87-96 in R.R. Ziemer (technical coordinator). Proceedings of the Conference on Coastal Watersheds: the Caspar Creek Story, 6 May 1998, Ukiah, California. General Technical Report PSW GTR-168. Pacific Southwest Research Station, Forest Service, US Department of Agriculture, Albany, California.

Naman, S.W. 2008. Predation by hatchery steelhead on natural salmon fry in the Upper Trinity River, California. M.S. Thesis, Humboldt State University, December 2008. 74 pp. Available online at: http://hdl.handle.net/2148/449.

Naman, S.W. and C.S. Sharpe. 2010. Predation by juvenile hatchery salmonids on natural produced salmonids in the freshwater environment: A review of studies, two case histories, and implications for management.

Narver, D.W. 1978. Ecology of juvenile coho salmon: can we use present knowledge for stream enhancement? Pages 38-42 in B. G. Shephard and R. M. J. Grinetz (eds.). Proc. 1977 Northeast Pacific chinook and coho salmon workshop. Dept. Fish. Environ., Vancouver. Canada Fish. Marine Servo Tech. Rep. 759.

National Marine Fisheries Service (NMFS). 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. September 1996. 5pp.

National Marine Fisheries Service (NMFS). 1997. Endangered Species Act - Section 7 Consultation, Biological Opinion and Conference Opinion on Continued Implementation of Land and Resource Management Plans (USFS) and Land Use Planning Documents (BLM): USDA Forest Service: Klamath, Mendocino, Shasta-Trinity, and Six Rivers National Forests; USDI Bureau of Land Management: Arcata, Clear Lake, and Redding Resource Areas. National Marine Fisheries Service (NMFS), Southwest Region, Long Beach, California. June 20.

National Marine Fisheries Service (NMFS). 1998. Factors Contributing to the Decline of Chinook Salmon: An Addendum to the 1996 West Coast Steelhead Factors for Decline Report. Northwest Region, Protected Resources Division. Portland, Oregon. 74 p.

National Marine Fisheries Service (NMFS). 1999a. Supplemental Biological Opinion and Incidental Take Statement: The Pacific Coast Salmon Plan and Amendment 13 to the Plan. 51 p.

National Marine Fisheries Service (NMFS). 1999b. Memo to file: Endangered Species Act – Section 7 Consultation on the Fishing Conducted Under the Pacific Coast Groundfish Fishery Management Plan. From: William Stelle, Jr. June 30, 1999. 9 p.

National Marine Fisheries Service (NMFS). 2001. Status review update for coho salmon (*Oncorhynchus kisutch*) from the Central California Coast and the California Portion of the Southern Oregon/Northern California Coast Evolutionarily Significant Units. Southwest Fisheries Science Center, Santa Cruz, California. April 12. 43 p.

National Marine Fisheries Service. 2002a. Biological Opinion on Artificial propagation in the Hood Canal and Eastern Strait of Juan de Fuca Regions of Washington State. 285 pages.

National Marine Fisheries Service. 2002b. Endangered Species Act Section 7 Consultation Biological Opinion for the Proposed License Amendment for the Potter Valley Project (FERC Project #77-110). Issued for Federal Energy Regulatory Commission on 11/26/02 by NOAA NMFS Southwest Region, Long Beach, CA. 140 p.

National Marine Fisheries Service (NMFS). 2003a. Amendment 17 to the Pacific Coast Groundfish Fishery Management Plan (Multi-year Management and the Specifications and Management Measures Process), including Environmental Assessment, Regulatory Impact Review, and Initial Regulatory Flexibility Analysis. 124 p.

National Marine Fisheries Service (NMFS). 2006. Endangered Species Act (ESA) Section 7 Consultation – Supplemental Biological Opinion on the Pacific Fishery Management Council's Groundfish Fishery Management Plan. Sustainable Fisheries Division, Northwest Regional Office. Signed March 11, 2006. Consultation number 2006/00754.

National Marine Fisheries Service (NMFS). 2007. Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance. NOAA's National Marine Fisheries Service Northwest Region and Northwest Fisheries Science Center. 66 p.

National Marine Fisheries Service (NMFS). 2008. Environmental Protection Agency Registration of Pesticides Containing Chlorpyrifos, Diazinon, and Malathion. National Marine Fisheries Service Endangered Species Act Section 7 Consultation Biological Opinion. NMFS, Silver Springs Md. 478 p.

National Marine Fisheries Service (NMFS). 2009. Letter to Stan Dixon, Chair of the California Board of Forestry and Fire Protection regarding NMFS' comments on the development of the Anadromous Salmonid Protection Rules. Southwest Region. September 8.

National Marine Fisheries Service (NMFS). 2010. Biological Opinion on the Continued Prosecution of the U.S. West Coast Pacific Sardine Fishery under the Coastal Pelagic Species Fishery Management Plan. 82 p. December 10, 2010.

National Marine Fisheries Service (NMFS). 2011. Southern Oregon/Northern California Coast Recovery Domain 5-Year Review: Summary and Evaluation of Southern Oregon/Northern California Coast Coho Salmon ESU. National Marine Fisheries Service Southwest region. Long Beach, California. 59 p.

National Marine Fisheries Service (NMFS). 2013. Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species. October 1, 2010 – September 30, 2012. National Marine Fisheries Service. Silver Spring, Maryland. 28 p.

National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). 2013. Biological Opinions on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species. 590 p.

National Marine Fisheries Service (NMFS) and California Department of Fish and Game (CDFG). 2001. Joint Hatchery Review Committee Final report on Anadromous Salmonid Fish Hatcheries in California. December 3, 2001

National Oceanic and Atmospheric Administration (NOAA). 2004. Report on the delineation of regional ecosystems. Produced by the NOAA Regional Ecosystem Delineation Workgroup as a result of the Regional Ecosystem Delineation Workshop. Charleston, SC. August 21-September 1, 2004.

National Oceanic and Atmospheric Administration (NOAA). 2012. State of the Climate, 2012. Available at: www.ncdc.noaa.gov/sotc/.

National Research Council (NRC). 1996. Upstream: salmon and society in the Pacific Northwest. National Academy Press. Washington, D.C. 452 p.

National Research Council (NRC). 1996. Upstream: Salmon and Society in the Pacific 25 Northwest. National Research Council Committee on Protection and Management of Pacific Northwest Anadromous Salmonids. National Academy Press. Washington, DC.

National Research Council (NRC). 2004. Endangered and threatened fishes in the Klamath River basin: causes of decline and strategies for recovery. Committee on Endangered and Threatened Fishes in the Klamath River Basin, Board of Environmental Toxicology, Division on Earth and Life Studies, Washington D.C. 398 p.

National Research Council (NRC). 2006. Dynamic Changes in Marine Ecosystems: Fishing, Food Webs, and Future Options. Washington (DC), National Academies Press.

Natural Resources Conservation Service (NRCS). 2013. Natural Resources Conservation Service Conservation Practice Standard. Riparian Forest Buffer. Code 391.

National Wildlife Federation (NWF). 2007. Sea Level Rise and Coastal Habitats in the Pacific Northwest: An analysis for the Puget Sound, Southwestern Washington, and Northwestern Oregon. 106 pp.

Neave, F. 1949. Game fish populations on the Cowichan River. Fisheries Research Board of Canada Bulletin 84.

Nehlsen. W., J. Williams, and J. Lichatowich. 1991. Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. Fisheries 16(2): 4–21.

Newcombe, C.P. and J.O.T. Jensen. 1996. Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. North American Journal of Fisheries Management 16: 693-727.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Ecosystems. North American Journal of Fisheries Management. 11: 72-82.

Nichols, K. and J.S. Foott. 2005. Health Monitoring of Juvenile Klamath River Chinook Salmon, FY 2004 Investigational Report. USFWS California-Nevada Fish Health Center, Red Bluff, CA.

Nichols K, K. True, R. Fogerty, and L. Ratcliff. 2008. Klamath River juvenile salmonid health monitoring, April-August 2007. FY 2007 Investigational report. US Fish and Wildlife Service, CA-NV Fish Health Center

Nichols, K. M., Young, W. P., Danzmann, R. G., Robison, B. D., Rexroad, C., Noakes, M., Phillips, R. B., Bentzen, P., Spies, I., Knudsen, K., Allendorf, F. W., Cunningham, B. M., Brunelli, J., Zhang, H., Ristow, S., Drew, R., Brown, K. H., Wheeler, P. A. and Thorgaard, G. H. 2003. A consolidated linkage map for rainbow trout (*Oncorhynchus mykiss*). Animal Genetics, 34: 102–115. doi: 10.1046/j.1365-2052.2003.00957.x

Nickelson, T.E. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon (*Oncorhynchus kisutch*) in the Oregon production area. Canadian Journal of Fisheries and Aquatic Sciences 43: 527-535.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43: 2443-2449.

