SOUTH-CENTRAL CALIFORNIA STEELHEAD RECOVERY PLAN

Public Review Draft

Southwest Regional Office
National Marine Fisheries Service
Long Beach, CA

September 2012

DISCLAIMER

Recovery Plans identify recovery actions, based upon the best scientific and commercial data available, necessary for the protection and recovery of listed species. Recovery Plans published by the National Marine Fisheries Service (NMFS) are guidance documents, not regulatory documents; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. 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. 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 warranted by new findings, changes in a species' status, and the completion of recovery actions.

LITERATURE CITATION:

This document should be cited as: National Marine Fisheries Service. 2012. Public Review Draft South-Central California Coast Steelhead Recovery Plan. Southwest Region, Protected Resources Division, Long Beach, California.

Cover Photograph: South-Central California Steelhead, San Carpoforo Creek, San Luis Obispo County, California April 17, 2007. Mark H. Capelli, South-Central/Southern California Steelhead Recovery Coordinator, National Marine Fisheries Service.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

National Marine Fisheries Service
Protected Resources Division
501 West Ocean Blvd., Suite 4200, Long Beach, CA 90802
562-980-4000

Final recovery plans can be downloaded from the NMFS website:

http://www.nmfs.noaa.gov/pr/recovery/plans.htm

ACKNOWLEDGEMENTS

NMFS wishes to thank and acknowledge Dr. David A. Boughton (NMFS's Southwest Fisheries Science Center, Sana Cruz) who chaired NMFS's South-Central/Southern California Steelhead Technical Recovery Team (TRT), and under whose leadership the scientific foundation and framework of the South-Central California Coast Steelhead Recovery Plan was developed.

Thanks also are due to the members of the TRT who contributed their time and expertise to the development of the National Marine Fisheries Service's Southwest Fisheries Science Center's Technical Memoranda that have extended our understanding of the distinctive biology and ecology of South-Central California steelhead: Dr. Peter B. Adams, Dr. Eric C. Anderson, Dr. Craig A. Fusaro, Dr. Edward A. Keller, Dr. Elise Kelley, Leo D. Lentsch, Dr. Jennifer L. Nielsen, Kathleen Y. Perry, Dr. Helen M. Regan, Dr. Jerry J. Smith, Dr. Camm C. Swift, Dr. Lisa C. Thompson, and Dr. Fred G. R. Watson. Mary L. Larson, Senior Fisheries Biologist with the California Department of Fish and Game, Region 5, also contributed materially to the TRT discussions.

Dr. John Carlos Garza and his colleagues on the Southwest Fisheries Science Center's Molecular Ecology Genetic Analysis Team have provided significant insights into the population structure and distribution of steelhead in South-Central California. Heidi Fish, Research Fish Biologist, and Associate Fisheries Biologist, Kerrie Pipal, with the Fisheries Ecology Division of the Southwest Fisheries Science Center, were instrumental in the collection of many of the fish samples used in this genetic work.

The Draft Recovery Plan also benefited from the independent scientific reviews of Dr. J. A. Hutchings, Dr. E. Eric Knudsen, and Dr. T. Potter, and from the co-manager and public comments received on the initial draft of the Recovery Plan. Dr. Scott D. Cooper, Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, and Dr. David Jacobs, Department of Ecology and Evolutionary Biology, University of California, Los Angeles, also provided valuable comments at various stages of the recovery planning process. NMFS also would like to acknowledge the staffs of NMFS's Southwest Regional offices for their review of the Draft Recovery Plan, particularly Jonathan M. Ambrose, Joyce E. Ambrosius, Devin M. Best, Joel M. Casagrande, Joseph C. Heublein, John P. McKeon, Anthony P. Spina, William L. Stevens, R. Craig Wingert. Charleen A. Gavette prepared the maps and compilation of data on the physical and land-use characteristics of the South-Central California Steelhead Recovery Planning Area, and Laura Riley of the Pacific States Marine Fisheries Commission prepared the fish passage maps based on the California Department of Fish and Game's Passage Assessment Data Base.