Nickelson, T.E. 1998. A Habitat-Based Assessment of Coho Salmon Production Potential and Spawner Escapement Needs for Oregon Coastal Streams. Oregon Department. Fish and Wildlife, Information Report, 98-4, Salem

Nickelson, T. E. 2001. Population assessment: Oregon Coast Coho Salmon ESU. Oregon Department of Fish and Wildlife, Portland, Oregon, Oregon Department of Fish and Wildlife Information Report 2001-02.

Nickelson, T. 2003. The influence of hatchery coho salmon (Oncorhynchus kisutch) on the productivity of wild coho salmon populations in Oregon coastal basins. Can J Fish Aquat Sci 60:1050–1056

Nickelson, T.E., and P.W. Lawson. 1998. Population viability of coho salmon, *Oncorhynchus kisutch*, in Oregon coastal basins: application of a habitat-based life cycle model. Canadian Journal of Fisheries and Aquatic Sciences 55:2383-2392.

Nickelson, T.E., J.W. Nicholas, A.M. McGie, R.B. Lindsay, D.L. Bottom, R.J. Kaiser, and S.E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Oregon Department of Fish and Wildlife, Research Development Section and Ocean Salmon Management. 83 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Nielsen, J. L. 1994. Invasive cohorts: impacts of hatchery reared coho salmon on the trophic, developmental, and genetic ecology of wild stocks. Pages 361–385 *in* D. J. Stouder, K. L. Fresh, and R. Feller, editors. Theory and application in fish feeding ecology. University of South Carolina Press, Columbia.

Nielsen-Pincus, M. and C. Moseley. 2010. Economic and employment impacts of forest and watershed restoration in Oregon. Ecosystem Workforce Program Briefing Paper Number 24, Spring 2010, University of Oregon Institute for a sustainable environment. 28 p. Available at: http://www.oregon.gov/OWEB/MONITOR/Pages/job_creation_local_economies.aspx.

Nimick, D.A., C.H. Gammons, and S.R. Parker. 2011. Diel biogeochemical processes and their effect on the aqueous chemistry of streams: A review. Chemical Geology 283:3–17.

Nislow, K.H. and J.D. Armstrong. 2012. Towards a life-history based management framework for the effects of flow juvenile salmonids in streams and rivers. Fisheries Management and Ecology 19, 451–463.

North Coast Regional Water Quality Control Board (NCRWQCB). 2005. Staff Report for the Action Plan for the Scott River Watershed Sediment and Temperature Total Maximum Daily Loads. NCRWQCB, Santa Rosa, CA. http://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/scott_river/staff_report.shtml

Northcote, T.G. and D.Y. Atagi. 1997. Pacific salmon abundance trends in the Fraser River watershed compared with other British Columbia systems. In: Pacific salmon and their ecosystems. D. J. Strouder, P.A Bisson, and R. J. Naiman, editors. Chapman and Hall. New York, New York.

Ock, G., and G. M. Kondolf. 2012. Assessment of Ecological Roles of Gravel Bar Features Restored by Gravel Augmentation and Channel Rehabilitation Activities Below Lewiston Dam in the Trinity River, California. USBR Science and Technology Program Scoping Report, Weaverville, California.

O'Neal, J.S. 2007. Snorkel surveys. Pp. 335-340. *In* Johnson, D.H., B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons, Eds. Salmonid Field Protocols Handbook. Techniques for Assessing Status and Trends in Salmon and Trout Populations. Amer. Fish. Soc., State of the Salmon. 497 p.

Opperman, J.J., K.A. Lohse, C. Brooks, N.M. Kelly,, and A.M. Merenlender.2005. Influence of land use on fine sediment in salmonid spawning gravels within the Russian River Basin, California. Canadian Journal of Fisheries and Aquatic Sciences 62: 2740–2751.

Oregon Coastal Salmon Restoration Initiative. 1997. The Oregon Plan for Salmon and Watersheds. Submitted to National Marine Fisheries Service March 1997. Available for download here: http://www.oregon.gov/OPSW/pages/archives/archived.aspx#anchor-plan.

Oregon Department of Environmental Quality (ODEQ). 2000. Oregon Nonpoint Source Control Program Plan, 2000 Update. ODEQ, Portland, Oregon. 190 p.

Oregon Department of Environmental Quality (ODEQ). 2005. Oregon Coast Coho Assessment: Water Quality Report to Oregon Plan for Salmon and Watershed Assessment of the Status of Oregon Coastal Coho. Oregon Department of Environmental Quality, Portland, OR.

Oregon Department of Fish and Wildlife (ODFW). 1998. Hatchery Genetic Management Plan for Cole Rivers Hatchery. 49 p.

Oregon Department of Fish and Wildlife (ODFW). 2003. Native Fish Conservation Policy, 635-007-0502 through 0509. November 8, 2002; revised September 12, 2003.

Oregon Department of Fish and Wildlife (ODFW). 2005a. Oregon Native Fish Status Report. Volume II. Assessment Methods and Population Results. Salem, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 2005b. The Importance of Beaver (Castor Canadensis) to Coho Habitat and Trend in Beaver Abundance in the Oregon Coast Coho ESU. ODFW, Portland, OR. 11 p.

Oregon Department of Fish and Wildlife (ODFW). 2006. Letter to Tommy Williams, Chair, SONCC TRT Workgroup. February 15, 2006. 15 p.

Oregon Department of Fish and Wildlife (ODFW). 2007. Letter to Tommy Williams, Chair, SONCC TRT Workgroup. September 19, 2007. 11 p.

Oregon Department of Fish and Wildlife (ODFW). 2008a. Oregon fish passage barriers database. State-wide inventory of known barriers to fish passage. Accessed online on 6/23/2014 at http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=134&XMLname=44.xml

Oregon Department of Fish and Wildlife (ODFW). 2008b. Limiting factors and threats to the recovery of Oregon coho populations in the Southern Oregon-Northern California Coast Evolutionarily Significant Unit: Results of Expert Panel deliberations. September 5, 2008. 38 p.

Oregon Department of Fish and Wildlife (ODFW). 2008b. Oregon guidelines for timing of in-water work to protect fish and wildlife resources. June.

Oregon Department of Fish and Wildlife (ODFW). 2010. Number wild coho salmon observed at Gold Ray Dam Counting Station, 1987-2009. Obtained from Tom Satterthwaite, ODFW, 7/15/10.

Oregon Department of Fish and Wildlife (ODFW). 2011. 2011 Oregon Sport Fishing Regulations. 108 p.

Oregon Department of Fish and Wildlife (ODFW). 2012. Estimates of abundance of wild adult coho spawners in the Southern Oregon/Northern California Coast Coho ESU, 1998-2012, based on counts at Huntley Park . Accessed 1/13/14 from site: http://oregonstate.edu/dept/ODFW/spawn/pdf%20files/coho/AnnualEstSONCC1998-2012.pdf

Oregon Department of Fish and Wildlife (ODFW). 2014a. Cole Rivers Hatchery Operation Plan. 32 p.

Oregon Department of Fish and Wildlife (ODFW). 2014b. Elk River Hatchery Operation Plan. 17 p.

Oregon Division of State Lands. 1999. Placer mining in the State of Oregon. A Guide To Recreational And Small-Scale Placer Mining In Oregon's Waterways: What You Should Know Before You Begin. 21 pages.

Oregon Department of Transportation (ODOT). 1999. Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices. Salem, OR. July. 51 p.

Oregon Water Resources Department (OWRD). 2009. Water Rights in Oregon, An Introduction to Oregon's Water Laws. Centennial Edition. September 2009. 48 Pages

Pacific Fishery Management Council (PFMC). 1999. Review of the 1998 ocean salmon fisheries. Chapter 3 – Inside Coho salmon fisheries and spawning escapements. Pacific Fishery Management Council, Portland, Oregon. *Available from* Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Pacific Fishery Management Council (PFMC). 2000a. *Review of 1999 Ocean Salmon Fisheries.* (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2000b. Amendment 14 to the Pacific Coast Salmon Plan (1997), Incorporating the Regulatory Impact Review/Initial Regulatory Flexibility Analysis and Final Supplemental Environmental Impact Statement. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384. Accessed 5/5/14 from www.pcouncil.org.

Pacific Fishery Management Council (PFMC). 2001. Review of 2000 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2002. Review of 2001 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2003. Review of 2002 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council(PFMC). 2004. Review of 2003 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2005a. Review of 2004 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2005b. Regulatory Amendment for the Coastal Pelagic Species Fishery Management Plan: Allocation of the Pacific Sardine Harvest Guideline. August 2003.