The Draft South-Central California Coast Steelhead Recovery Plan has drawn on the work of Kier Associates - Fisheries and Watershed Professionals, and Hunt & Associates - Biological Consulting Services for the identification of threats and recovery actions. Paul D. Hoobyar and his staff at Watershed Initiatives effectively facilitated the workshops and public meetings on the threats and recovery actions elements of the Draft Recovery Plan.

Finally, NMFS would like to recognize the many public officials, particularly the staff of the California Department of Fish and Game, and private individuals who have worked to preserve and recover South-Central California steelhead. The Draft South-Central California Coast Steelhead Recovery Plan builds on the dedication of these individuals and their efforts to preserve a species whose varied life histories uniquely reflect the diverse aquatic and terrestrial habitats of South-Central California watersheds.

TABLE OF CONTENTS

List of Figures

Note: Unless otherwise indicated, all photographs were taken by Mark H. Capelli, South-Central/Southern California Steelhead Recovery Coordiantor, National Marien Fisheries Service, or are from the Mark H. Capelli Southern California Steelhead Watershed Archive,Donald E. Davidson Library, University of California, Santa Barbara.

List of Tables

Appendices

EXECUTIVE SUMMARY

The goal of this Recovery Plan is *to prevent the extinction of South-Central California Coast steelhead (Oncorhynchus mykiss) in the wild and to ensure the long-term persistence of viable, self-sustaining, populations of steelhead distributed across the South-Central California Coast Steelhead (SCCCS) Distinct Population Segment (DPS). It is also the goal of this Recovery Plan to establish a sustainable South-Central California steelhead sport fishery.*

Recovery of the SCCCS DPS will require the protection, restoration, and maintenance of a range of habitats throughout the DPS in order to allow the natural diversity of *O. mykiss* to be fully expressed (*e.g.*, anadromous and resident forms, timing and frequency of runs, and dispersal between watersheds).

Status of South-Central California Coast Steelhead

Steelhead are the anadromous, or ocean going form of the species *Oncorhynchus mykiss*, with adults spawning in freshwater, and juveniles rearing in freshwater before migrating to the ocean to grow and sexually mature before returning as adults to reproduce in freshwater. Steelhead populations along the West Coast of North America have experienced substantial declines as a result of human activities such as water development, flood control programs, forestry practices, agricultural activities, mining, and urbanization that have degraded, simplified, and fragmented aquatic habitats. In South-Central California, near the southern limit of the range for anadromous *O. mykiss* in North America, it is estimated that annual runs have declined dramatically from an estimated 25,000 returning adults historically, to currently less than 500 returning adults (Williams *et al.* 2011, Good *et al.* 2005, Helmbrecht and Boughton 2005, Boughton and Fish 2003).

Steelhead along South-Central California Coast comprise a "distinct population segment" of the species *O. mykiss* that is ecologically discrete from the other populations of *O. mykiss* along the West Coast of North America. Under the U.S. Endangered Species Act of 1973 (ESA), this DPS qualifies for protection as a separate species. In 1997, the SCCCS DPS - originally referred to as an Evolutionarily Significant Unit (ESU) - was listed as a "threatened" species - a species that is likely to become in danger of extinction within the foreseeable future throughout all or a significant portion of its range.

South-Central California Steelhead Angling Heritage – Salinas River c. 1940s.

Recovery Planning

The ESA mandates that the National Marine Fisheries Service (NMFS) develop and implement Recovery Plans for the conservation (recovery) of listed species. The development and implementation of a Recovery Plan for the SCCCS DPS is considered vital to the continued persistence and recovery of anadromous *O. mykiss* in South-Central California.

The SCCCS DPS encompasses *O. mykiss* populations in watersheds from the Pajaro River (Monterey County) south to Arroyo Grande

Creek (San Luis Obispo County). For recovery planning purposes, the South-Central California Coast Steelhead (SCCCS) Recovery Planning Area includes those portions of coastal watersheds that are seasonally accessible to anadromous *O. mykiss* entering from the ocean, including the upper portions of watersheds above anthropogenic fish passage barriers that historically contributed to the maintenance of anadromous populations.

Recovery plans developed under the ESA are guidance documents, not mandatory regulatory documents. However, the ESA envisions Recovery plans as the central organizing tool for guiding the recovery of listed species. Recovery plans also guide federal agencies in fulfilling their obligations under Section 7(a)(1) of the ESA, which 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 proactive measures to achieve species recovery, Recovery plans provide a context and framework for other provisions of the ESA with respect to federally listed species, including but not limited to consultations on federal agency activities under Section 7(a)(2) and the development of Habitat Conservation Plans in accordance with Section 10(a)(1)(B).

This Recovery Plan serves as a guideline for achieving recovery goals by describing the criteria by which NMFS would measure species recovery, the strategy to achieve recovery, and the recommended recovery actions necessary to achieve viable populations of steelhead within the SCCCS Recovery Planning Area.

Environmental Setting

The SCCCS Recovery Planning Area is dominated by a series of steep mountain range and coastal valleys and terraces. Watersheds within the region fall into two basic types: those characterized by short coastal streams draining mountain ranges immediately adjacent to the coast (*e.g.*, Santa Cruz and Santa Lucia Mountains), and those watersheds containing larger river systems that extend inland through gaps in the coastal ranges (*e.g.*, Pajaro and Salinas Rivers, and Arroyo Grande Creek).

The SCCCS Recovery Planning Area has a Mediterranean climate, with long dry summers and brief winters with short, sometimes intense cyclonic winter storms. Rainfall is restricted almost exclusively to the late fall, winter, and early spring months (November through May). Additionally, there is a wide disparity between winter rainfall from north to south, as well as between coastal plains and inland mountainous areas. Snow accumulation is generally small and of short duration, and does not typically contribute significantly to peak run-off in South-Central California watersheds. The SCCCS Recovery Planning Area is also subject to an El Niño/La Niña weather cycle that can significantly affect winter precipitation, causing highly variable rainfall and significant changes in oceanic conditions.

Base flows (average dry-season flows) in South-Central California watersheds are strongly influenced by groundwater which is transported to the surface through faults and fractured rock formations. Many rivers and streams in this region naturally exhibit interrupted base flow patterns (*i.e.*, alternating reaches with perennial and seasonal surface flow) controlled by geologic formations, and the strongly seasonal precipitation pattern characteristic of a Mediterranean climate. Water temperatures are generally highest during summer months, but can be locally cooled by springs, seeps, and rising groundwater, creating refugia where conditions remain suitable for rearing salmonids, even during the summer.

Significant portions of the upper watersheds within the SCCCS Recovery Planning Area are contained within the Los Padres National Forest (Monterey and Santa Lucia Ranger Districts). These forests are managed primarily for water production, recreation, and protection of native fish, wildlife, and botanical resources (with limited cattle grazing).

Urban development is concentrated in coastal areas and inland valleys, with the most extensive and densest urban development located within the Pajaro Salinas, San Luis Obispo and Arroyo Grande watersheds. The SCCCS Recovery Planning Area is home to more than 2.8 million people. Some coastal valleys and foothills are extensively developed with agriculture - principally row-crops, orchards, and vineyards (*e.g.,* Pajaro, Salinas and Arroyo Grande valleys).

Recovery Goals and Viability Criteria

The overarching goal of this Recovery Plan is recovery of the SCCCS DPS and its removal from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11). To achieve this goal, the ESA requires that Recovery plans, to the maximum extent practical, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be delisted (50 CFR 17.11 and 17.12).

Recovery criteria are built upon viability criteria developed by NMFS's Technical Recovery Team (TRT) for the individual anadromous *O. mykiss* populations and the DPS as a whole. A ***viable population*** is defined as a population having a negligible risk (< 5%) of extinction due to threats from demographic variation, natural environmental variation, and genetic diversity changes over a 100-year time frame. A ***viable DPS*** is comprised of a sufficient number of viable populations spatially dispersed, but proximate enough to maintain long-term (1,000-year) persistence and evolutionary potential (McElhany *et al*. 2000). The viability criteria are intended to describe characteristics of the species, within its natural environment, necessary for both individual populations and the SCCCS DPS as a whole to be viable, *i.e.,* persist over a specific period of time, regardless of other ongoing effects caused by human actions.