Pacific Fishery Management Council (PFMC). 2006. Review of 2005 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2007. Review of 2006 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2008. Review of 2007 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2009. Review of 2008 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384

Pacific Fishery Management Council (PFMC). 2010. Review of 2009 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2011a. Review of 2010 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2011b. Coastal Pelagic Species Fishery Management Plan. As amended through Amendment 13. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2011. Amendment 16 to the Pacific Coast Salmon Plan (1997), Incorporating the Regulatory Impact Review/Initial Regulatory Flexibility Analysis and Final Supplemental Environmental Impact Statement. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384. Accessed 5/5/14 from www.pcouncil.org.

Pacific Fishery Management Council (PFMC). 2012. Review of 2011 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2013a. Review of 2012 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery

Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council. 2013b. Pacific Coast Fishery Ecosystem Plan for the U.S. Portion of the California Current Large Marine Ecosystem –Public Review Draft, February 2013. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2013. Pacific Coast Fishery Ecosystem Plan for the U.S. Portion of the California Current Large Marine Ecosystem – Public Review Draft, February 2013. (Document prepared by the Council for its advisory entities. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384. Accessed 5/5/14 from www.pcouncil.org.

Pacific Fishery Management Council (PFMC). 2014. Status of the Pacific Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches. Stock Assessment and Fishery Evaluation 2013. 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220.

Pacific Fishery Management Council (PFMC) and National Marine Fisheries Service (NMFS). 2011. Environmental assessment for Pacific coast salmon plan amendment 16: classifying stocks, revising status determination criteria, establishing annual catch limits and accountability measures, and *de minimis* fishing provisions. PFMC, Portland, Oregon. 525 p.

PacifiCorp. 2012. PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon. Prepared by PacifiCorp Energy, Inc, Portland, OR. Submitted to the National Marine Fisheries Service, Arcata Area Office, Arcata, CA. February 16, 2012.

Pacific Lumber Company (PALCO). 1999. Habitat Conservation Plan for the Properties of The Pacific Lumber Company, Scotia Pacific Holding Company, and Salmon Creek Corporation February 1999 Revision. 166 p.

Parker, M. 1986. Beaver, water quality and riparian systems. Pages 88-94 in: Proceedings of the Wyoming Water and Stream-side Zone Conference. Wyoming Water Research Centre, University of Wyoming, Laramie 1.

Parkhill K.L., J.S. Gulliver. 2002. Effect of inorganic sediment on whole-stream productivity. Hydrobiologia 472:5–17.

Patenaude, J. R. 2004. Preliminary Assessment of Flooding in Lower Elk River. Staff Report of the North Coast Regional Water Quality Control Board, Crescent City, California.

Pearcy, W.G. 1992. Ocean ecology of North Pacific salmonids. Seattle, WA, Washington Sea Grant Program, University of Washington Press.

Pearse, D.E., C.J. Donohoe, and J.C. Garza. 2007. Population genetics of steelhead (*Oncorhynchus mykiss*) in the Klamath River. Environmental Biology of Fishes 80, 377-387.

Pearsons, T. N., A. L. Fritts, and J. L. Scott. 2007. The effects of hatchery domestication on competitive dominance of juvenile spring Chinook salmon (*Oncorhynchus tshawytscha)*. Canadian Journal of Fisheries and Aquatic Sciences 64:803-812.

Pearsons, T.N., G.A. McMichael, S.W. Martin, E.L. Bartrand, M. Fischer, and S.A. Leider. 1994. Yakima River species interactions studies. Annual Report for FY 1993. DOE/BP-99852- 2. Bonneville Power Administration, Portland, Oregon.

Perry, R.W, Risley, J.C., Brewer, S.J., Jones, E.C., Rondorf, D.W. 2011. Simulating daily water temperatures of the Klamath River under dam removal and climate change scenarios. U.S. Geological Survey Open-File Report 2011-1243:78pp.

Perry, T. D. 2007. Do vigorous young forests reduce streamflow? Results from up to 54 years of streamflow records in eight paired-watershed experiments in the HJ Andrews and South Umpqua Experimental Forests (Doctoral dissertation).

Pess, G. R., M.L. McHenry, T.J. Beechie, and J. Davies. 2008. Biological impacts of the Elwha River dams and potential salmonid responses to dam removal. Northwest Science 82(sp1): 72-90.

Pess, G.R., D.R. Montgomery, E.A. Steel, R.E. Bilby, B.E. Feist, and H.M. Greenberg. 2002. Landscape characteristics, land use, and coho salmon (Oncorhynchus kisutch) abundance, Snohomish River, Wash., U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 59(4): 613-623.

Peterman, R.M. 1982. Non-linear relation between smolts and adults in Babine Lake sockeye populations and implications for other salmon populations. Canadian Journal of Fisheries and Aquatic Sciences 39: 904-913.

Peterson, N.P. 1982. Immigration of juvenile coho salmon (*Oncorhynchus kisutch*) into riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39: 1308-1310.

Peterson, W.T. and J.E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: a multivariate approach. Deep-Sea Research Part II 50: 2499-2517.

Peterson, W.T. and F.B. Schwing. 2003. A new climate regime in northeast pacific ecosystems. Geophysical Research Letters 30.

Peterson, W.T. and Hooff, R.C. 2005. Long term variations in hydrography and zooplankton in coastal waters of the northern California Current off Newport Oregon, *In* Proceedings of International Symposium on Long-term variations in the Coastal Environments and Ecosystems. 27-28 September 2004, Matsuyama, Japan, pp. 36-44.

Peterson, W. T., C. A. Morgan, E. Casillas, J. L. Fisher, and J. W. Ferguson. 2012. Ocean ecosystem indicators of salmon marine survival in the Northern California Current. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center. Available from: http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/documents/Peterson_etal_2012.pdf

Peterson, W. T., C. A. Morgan, J. O. Peterson, J. L. Fisher, B. J. Burke, and K. Fresh. 2013. Ocean ecosystem indicators of salmon marine survival in the Northern California Current. December.

Petersson, E., and T. Järvi. 1993. Differences in reproductive traits between sea-ranched and wild sea-trout (*Salmo trutta*) originating from a common stock. Nordic Journal of Freshwater Research 68:91–97.

Pfeffer, W.T., J.T. Harper, and S. O'Neel. 2008. Kinematic constraints on glacier contributions to 21st-century sea level rise. Science AAAS. W.T. Science 321. Available at: http://www.sciencemag.org/content/321/5894/1340.full

Pinnix, W., P. Nelson, G. Stutzer, and K. Wright. 2013. Residence time and habitat use of coho salmon in Humboldt Bay, California: An acoustic telemetry study. Environmental Biology of Fishes 96: 315-323.

Platts, W.S., R.J. Torquemada, M.L. McHenry, and C.K. Graham. 1989. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South-Fork Salmon River, Idaho. Transactions of the American Fisheries Society 118: 274–283.

Poff, B., K. A. Koestner, D. G. Neary, and V. Henderson. 2011. Threats to Riparian Ecosystems in Western North America: An Analysis of Existing Literature. Journal of the American Water Resources Association p. 1-14.

Pollet, J. and P. N. Omi. 2002. Effect of thinning and prescribed burning on crown fire severity in ponderosa pine forests. International Journal of Wildland Fire 11(1): 1-10. Pollock, M. M. and T. J. Beechie. 2014. Does riparian forest restoration thinning enhance biodiversity? The ecological importance of large wood. Journal of the American Water Resources Association *In Press*:1-17.

Pollock, M. M., T. J. Beechie, and H. Imaki. 2012. Using reference conditions in ecosystem restoration: an example for riparian conifer forests in the Pacific Northwest. Ecosphere **3**:art98 (online).

Pollock M.M., T.J. Beechie, C.E. Jordan. 2007. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms 32: 1174–1185.

Pollock, M.M., M. Heim, M. and D. Werner. 2003. Hydrologic and geomorphic effects of beaver dams and their influence on fishes. *In*: The Ecology and Management of Wood in

World Rivers, S.V. Gregory, K. Boyer and A. Gurnell, eds. American Fisheries Society, Bethesda, MD, pp. 213–233.

Pollock, M.M., G.R. Pess, T.J. Beechie, and D.R. Montgomery. 2004. The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA. North American Journal of Fisheries Management 24:749–760.

Pollock, M. M. and T. J. Beechie. 2014. Does riparian forest restoration thinning enhance biodiversity? The ecological importance of large wood. Journal of the American Water Resources Association **xx**:1-17.

Pollock, M.M., Beechie, T.J. and Jordan, C.E. 2007. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms 32: 1174–1185.

Pollock, M. M., T. J. Beechie, and H. Imaki. 2012. Using reference conditions in ecosystem restoration: an example for riparian conifer forests in the Pacific Northwest. Ecosphere **3**:art98 (online).