Recovery of the threatened SCCCS DPS will require recovery of a minimum number of viable populations within each of four Biogeographic Population Groups (BPGs) within the SCCCS Recovery Planning Area. Recovery of these individual populations is necessary to conserve the natural diversity (genetic, phenotypic, and behavioral), spatial distribution, and abundance of the species, and thus the long-term viability of the SCCCS DPS. Each population must exhibit a set of biological characteristics (*e.g.,* minimum mean annual run size, persistence over variable oceanic conditions, spawner density, anadromous fraction, *etc.*) in order to be considered viable. (Boughton *et al.* 2007b).

Recovery Strategy

Recovery of South-Central California steelhead will require effective implementation, as well as a scientifically based biological, recovery strategy. The framework for a durable implementation strategy involves two key principles: 1) solutions that focus on fundamental causes for watershed and river degradation, rather than short-term remedies; and 2) solutions that emphasize resilience in the face of projected climate change to ensure a sustainable future for both human communities and steelhead (Beechie *et al*. 2010, 1999; Boughton 2010a, Naiman 2005, Lubchenco 1998). Such a strategy:

- ❑ Looks for opportunities for sustainable water and land-use practices;
- ❑ Restores river and estuary processes that naturally sustain steelhead habitats;
- ❑ Provides diverse opportunities for steelhead within the natural range of ecological adaptability;
- ❑ Sustains ecosystem services for humans by reinforcing natural capital and the self-maintenance of watersheds and river systems; and
- ❑ Builds natural and societal adaptive capacity to deal with climate change.

A comprehensive strategic framework is necessary to serve as a guide to integrate the actions contributing to the goal of recovery of the SCCCS DPS. This strategic framework incorporates the concepts of viability at both the population and DPS levels, and the identification of threats and recovery actions for each of the four BPGs.

NMFS has identified core populations intended to serve as the foundation for the recovery of the species in the SCCS Recovery Planning Area. Threats assessments for the species indicate that recovery actions related to the modification of existing fish passage barriers and changes in water storage and management regimes within certain rivers of the SCCCS Recovery Planning Area are essential to the recovery of the species. Extensive, high quality habitat exists above a large number of passage barriers in these river systems. These areas are currently not included within the SCCCS DPS as defined in the listing rule (71 FR 834). However, because these habitat areas comprise a majority of the prime steelhead spawning and rearing habitat within the species' natural range, they are a major focus of recovery actions.

Uncertainties remain regarding the level of recovery necessary to achieve population and DPS viability, therefore, additional research and monitoring of *O. mykiss* populations within the SCCCS Recovery Planning Area is an essential component of this Recovery Plan. As the Recovery Plan is implemented, additional information will become available to: (1) refine the viability criteria; (2) update and refine the threats assessment and related recovery actions; (3) determine whether individual threats have been abated or new threats have arisen; and (4) evaluate the overall viability of anadromous *O. mykiss* in the SCCCS Recovery Planning Area. Additionally, there will be a review of the recovery actions implemented and population and habitat responses to these actions during the 5-year status reviews of the DPS.

Recovery Actions

Many complex and inter-related biological, economic, social, and technological issues must be addressed in order to recover anadromous *O. mykiss* in the SCCCS DPS. Policy changes at the federal, state and local levels will likely be necessary to implement many of the recovery actions identified in this Recovery Plan. For example, without substantial strides in water conservation, efficiency, and re-use throughout South-Central California, flow conditions for anadromous salmonids will limit recovery. Similarly, recovery is unlikely without programs to restore properly functioning historic habitats such as estuaries, and access to upstream spawning and rearing habitat.