Pollock, M. M., J. M. Wheaton, N. Bouwes, C. Volk, N. Weber, C. E. Jordan. 2012. Working with beaver to restore salmon habitat in the Bridge Creek intensively monitored watershed: Design rationale and hypotheses. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-120, 47 p.

Swales, S and M. M. Pollock (in prep). North American Beaver and the Recovery of California Coho Salmon. Fisheries Branch, California Department of Fish and Wildlife.

Polos, J. (Yurok Tribal Fisheries Program). 1994. Memo to Greg Bryant (NMFS), 5/7/94.

Power, M.E., W.E. Dietrich, and J.C. Finlay. 1996. Dams and downstream aquatic biodiversity: Potential food web consequences of hydrologic and geomorphic change. Environmental Management 20:887–895.

Preusch, M. 2009. Feds cracking down on illegal mining on Oregon's public lands. The Oregonian, Tuesday, December 2, 2009. 1 p.

Price, E. O. 1984. Behavioral aspects of animal domestication. Quarterly Review of Biology 59(1):1– 32.

Quartz Valley Indian Reservation. 2009. Water Quality Monitoring and Assessment Report 2008. By Crystal Bowman, Environmental Director, QVIR, Fort Jones, CA. 65 p.

Quinn, T. P. 1993. A review of homing and straying of wild and hatchery-produced salmon. Fisheries Research 18:29-44.

Quinn, T. P. 1997. Homing, straying, and colonization. W. Stewart Grant (editor). Genetic effects of straying of non-native fish hatchery fish into natural populations: proceedings of the workshop. U.S. Department of Commerce, NOAA Technical Memo. NMFS-

NWFSC-30. Available: www.nwfsc.noaa.gov/publications/techmemos/tm30/tm30.html#toc. (September 2003).

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. UBC Press, Vancouver.

Quinn, T.P., N. Harris, J. A. Shaffer, C. Byrnes, and P. Crain. 2013. Juvenile coho salmon in the Elwha River estuary prior to dam removal: seasonal occupancy, size distribution, and comparison to nearby Salt Creek. Transactions of the American Fisheries Society 142: 1058–1066.

Quinn, T. P. and N. P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53: 1555-1564.

Quinn, T.P., L.A. Vollestad, J. Peterson, and V. Galluci. 2004. Influence of freshwater and marine growth on egg size-egg number tradeoffs in coho and Chinook salmon. Transactions of the American Fisheries Society 133: 55-65.

Ransom, B.O. 2007. Extended freshwater rearing of juvenile Coho salmon (*Oncorhynchus kisutch*) in Northern California streams. Master's Thesis – Humboldt State University, Arcata, CA.

Raymond, H.L. 1979. Effects of dams and impoundments on migrations of juvenile Chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108: 505-529.

Reeves, G., L. Benda, K. Burnett, P. Bisson, J. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. Pp. 334-349 *In*: J.L. Nielsen (ed). Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Special Symposium 17, Bethesda, Maryland.

Reeves, G.H., F.H. Everest and J.R. Sedell. 1993. Diversity of juvenile anadromous salmonid assemblages in coastal Oregon basins with different levels of timber harvest. Transactions of the American Fisheries Society: 122(3). May 1993.

Reeves G. H., F.H. Everest, and T.E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. US Forest Service General Technical Report PNW 245.

Reeves, G.H., P.A. Bisson, and J.M Dambacher. 1998. Fish communities. Pages 200–234 in R. J. Naiman, R. E. Bilby, and S. Kantor editors. River ecology and management: lessons from the Pacific coastal ecosystem. Springer, New York.

Reid, L.M., N.J. Dewey, T.E. Lisle, S. Hilton. 2010. The incidence and role of gullies after logging in a coastal redwood forest. Geomorphology 117: 155–169.

Reid L.M. and J. Lewis. 2009. Rates, timing, and mechanisms of rainfall interception loss in a coastal redwood forest. Journal of Hydrology 375: 459–470.

Reinhardt, U. 2001. Selection for surface feeding in farmed and sea - ranched Masu salmon juveniles. Transactions of the American Fisheries Society 130:155–158.

Reisenbichler, R.R. and McIntyre, J.D. 1977 Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, Salmo gairdneri. Can. J. Fish. Res. Board 34, 123–128.

Reisenbichler, R.R. and S.P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES J. Mar. Sci. 56:459–466.

Resighini Rancheria Environmental Department. 2006. Draft Revised Tribal Water Quality Ordinance of the Resighini Rancheria. Prepared with assistance from Kier Associates, Arcata, CA. Resighini Rancheria, Klamath, CA.

Richter, A. and S.A. Kolmes. 2003. Maximum Temperature: Upper Optimal Temperature Limits for Salmonids in the Willamette and Lower Columbia Rivers. Appendix L of Interim Report on viability criteria for Willamette and Lower Columbia Basin Pacific salmonids.

Richardson, C. J., N.E. Flanagan, M. Ho, & J.W. Pahl. 2011. Integrated stream and wetland restoration: a watershed approach to improved water quality on the landscape. Ecological Engineering, 37(1), 25-39.

Richardson, J. S., R. J. Naiman, and P. A. Bisson. 2012. How Did Fixed-Width Buffers Become Standard Practice for Protecting Freshwaters and their Riparian Areas from Forest Harvest Practices? Freshwater Science 31(1):232-238.

Ricker, S. 2002. Annual report; Bear River juvenile salmonid emigration run-size estimates, 2000-2001. Project 2a4. California Department of Fish and Game, Northern California - North Coast Region. Steelhead Research and Monitoring Program . Arcata, CA January.

Ricks, C.L. 1995. Effects of channelization on sediment distribution and aquatic habitat at the mouth of Redwood Creek, northwestern California. Pages Q1-Q17, in: Nolan, K.M., H.M. Kelsey, and D.C. Marron, eds., Geomorphic processes and aquatic habitat in the Redwood Creek basin, northwestern California . U.S. Geological Survey Professional Paper 1454. Washington, DC. 21 pp.

Rieman, B., R. Gresswell, J. Rinne. 2012. Fire and Fish: a synthesis of observation and experience. *In*: C. Luce, P. Morgan, K. Dwire, D. Isaak, Z. Holden, B. Rieman. 2012. Climate change, forests, fire, water, and fish: Building resilient landscapes, streams, and managers. Gen. Tech. Rep. RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 207 p.

Riverbend Sciences. 2014. Beaver Mapper. Online map of beaver distribution in California and Oregon. Riverbend Sciences, Weaverville, California. Available online at http://www.riverbendsci.com/projects/beavers. Accessed 5/16/2014.

Roberts, R.G. and M. Church. 1986. The sediment budget in severely disturbed watersheds, Queen Charlotte Ranges, British Columbia. Canadian Journal of Forest Resources 16: 1092–1106.

Robichaud, Peter R.; Beyers, Jan L.; Neary, Daniel G. 2000. Evaluating the effectiveness of postfire rehabilitation treatments. Gen. Tech. Rep. RMRS-GTR-63. Fort Collins: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 85 p.

Rodgers, J.D. 2002. Abundance Monitoring of Juvenile Salmonids in Oregon coastal Streams. Western Oregon Rearing Project. Oregon Department of Fish and Wildlife, Corvalis. 50 p.

Rodgers, J.D., K.K. Jones, A.G. Talabere, C.H. Stein, and E.H. Gilbert. 2005. Oregon coast coho habitat assessment, 1998-2003. OPSW-ODFW-2005-5, Oregon Department of Fish and Wildlife, Salem.

Rodgers, J.D., R.D. Ewing, and J.D. Hall. 1987. Physiological changes during seaward migration of wild juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 44:452–457.

Rodgers, J.D., S.L. Johnson, T.E. Nickelson, and M.F. Solazzi. 1993. The seasonal use of natural and constructed habitat by juvenile coho salmon (*Oncorhynchus kisutch*) and preliminary results from two habitat improvement projects on smolt production in Oregon coastal streams. *In* L. Berg and P.W. Delaney (editors), Proceedings of the Coho Workshop, Nanaimo, B.C., May 26-28, 1992, p. 344-351. (Available from Department of Fisheries and Oceans, Habitat Management Sector, Policy and Information Unit, 327-555 West Hastings Street, Vancouver, BC V6B 5G3.)

Rodnick, K.J., S. St-Hilaire, P.K. Battiprolu, S.M. Seiler, M.L. Kent, M.S. Powell, J.L. Ebersole. 2008. Habitat selection influences sex distribution, morphology, tissue biochemistry, and parasite load of juvenile coho salmon in the West Fork Smith River, Oregon. Transactions of the American Fisheries Society 137: 1571-1590.

Roering, J.J., Schmidt, K.M., Stock, J.D., Dietrich, W.E., Montgomery, D.R., 2003. Shallow landsliding, root reinforcement, and the spatial distribution of trees in the Oregon Coast Range. Canadian Geotechnical Journal 40: 237–253.

Roffe, T.J. and B.R. Mate. 1984. Abundance and feeding habits of pinnipeds in the Rogue River, Oregon. Journal of Wildlife Management 48(4): 1262–1274.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22: 1-20.

Roni, P., T. R. Bennett, R. Holland, G. R. Pess, K. M. Hanson, R. Moses, M. McHenry, W. Ehinger, and J. Walter. 2012. Factors affecting migration timing, growth, and survival of juvenile coho salmon in two coastal Washington watersheds. Transactions of the American Fisheries Society 141: 890–906.

Roos, M. 2003. The Effects of global climate change on California water resources. Contractors Report, Public Interest Energy Research, California Energy Commission, P500-03-025, Sacramento, California.

Rosenfeld, J.S. and L. Huato. 2003. Relationship between large woody debris characteristics and pool formation in small coastal British Columbia streams. North American Journal of Fisheries Management 23: 928-938.

Roughgarden, J.A. 1975. A simple model for population dynamics in stochastic environments. American Naturalist 109: 713-736. 1975.

Ruggerone, G.T. and D.E. Rogers. 1993 Predation on sockeye salmon fry by juvenile coho salmon in the Chignik Lakes, Alaska: implications for salmon management. North American Journal of Fisheries Management 12: 87-102.

Ruggerone, G.T., and J.L. Nielsen. 2004. Evidence for competitive dominance of pink salmon (*Oncorhynchus gorbuscha*) over other salmonids in the North Pacific Ocean. Rev. Fish Biol. Fish. 14: 371-390.

Rupp D.E., T.C. Wainwright P.W. Lawson, W.T. Peterson. 2012a. Marine environment-based forecasting of coho salmon (Oncorhynchus kisutch) adult recruitment. Fisheries Oceanography 21:1–19.

Rupp, D.E., T.C. Wainwright, P.W. Lawson. 2012b. Effect of forecast skill on management of the Oregon coast coho salmon (*Oncorhynchus kisutch*) fishery. Canadian Journal of Fisheries and Aquatic Sciences, 2012, 69(6): 1016-1032.

Russell, W. 2009. The Influence of Timber Harvest on the Structure and Composition of Riparian Forests in the Coastal Redwood Region. Forest Ecology and Management 257:1427-1433.

Ruzicka JJ, Wainwright TC, Peterson WT. 2011. A model-based meso-zooplankton production index and its relation to the ocean survival of juvenile coho (*Oncorhynchus kisutch*). Fisheries Oceanography 20:544–559.

Ruzzante D. E. 1994. Domestication effects on aggressive and schooling behavior in fish. Aquaculture 120:1–24.

Ryall, P.E., and C.D. Levings. 1987. Juvenile salmon utilization of rejuvenated tidal channels in the Squamish Estuary, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1904:1–23.

Ryan, K.C. 2002. Dynamic interactions between forest structure and fire behavior in boreal ecosystems. Silva Fennica 36:13-39.

Ryan P.A. 1991. Environmental effects of sediment on New Zealand streams: a review. New Zealand Journal of Marine and Freshwater Research 25: 207–221.

Ryding, K.E., and Skalski, J.R. 1999. Multivariate regression relationships between ocean conditions and early marine survival of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 56: 2374–2384.

Saldi-Caromile, K., K. Bates, P. Skidmore, J. Barenti, D. Pineo. 2004. Stream Habitat Restoration Guidelines: Final Draft. Co-published by the Washington Departments of

Fish and Wildlife and Ecology and the U.S. Fish and Wildlife Service. Olympia, Washington. http://wdfw.wa.gov/publications/00043/wdfw00043.pdf.

Salmon and Steelhead Hatchery Assessment Group (SSHAG). 2003. Hatchery broodstock summaries and assessments for chum, coho, and Chinook salmon and steelhead stocks within the Evolutionarily Significant Units listed under the Endangered Species Act. NOAA Fisheries Northwest Fisheries Science Center and NOAA Fisheries Southwest Fisheries Science Center. 325 p.

Salo, E., and W.H. Bayliff. 1958. Artificial and natural production of silver salmon, *Oncorhynchus kisutch*, at Minter Creek, Washington. Wash. Dep. Fish. Res. Bull. 4, 76 p.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins & N.L. Scholz. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science & Technology 41:2998-3004.

Sandercock, F.K. 1991. Life-history of coho salmon (*Oncorhynchus kisutch*). Pp. 397-445 *In* C. Groot and L. Margolis (Eds.). 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver, B. C.

Saunders, R.L. 1991. Potential interaction between cultured and wild Atlantic salmon. Aquaculture, 98:51-61

Scanlon, H. 2007. Progression and Behavior of the Canoe Fire in Coast Redwood. *In*: Standiford, R.B., G.A. Giusti, Y. Valachovic, W. Zielinski, and M.J Furniss, technical editors. 2007. Proceedings of the redwood region forest science symposium: What does the future hold? Gen. Tech. Rep. PSW-GTR-194. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; p. 223-232.

Scarnecchia, D. L. 1981. Effects of streamflow and upwelling on yield of wild coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 38: 471-475.

Scheffer P.M. 1938. The beaver as an upstream engineer. Soil Conservation 3: 178-181

Scheffer, T.H., and C.C. Sperry. 1931. Food habits of the Pacific harbor seal, *Phoca vitulina richardsi. Journal of Mammalogy* 12(3): 214–226.

Schindler, D.E, M.D. Scheuerell, J.W. Moore, S.M. Gende, T.B. Francis, and W.J. Palen. 2003. Pacific salmon and the ecology of coastal ecosystems. Frontiers in Ecology and the Environment 1: 31–37.

Schlenk, D. and R. Lavado. 2011. Impacts of Climate Change on Hypersaline Conditions of Estuaries and Xenobiotic Toxicity. Aquatic Toxicology 105S: 78-82.

Schlosser, I.J. 1987. The role of predation in age- and size-related habitat use by stream fishes. Ecology 68**:** 631–639.

Schmidt, K., Roering, J., Stock, J., Dietrich, W., Montgomery, D., Schaub, T., 2001. The variability of root cohesion as an influence on shallow landslide susceptibility in the Oregon Coast Range. Canadian Geotechnical Journal 38: 995–1024.

Scholz, Nathaniel L., N.K. Truelove, B.L. French, B.A. Berejikian, T.P. Quinn, E. Casillas, and T.K. Collier. 2000. Diazinon disrupts antipredator and homing behaviors in Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 57: 1911-1918.

Scrivener, J.C. and Andersen, B.C. 1982. Logging impacts and some mechanisms which determine the size of spring and summer populations of coho salmon fry in Carnation Creek. *In* Proceedings of the Carnation Creek Workshop: a ten year review. *Edited by* G. F. Hartman. Pacific Biological Station, Nanaimo, BC, Canada. pp. 257-272.

Scrivener, J.C., and B.C. Andersen. 1984. Logging impacts and some mechanisms that determine the size of spring and summer populations of coho salmon fry (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 41: 1097-1105.

Sedell, J. R., P. A. Bisson, E J. Swanson, and S. V. Gregory. 1988. What we know about large trees that fall into streams and rivers. Pages 47-81 in C. Maser, R. F. Tarrant, J. M. Trappe, and J. E Franklin, From the forest to the sea: a story of fallen trees. U.S. Forest Service General Technical Report PNW-GTR-229.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience 31: 131-134.

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*). Fish and Game Bulletin 98. 275 pp.

Sharma R, Vélez-Espino LA, Wertheimer AC, Mantua N, Francis RC. 2013. Relating spatial and temporal scales of climate and ocean variability to survival of Pacific Northwest Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography 22: 14–31.

Shankman, D., & Drake, L. G. (1990). Channel migration and regeneration of bald cypress in western Tennessee. Physical Geography, 11(4), 343-352.

Sharr, S., C. Melcher, T. Nickelson, P. Lawson, R. Kope, and J. Coon. 2000. 2000 review of amendment 13 to the Pacific Coast salmon plan. Exhibit B.3.b. OCN workgroup report. Pacific Fisheries Management Council, Portland, OR.

Shaver, E., J. Maxted, G. Curtis and D. Carter. 1995. Watershed Protection Using an Integrated Approach. *In* Stormwater NPDES Related Monitoring Needs. Engineering Foundation. American Society of Civil Engineers. Crested Butte, CO. August 7-12, 1994.

Sholes, W.H. and R.J. Hallock. 1979. An evaluation of rearing fall-run Chinook salmon *Oncorhynchus tshawytscha*, to yearlings at Feather River Hatchery, with a comparison of returns from hatchery and downstream releases. California Fish and Game 64: 239-255.