Many of the recovery actions identified in this Recovery Plan also address watershed-wide processes (*e.g.*, wild-fire cycle, erosion and sedimentation, runoff and waste discharges) which will benefit a wide variety of native species (including other state and federally listed species, or species of special concern) by restoring natural ecosystem functions. Some of the listed species which co-occupy coastal watersheds with South-Central California steelhead include: Tidewater goby, Foothill yellow-legged frog, California least tern, California red-legged frog, Southwestern pond turtle, Arroyo toad, Least Bell's Vireo. Additionally, Pacific lamprey, another anadromous species occupying South-Central California watersheds, and whose numbers have declined significantly, can also be expected to benefit from many of the recovery actions identified in this Recovery Plan.

Restoration of steelhead habitats in coastal watersheds will also provide substantial benefits for human communities. These include, but are not limited to, improving and protecting the water quality of important surface and groundwater supplies, reducing damage from periodic flooding resulting from floodplain development, and controlling invasive exotic animal and plant species which can threaten water supplies and increase flooding risks.

Restoring and maintaining ecologically functional watersheds also enhances important human uses of aquatic habitats occupied by steelhead; these include activities such as outdoor recreation, environmental education (at primary and secondary levels), field-based research of both physical and biological processes of coastal watersheds, aesthetic benefits, and the preservation of tribal and cultural heritage values.

The final category of benefits accruing to recovered salmon and steelhead populations involve the ongoing costs associated with maintaining populations that are at risk of extinction. Significant resources are spent annually by federal, state, local, and private entities to comply with the regulatory obligations that accompany species that are listed under the ESA. Important activities, such as water management for agriculture and urban uses, can be constrained to protect ESA listed species. As a result of these ESA related obligations, such as compliance with Section 7 requirements, the take prohibitions of Section 9, and the development of Section 10 Habitat Conservation Plans, a degree of uncertainty is often experienced by regulated entities. Recovering listed salmonid species will reduce the regulatory obligations imposed by the ESA, and allow land and water managers greater flexibility to optimize their activities, and reduce costs related to ESA protections.

Although the recovery of South-Central California steelhead is expected to be a long process, the TRT recommended certain actions that should be implemented as soon as possible to help facilitate the recovery process for the SCCCS DPS. These include identifying a set of core populations on which to focus recovery efforts, protecting extant parts of inland populations, identifying refugia habitats, protecting and restoring estuaries, and collecting population data (Boughton *et al.* 2007b). Recovery actions for individual watersheds are identified in separate chapters covering the five BPGs within the SCCCS Recovery Planning Area (see Chapters 9-12).

Implementation and Recovery Action Cost Estimates

Implementation of this Recovery Plan will require a shift in societal attitudes, understanding, priorities, and practices. Many of the current land and water use practices that are detrimental to steelhead (particularly water supply and flood control programs) are not sustainable. Modification of these practices is necessary to both continue to meet the needs of the human communities of South-Central California and restore the habitats upon which viable steelhead populations depend.

Since the listing of South-Central California steelhead as threatened in 1997, efforts have accelerated to change many unsustainable water and land-use practices; however a great deal more needs to be done before steelhead are recovered and ultimately removed from the list of federally endangered or threatened species.

Investment in the recovery of South-Central California steelhead will provide economic and societal as well as environmental benefits. Monetary investments in watershed restoration projects can benefit the economy in multiple ways. These include stimulating the economy directly through the employment of workers, contractors and consultants, and the expenditure of wages and restoration dollars for the purchase of goods and services. Habitat restoration projects have been found to stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects (Sunderstrom *et al.* 2011, Nielsen-Pincus and Moseley 2010, Meyer Resources Inc., 1988). In addition, viable salmonid populations provide ongoing direct and indirect economic benefits as a natural resource base for angling, outdoor recreation, and tourist related activities. Dollars spent on steelhead recovery have the potential to generate significant new dollars for local, state, federal and tribal economies.