Sibert, J.T., Brown, T.J., Healey, M.C., Kask, B.A., and Naiman, R.J. 1977. Detritus-based food webs: Exploitation by juvenile chum salmon (*Oncorhynchus keta*). Science 196: 649-650.

Sidle, R.C., A.J. Pearce and C.L. O'Loughlin. 1985. Hillslope stability and land use. Water Resources Monograph Series, Volume 11. American Geophysical Union, Washington, D.C.

Silloway S. 2010. Fish Surveys Related to the Proposed Del Norte Highway 101 Klamath Grade Raise Project Contract No. 03A1317 Task Order 48. Accessed online 12/13/2011: http://www.yuroktribe.org/departments/fisheries/documents/YTFP2010KlamathGradeRaisebyCaltransFishReportFINAL.pdf

Silver, S., C. Warren, and P. Doudoroff. 1963. Dissolved Oxygen Requirements of Developing Steelhead Trout and Chinook Salmon Embryos at Different Water Velocities. Transactions of the American Fisheries Society 92, 327-343.

Sinnen, W. 2002. Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project, 2001– 2002 Season. Task 3: Survival and spawner escapements made by Coho salmon produced at the Trinity River Hatchery.

Sinnen, W., P. Garrison, M. Knechtle, A. Hill, J. Hileman, and S. Borok. 2009. Trinity River basin salmon and steelhead monitoring project: 2006-2007 season. Annual report. February 2009. 172 p.

Skeesick, D.G. 1970. The fall immigration of juvenile coho salmon into a small tributary. Fish Commission of Oregon, Research Division Research Report 2, Subject: Coho data collected during harvest monitoring activities on Yurok Indian Reservation, CA.

Snyder, J.O. 1931. Salmon of the Klamath River, California. Div. of Fish and Game of Calif., Fish Bulletin No. 34.

Solazzi, M. F., T.E. Nickelson, S.L. Johnson, and J.D. Rogers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences 57(5): 906-914.

Soloman, S., G. Plattner, R. Knutti, and P. Friedlingstein. 2008. Irreversible Climate Change due to Carbon Dioxide Emissions. PNAS 106(6):1704-1709.

Sommer, T.R, W.C. Harrell and M.L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. North America Journal of Fisheries Management 25:1493-1504

Sorenson, P. W., J. R. Cardwell, T. Essington, and D. E. Weigel. 1995. Reproductive interactions between sympatric brook and brown trout in a small Minnesota stream. Canadian Journal of Fisheries and Aquatic Sciences 52:1958–1965.

Soto, T., A. Corum, H. Voight, D. Hillemeier, and L. Lestelle. 2008. The role of the Klamath River mainstem corridor in the life-history and performance of juvenile coho salmon (Oncorhynchus kisutch). Phase I Report 2006-07 Winter. Submitted to U.S. Bureau of Reclamation, Klamath Falls, Oregon. December 2008.

Sparkman, M. D. 2003. Negative Influences of Predacious Egg-Eating Worms, *Haplotaxis ichthyophagous*, and Fine Sediments on Coho Salmon, *Oncorhynchus kisutch*, in Natural and Artificial Redds. Master's thesis, Humboldt State University, Arcata, California.

Species Interaction Work Group (SIWG). 1984. Evaluation of potential species interaction effects in the planning and selection of salmonid enhancement projects. J. Rensel, chairman and K. Fresh, editor. Report prepared for the Enhancement Planning Team for implementation of the Salmon and Steelhead Conservation and Enhancement Act of 1980. Washington Department of Fisheries. Olympia, WA. 80pp.

Spence, B.C., E.P. Bjorkstedt, J.C. Garza, J.J. Smith, D.G. Hankin, D. Fuller, W.E. Jones, R. Macedo, T.H. Williams, and E. Mora. 2008. A framework for assessing the viability of threatened and endangered salmon and steelhead in the North-Central California Coast recovery domain. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-423. 173 p.

Spence, B.C. and E.J. Dick. 2014. Geographic variation in environmental factors regulating outmigration timing of coho salmon (Oncorhynchus kisutch) smolts. Canadian Journal of Fisheries and Aquatic Sciences 71: 56-69.

Spence, B.C. and J.D. Hall. 2010. Spatiotemporal patterns in migration timing of coho salmon (Oncorhynchus kisutch) smolts in North America. Canadian Journal of Fisheries and Aquatic Sciences 67: 1316-1334.

Spence, B.C., G.A. Lomnicky, R.M. Hughes and R. P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. Funded jointly by the U.S. EPA, U.S. Fish and Wildlife Service and National Marine Fisheries Service. TR-4501-96-6057. Man Tech Environmental Research Services Corp., Corvallis, OR.

Spencer, C.N., K.O. Gabel, and F.R. Hauer. 2003. Wildfire effects on stream food webs and nutrient dynamics in Glacier National Park, USA. Forest Ecology and Management 178: 141-153.

Spidle, A. P., T. P. Quinn, and P. Bentzel. 1998. Sex-biased survival and growth in a population of coho salmon. Journal of Fish Biology 52: 907–915.

State of Oregon, J.W. Nichols, principal writer. 1997. The Oregon Plan (Oregon Coastal Salmon Restoration Initiative). Oregon Governor's Office. Salem, OR. 134 p.

State of Oregon 2013. Key elements of the Oregon plan. Page accessed 12/12/13: http://www.oregon.gov/OPSW/Pages/about_us.aspx#Key_Elements_of_the_Plan.

State Water Resources Control Board (SWRCB). 1998. Declaration of Fully Appropriated Stream Systems, Water Right Order 98-08, Exhibit A, November 19, 1998. State Of California, State Water Resources Control Board, Sacramento, California.

Steel, E.A., D.W. Jensen, K.M. Burnett, K. Christiansen, J.C. Firman, B.E. Feist, K.J. Anlauf, and D.P. Larsen. 2012. Landscape characteristics and coho salmon (*Oncorhynchus kisutch*) distributions: Explaining abundance versus occupancy. Canadian Journal of Fisheries and Aquatic Sciences 69:457-468.

Stephens, S.L. and D.L. Fry. 2005. Fire history in coast redwood stands in the northeastern Santa Cruz Mountains, California. Fire Ecology 1:2-19.

Stevens, D.L. Jr. 2002. Sampling design and statistical analysis methods for the integrated biological and physical monitoring of Oregon streams. OPSW-ODFW-2002-07, Department of Statistics, Oregon State University, Corvallis.

Stevens, D.L., Jr. and Olsen, A.R. 2004. Spatially-balanced sampling of natural resources. Journal of American Statistical Association 99: 262–278.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. Idaho Cooperative Fisheries and Wildlife Research Unit, Univ. of Idaho, Moscow, ID, Tech. Report 901.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? Ecology 67:929-940.

Stillwater Sciences, and W. E. Dietrich. 2002. Napa River basin limiting factors analysis. Final technical report. Prepared by Stillwater Sciences, Berkeley, California and Department of Earth and Planetary Sciences, University of California, Berkeley for San Francisco Bay Water Quality Control Board, Oakland, California and California State Coastal Conservancy, Oakland.

Stocking, R.W. and J.L. Bartholomew. 2004. Assessing links between water quality, river health and Ceratomyxosis of salmonids in the Klamath River system. Department of Microbiology, Oregon State University, Corvallis, OR. 5 p.

Stubblefield A, Kaufman M, Blomstrom G, Rogers J. 2011. Summer water use by mixed-age and young forest stands, Mattole River, Northern California, USA. In: Standiford, R.B.; T.J Weller, D.D. Piirto, J.D. Stuart, tech. coords. Proceedings of coast redwood forests in a changing California: A symposium for scientists and managers. Gen. Tech. Rep. PSW-GTR-238. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. pp.183-193. Available online at: http://www.treesearch.fs.fed.us/pubs/41298

Sumner, F.H. 1953. Migrations of salmonids in Sand Creek, Oregon. Transactions of the American Fisheries Society82: 139-149.

Sumpter, J.P. and A.C. Johnson. 2005. Lessons from endocrine disruption and their application to other issues concerning trace organics in the aquatic environment. Environ Sci Technol 39, 4321-4332.

Surfleet C.G., A.E. Skaugset. 2013. The Effect of Timber Harvest on Summer Low Flows, Hinkle Creek, Oregon. Western Journal of Applied Forestry 28:13-21.

Suttle, K.B, Power, M.E., Levine, J.M., McNeely, C. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications 14(4): 969–974.

Swain, D.P., and L.B. Holtby. 1989. Differences in morphology and behavior between juvenile coho salmon (*Oncorhynchus kisutch*) rearing in a lake and in its tributary stream. Canadian Journal of Fisheries and Aquatic Sciences 46:1406-1414.

Sweeting, R.M., Beamish, R.J., Noakes, D.J., and Neville, C.M. 2003. Replacement of wild coho salmon by hatchery-reared coho salmon in the Strait of Georgia over the past three decades. North American Journal of Fisheries Management 23:492-502.

Sweka, J.A., and K.J. Hartman. 2001. Influence of turbidity on brook trout reactive distance and foraging success. Transactions of the American Fisheries Society 130:138– 146.

Tappe, D. T. 1942. The status of beavers in California. State of California, Department of Natural Resources, Division of Fish and Game.

Taylor, S.N. 1978. The status of salmon populations in California coastal rivers. California Department of Fish and Game, File Report. Anadromous Fisheries Branch. April 1978. 13 p.

Taylor, E.B., and J.D. McPhail. 1985. Variation in body morphology among British Columbia populations of coho salmon, *Oncorhynchus kisutch*. Canadian Journal of Fisheries and Aquatic Sciences 42:2020-2028.

The Nature Conservancy (TNC). 2003. Landscape-scale conservation: a practitioner's guide. Available online at http://conserveonline.org/workspaces/cbdgateway/cap/resources/4/2/Landscape_Practicitioners_Handbook_July03_PR.pdf.

The Nature Conservancy (TNC). 2006. Pool and wood summaries for Siskiyou mountain streams by stream size. Illinois Valley Conservation Action Plan. 6 p.

Thériault, V., G.R. Moyer, L.S. Jackson, M.S. Blouin, and M.A Banks. 2011. Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms. Molecular Ecology 20: 1860–1869. doi:10.1111/j.1365-294X.2011.05058.x. PMID:21438931.

Thomas, C.D. 1990. What do real population dynamics tell us about minimum viable population sizes. Conservation Biology 4 (3): 324–327.

Thomas, C.D. 1994. Extinction, colonization, and metapopulations: environmental tracking by rare species. Conservation Biology 8:373-378.

Thompson, K. G., R. B. Nehring, D. C. Bowden, and T. Wygant. 1999. Field exposure of seven species or subspecies of salmonids to Myxobolus cerebralis in the Colorado River, Middle Park, Colorado. Journal of Aquatic Animal Health 11:312–329.

Tiegs, S.D., P.S. Levi, J. Rüegg, D.T. Chaloner, J.L. Tank, and G.A. Lamberti. 2011 Ecological effects of live salmon exceed those of carcasses during an annual spawning migration. Ecosystems 14: 598–614. doi:10.1007/s10021-011-9431-0.

Treuren, R.V., R Bijlsma, W. Van Delden, and N.J. Ouborgi. 1991. The significance of genetic erosion in the process of extinction. I. Genetic differentiation in *Salvia pratensis* and *Scabiosa columbaria* in relation to population size. Heredity 66: 181-189.

Tripp, D., and P. McCart. 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. Canadian Technical Report of Fisheries and Aquatic Sciences 1212: 176 pp.

True, K. 2011. 2011 Klamath River Salmonid Health Monitoring. Memorandum dated September 28, 2011, to Nick Hetrick, Arcata Fish and Wildlife Office. U.S. Fish and Wildlife Service. 7 p.

Tschaplinski, P.J. 1988. The use of estuaries as rearing habitats by juvenile coho salmon. In T.W. Chamberlain (ed.), *Proceedings of a workshop: Applying 15 years of Carnation Creek results.* (pp. 123-142). Nanaimo, BC: British Columbia Ministry of Environment, Lands, and Parks.

Turner, M., W. Hargrove, R. Garner, W. Romme. 1994. Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming. Journal of Vegetation Science 5:731-742.

University of the Pacific. 2010. Employment impacts of California salmon fishery closures in 2008 and 2009. Eberhardt School of Business Forecasting Center. 6 p.

Unwin M. J. 1997. Fry-to-adult survival of natural and hatchery-produced chinook salmon (Oncorhynchus tshawytscha) from a common origin. Canadian Journal of Fisheries and Aquatic Sciences 54: 1246-1254.

U.S. Department of Agriculture (USDA) and U.S. Department of the Interior (USDOI). 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl: Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl. USDA Forest Service and USDI Bureau of Land Management, Washington, DC.

U.S. Department of Interior (US.DOI) and California Department of Fish and Game (CDFG). 2012. Klamath Facilities Removal Final Environmental Impact Statement/ Environmental Impact Report. U.S. Department of Interior (U.S. DOI), Bureau of Reclamation, Sacramento, CA.

U.S. Environmental Protection Agency (EPA). 1999. South Fork Eel River Total Maximum Daily Loads for Sediment and Temperature. Region IX.

U.S. Fish and Wildlife Service (USFWS). 1994. Biological assessments for operation of U.S. Fish and Wildlife Service operated or funded hatcheries in the Columbia River Basin in 1995-1998. Submitted to National Marine Fisheries Service under cover letter, dated August 2, 1994, from William F. Shake, Acting USFWS Regional Director, to Brian Brown, NMFS.

U.S. Fish and Wildlife Service (USFWS). 2003. Klamath River Fish Die Off September 2002 – Caustitive Factors of Mortality. Report Number AFWO-F-02-03. 128 p.

U.S. Fish and Wildlife Service (USFWS) and Hoopa Valley Tribe (HVT). 1999. Trinity River Flow Evaluation Final Report. Report to the Secretary, U.S. Department of the Interior. Washington, D.C. Available at: http://www.fws.gov/arcata/fisheries/reportsDisplay.html. Accessed October 2008.

U.S. Forest Service (USFS) and Bureau of Land Management (BLM). 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl: Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl. USDA Forest Service and USDI Bureau of Land Management, Washington, DC.

Van Doornik, D.M., D.J. Teel, D.R. Kuligowski, C.A. Morgan, and E. Casillas. 2007. Genetic analyses provide insight into the early ocean stock distribution and survival of juvenile coho salmon off the coasts of Washington and Oregon. North American Journal of Fisheries Management 27: 220-237.

Van Kirk, R.W., and S.W. Naman. 2008. Relative effects of climate and water use on base-flow trends in the lower Klamath Basin. Journal of the American Water Resources Association 44:1035–1052.

Villarin, L. A., D. M. Chapin, and J. E. Jones III. 2009. Riparian Forest Structure and Succession in Second-Growth Stands of the Central Cascade Mountains, Washington, USA. Forest Ecology and Management 257:1375-1385.

Wagener, S.M. and J.D. Laperriere. 1985. Effects of placer Mining on the Invertebrate Communities of Interior Alaska Streams. Freshwater Invertebrate Biology 4(4): 208-214.

Wainwright, T.C., M.W. Chilcote, P.W. Lawson, T.E. Nickelson, C.W. Huntington, J.S. Mills, K.M.S. Moore, G.H. Reeves, H.A. Stout, and L.A. Weitkamp. 2008. Biological Recovery Criteria for the Oregon Coast Coho Salmon Evolutionarily Significant Unit. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-91, 199 p.

Walters, C.J., R. Hilborn, R.M. Peterman, and M.J. Staley. 1978. Model for examining early ocean limitation of Pacific salmon production. Journal of the Fisheries Research Board of Canada 35:1303-1315.

Wang, L. and R. White. 1994. Competition between brown trout and hatchery greenback cutthroat trout of largely-wild parentage. North American Journal of Fisheries Management 14:475-487

Waples, R. 1991. Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. Mar. Fish. Rev. 53:11-22.

Warren, J.W. 1991. Diseases of hatchery fish, 6th edition. U.S. Fish and Wildlife Service, Pacific Region, Portland, Oregon.

Waters, T.F. 1983. Replacement of brook trout by brown trout over 15 years in a Minnesota stream: production and abundance. Transactions of the American Fisheries Society 112:137-146.

Washington Department of Fisheries (WDF). 1951. Lower Columbia River Fisheries Development Program: Planning reports for Grays River area, Elokomin area, Abernathy area, Cowlitz area, Kalama River area, Lewis River area, Washougal River area, Wind River area, Little White Salmon area, Big White Salmon area, and Klickitat River area. Preliminary draft, unnumbered. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.

Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), and Western Washington Treaty Indian Tribes (WWTIT). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Wash. Dep. Fish Wildl., Olympia, 212 p. plus three Appendices: Appendix One--Hood Canal and Strait of Juan de Fuca (December 1994, 424 p.), North Puget Sound (June 1994, 418 p.), and South Puget Sound (September 1994, 371 p.) Volumes; Appendix Two--Coastal stocks (August 1994, 587 p.); and Appendix Three--Columbia River stocks (June 1993, 580 p.). (Available Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington State Department of Agriculture (WSDA). 2010. The Endangered Species Act and the impacts to Pesticide Registration and Use. 21p.