Perhaps the largest direct economic returns resulting from recovered anadromous salmonids are associated with angling. On average 1.6 million anglers fish the Pacific region annually (Oregon, Washington and California) and 6 million fishing trips were taken annually between 2004 and 2006 (National Marine Fisheries Service 2010b). Most of these trips were taken in California and most of the anglers live in California. Projections of the economic and jobs impacts of restored salmon and steelhead fisheries for California have been estimated from $118 million to $5 billion dollars, and supporting thousands of jobs (Michael 2010, Southwick Associates 2009; see also, Meyer Resources, Inc. 1988).

Estimating total cost to recovery in the SCCS Recovery Planning Area is challenging for a variety of reasons. These include the need to 1) refine recovery criteria; 2) complete investigations such as barrier inventories and assessments, and habitat typing surveys in the core populations; 3) identify flow regimes for individual watersheds; and 4) develop site-specific designs and plans to carry out individual recovery actions. Additionally, the biological response of steelhead to many of the recovery actions is uncertain and will require extensive monitoring. The recovery action tables (Tables 9-4 through 13-13) for each BPG within the SCCCS Recovery Planning Area includes a preliminary estimate of the costs of individual recovery actions, based on the general recovery action descriptions contained in Chapter 8, Summary of DPS-Wide Recovery Actions, Table 8.2 (Recovery Actions Glossary).

Costs estimates have been provided wherever possible, but in some cases where the uncertainties regarding the exact nature of the recovery actions is unknown (*e.g.*, complete barrier removal versus modification), these costs estimates can only be provided after site-specific investigations are completed. Estimating the total cost to recovery is further complicated because achieving recovery will be a long-term effort, involving multiple decades. Based upon the costs of individual recovery actions identified, NMFS estimates that the cost of implementing recovery actions throughout the SCCCS Recovery Planning Area will be approximately 560 million dollars over the next 80 to 100 years. Appendix E (Estimated Costs of Recovery Actions) of the Recovery Plan contains estimates for categories of typical watershed restoration activities.

Many of the recovery actions identified in the recovery action tables are intended to restore basic ecosystem processes and functions. As a result, many of these recovery actions will be, or already have been, initiated by local, state and federal agencies, as well as non-governmental organizations and other private entities as a part of their local or regional environmental protection efforts. Recovery actions may be eligible for funding from multiple funding sources at the federal, state, and local levels. Many of these grant programs also offer technical assistance, including project planning, design, permitting, and monitoring. Regional personnel with NMFS, California Department of Fish and Game, and the U.S. Fish and Wildlife Service can also provide assistance and current information on the status of individual grant programs. Appendix E provides a list of federal, state, and local funding sources. In weighing the costs and benefits of recovery, the multiple long-term benefits derived from short-term costs must be considered in any assessment. South-Central California steelhead recovery should therefore be viewed as an opportunity to diversify and strengthen the regional economy while enhancing the quality of life for present and future generations.

Recovery Partners

Recovery of South-Central California steelhead depends most fundamentally on a shared vision of the future. Such a vision would include a set of rehabilitated watersheds, rivers, and estuaries which support steelhead and other native species over the long-term, efficiently sustain ecological services for people, and allow river systems to respond to climate change.

A shared vision for the future can align interests and encourage cooperation that, in turn, has the potential to improve rather than undermine the adaptive capacity of public resources such as functioning watersheds and river systems.

The construction of a shared vision for South-Central California steelhead will require a number of basic institutional arrangements: 1) a deliberative forum (or set of forums) where interested stakeholders, including non-governmental organizations, can share experiences and ideas; 2) information networks that allow stakeholders to disseminate information with a broad array of interested and effected parties; and 3) the development and maintenance of trust and reciprocity that allows meaningful deliberation on inherently complex and contentious issues.

Technical Recovery Team Members – Pajaro River 2006

Achieving recovery of South-Central California steelhead will also require a number of coordinated activities, including implementation of strategic and threat-specific recovery actions, monitoring of the existing population's response to recovery actions, and further research into the diverse life history patterns and adaptations of *O. mykiss* to a semi-arid and highly dynamic environment (including the ecological relationship between anadromous and non-anadromous life history patterns).