Weaver, W. and D. Hagans. 1996. Sediment treatments and road restoration: protecting and restoring watersheds from sediment-related impacts. pages 105-134 in The Pacific Rivers Council, Inc. 1996 Healing the watershed: a guide to the restoration of watersheds and native fish in the West.

Weitkamp, L.. and K. Neely. 2002. Coho salmon (*Oncorhynchus kisutch*) ocean migration patterns: insight from marine coded-wire tag recoveries, *Canadian Journal of Fisheries and Aquatic Sciences* **59** (7) (2002), pp. 1100–1115.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-24, Northwest Fisheries Science Center, Seattle, Washington. 258 p.

Wells, B.K., C.B. Grimes, J.C. Field and C.S. Reiss. 2006. Covariation between the average lengths of mature coho (*Oncorhynchus kisutch*) and Chinook salmon (*O. tshawytscha*) and the ocean environment, *Fisheries Oceanography* **15** (2006), pp. 67–79.

Welsch, D.J. 1991. Riparian Forest Buffers; Function and design for protection and enhancement of water resources. USDA publication NA-PR-07-91 http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm

Welsh, H.H., G.R. Hodgson, M.F. Roche, B.C. Harvey. 2001. Distribution of Juvenile Coho Salmon (Oncorhynchus kisutch) in Relation to Water temperature in Tributaries of a Northern California Watershed: Determining Management Thresholds for an Impaired Cold-water Adapted Fauna. August 2000 North American Journal of Fisheries Management. U.S.D.A. Forest Service, Redwood Sciences.

Weybright, A. 2011. Juvenile Coho Salmon Movement, Growth and Survival in a Coastal Basin of Southern Oregon. Master’s Thesis, Oregon State University. 110 pp.

Wharton S., M. Schroeder, U.K.T. Paw, M. Falk, and K. Bible. 2009. Turbulence considerations for comparing ecosystem exchange over old-growth and clear-cut stands for limited fetch and complex canopy flow conditions. Agricultural and Forest Meteorology 149: 1477-1490.

Whitcomb, A. C., M. A. Banks, and K. G. O’Malley. 2014. Influence of immune-relevant genes on mate choice and reproductive success in wild-spawning hatchery –reared and wild-born coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 71: 1-10. dx.doi.org/10.1139/cjfas-2013-0501

Wilkie, M.P. and C.M. Wood. 1995. Recovery from high pH exposure in the rainbow trout: White muscle ammonia storage. Physiological Zoology 68(3) 379-401.Wilkie, M.P. and C.M. Wood. 1996. The adaptations of fish to extremely alkaline environments.

Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology 113:665–673.

Willette, T.M., T., C.R., Patrick, V., Mason, D.M., Thomas, G.L. and Scheel, D. (2001) Ecological processes influencing mortality of juvenile pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound, Alaska. Fish. Oceanogr. 10(suppl 1): 14-41.

Williams, D. 2010. Harvest of species listed under the Endangered Species Act. Yurok Tribal Fisheries. March 2010. 9 p.

Williams, T.H., E.P. Bjorkstedt, W.G. Duffy, D. Hillemeier, G. Kautsky, T.E. Lisle, M. McCain, M. Rode, R.G. Szerlong, R.S. Schick, M.N. Goslin, and A. Agrawal. 2006. Historical population structure of coho salmon in the Southern Oregon/Northern California Coasts evolutionarily significant unit. NOAA-TM-NMFS-SWFSC-390.

Williams, T.H., B. Spence, W. Duffy, D. Hillemeier, G. Kautsky, T. Lisle, M. McCain, T. Nickelson, E. Mora, and T. Pearson. 2008. Framework for assessing viability of threatened coho salmon in the Southern Oregon / Northern California Coasts Evolutionarily Significant Unit. NOAA Technical Memorandum NMFS-SWFSC-432.

Williams, T.H., S.T. Lindley, B.C. Spence, D.A. Boughton. 2011. Status review update for Pacific salmon and steelhead under the Endangered Species Act: Southwest. 20 May 2011 – Update to 5 January 2011 report. . National Marine Fisheries Service, Southwest Fisheries Science Center. Santa Cruz, CA.

Williamson, K. and D. Hillemeier. 2001. An assessment of pinniped predation upon fall- run Chinook salmon in the Klamath River estuary, California. Yurok Tribal Fisheries Program. 1998.

Williamson, K.S., A.R. Murdoch, T.N. Pearsons, E.J. Ward, and M.J. Ford. 2010. Factors influencing the relative fitness of hatchery and wild spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Wenatchee River, Washington, USA. Canadian Journal of Fisheries and Aquatic Sciences 67(11): 1840‑1851. doi:10.1139/f10-099.

Wipfli, M.S., J.P. Hudson, and J.P. Caouette. 2004. Restoring productivity of salmon-based food webs: Contrasting effects of salmon carcass and salmon carcass analog additions on stream-resident salmonids. Transactions of the American Fisheries Society 133:1440–54.

Wiplfi, M.S., and C.V. Baxter. 2010. Linking ecosystems, food webs, and fish production: subsidies in salmonid watersheds. Fisheries 35: 373–87.

Wood, J.W. 1979. Diseases of Pacific salmon, their prevention and treatment. Washington Department of Fisheries, Olympia. 82 pp.

Wood J.W. 1987. The genetic demography of the Gainj of Papua New Guinea. 2. Determinants of effective population size. Am Nat 129:165–187.

Woodruff, K. 2013. Methow Beaver Project: Accomplishments and Outcomes. Unpublished report. Methow Beaver Project. US Forest Service. Winthrop, WA.

Wright, S. 1931. Evolution in Mendelian populations. Genetics 16:97-159.

Xu, C.L., B.H. Letcher, and K. H. Nislow. 2010. Context-specific influence of water temperature on brook trout growth rates in the field. Freshwater Biology 55, 2253–2264.

Yarnell, S. M., J. F. Mount, and E. W. Larsen. 2006. The Influence of Relative Sediment Supply on Riverine Habitat Heterogeneity. Geomorphology 80:310-324.

Yoshiyama, R.M. and P.B. Moyle. 2010. Historical review of Eel River anadromous salmonids, with emphasis on Chinook salmon, coho salmon and steelhead. University of California at Davis. Center for Watershed Sciences working paper; a report commissioned by California Trout. Davis, CA. February 1.

Young, M.K. 2012. Aquatic species invasions in the context of fire and climate change. *In*: C. Luce, P. Morgan, K. Dwire, D. Isaak, Z. Holden, B. Rieman. 2012. Climate change, forests, fire, water, and fish: Building resilient landscapes, streams, and managers. Gen. Tech. Rep. RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 207 p.

Yurok Tribe and Green Diamond Resource Company (GDRC). 2011. Assignment and Assumption Agreement with respect to a portion of the Green Diamond Resource Company Aquatic Habitat Conservation Plan/Candidate Conservation Agreement with Assurances. Effective April 14, 2011. 10 p.

Yurok Tribe Environmental Program (YTEP). 2004 Water Quality Control Plan For the Yurok Indian Reservation. Yurok Tribe Environmental Program, Klamath, CA. 37 p.

Yurok Tribal Fisheries Program (YTFP). 2014. Known portions of adult in-river coho run and ratio of Yurok harvest to the sum of known components of the run, 1994 – 2012. Unpublished table.

Ziemer, R.R. 1998. Flooding and stormflows. In: Ziemer, R.R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 6 May 1998; Ukiah, California. General Tech. Rep. PSW GTR-168. Albany, California: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 15-24.

**Federal Register Notices:**

55 FR 115. National Marine Fisheries Service. Notice. Endangered and threatened species; listing and recovery priority guidelines. June 15, 1990.

60 FR 142. National Marine Fisheries Service. Proposed rule. Endangered and threatened species; proposed threatened status for three contiguous ESUs of coho salmon ranging from Oregon through Central California. July 25, 1995.

62 FR 24588. National Marine Fisheries Service. Final rule. Endangered and Threatened Species; Threatened Status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU) of Coho Salmon. May 6, 1997.

64 FR 24049. National Oceanic and Atmospheric Administration. Final rule. Designated Critical Habitat; Central California Coast and Southern Oregon/Northern California Coasts Coho Salmon. May 5, 1999.

65 FR 42422. National Oceanic and Atmospheric Administration. Final rule. Endangered and Threatened Species; Final Rule Governing Take of 14 Threatened Salmon and Steelhead Evolutionarily Significant Units (ESUs). July 10, 2000.

69 FR 33102. National Marine Fisheries Service. Proposed rule. Endangered and Threatened Species: Proposed Listing Determinations for 27 ESUs of West Coast Salmonids. June 14, 2004.

70 FR 37160. National Marine Fisheries Service. Final rule. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. June 28, 2005.

70 FR 37204. National Oceanic and Atmospheric Administration. Final policy. Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead. June 28, 2005.