Effective implementation of recovery actions will entail: 1) development of cooperative relationships with private land owners, non-governmental organizations, special districts, and local governments with direct control and responsibilities over non-federal land-use practices to maximize recovery opportunities; 2) participation in the land use and water planning and regulatory processes of local, regional, state, and federal agencies to integrate recovery efforts into the full range of land and water use planning; 3) close cooperation with state resource agencies such as the California Department of Fish and Game, California Coastal Commission, CalTrans, California Department of Parks and Recreation, State Water Resources Control Board, and Regional Water Quality Control Boards, and University Cooperative Extension to ensure consistency of recovery efforts; and 4) partnering with federal resource agencies, including the U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, U.S. Bureau of Reclamation, U.S. Bureau of Land Management, U.S. Army Corps of Engineers, U.S. Department of Transportation, U.S. Department of Defense, and the U.S. Environmental Protection Agency, ad U.S. Natural Resource Conservation Service.

NMFS intends to promote the Recovery Plan and provide needed technical information and assistance to entities responsible for activities that may impact the species' recovery, including implementation of high priority recovery actions. Additionally it will be important to work with cities and counties to incorporate protective measures consistent with recovery objectives in their General Plans and Local Coastal Plans. NMFS also intends to work with state and federal regional entities on regional planning efforts such U.S. Forest Service Land Resource Management Plans, State Park General Plans, Regional Water Control Board Basin Plans, and Local Coastal Plans.

Estimated Time to Recovery and Delisting

Given the scope and complexity of the threats and recovery actions identified within the SCCS Recovery Planning, the time to full recovery can be provisionally estimated to vary from 80 to 100 years. Delays in the completion of recovery actions, time for habitats to respond to recovery actions, or the species' response to recovery actions would lengthen the time to recovery. A modification of the provisional population or DPS viability criteria resulting in smaller run-sizes, or the number or distribution of recovered populations, could shorten the time to recovery.

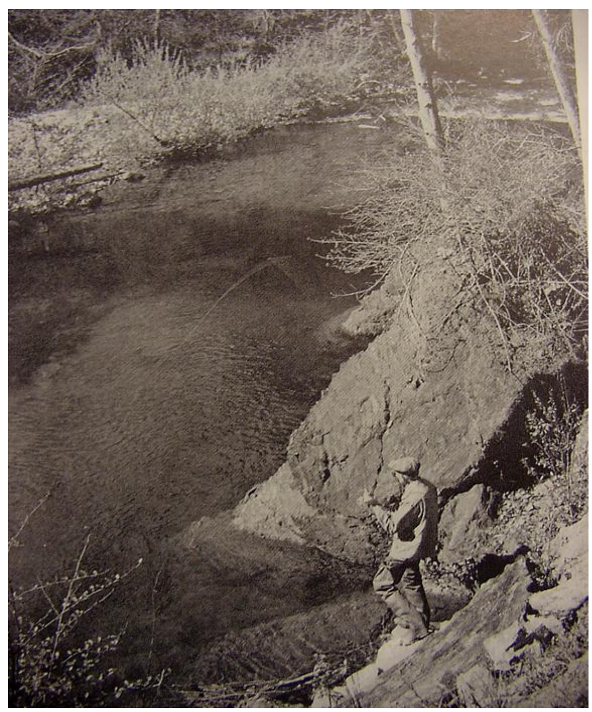
1. Introduction

"And so little rivers, granted sufficient rainfall to give them life, possess one thing in common. These sturdy migrants forge swiftly and surely over the tidal bars and up the current perhaps a dozen or two-score miles to the spawning bars at the headwaters far back in a deep dark canyon of the Coast Range. . . . Were I to conduct a visiting angler on a tour of these charming southern streams, I should like to first take him up to the Big Sur in the giant redwoods, where the rushing river comes downs through the forest from its birthplace far back in the mysterious shrouded canyons of the great Santa Lucia Range."

Claude M. Kreider. Steelhead.
G.P. Putnam's Sons, New York. 1948

1.1 South-Central California Coast Steelhead at Risk

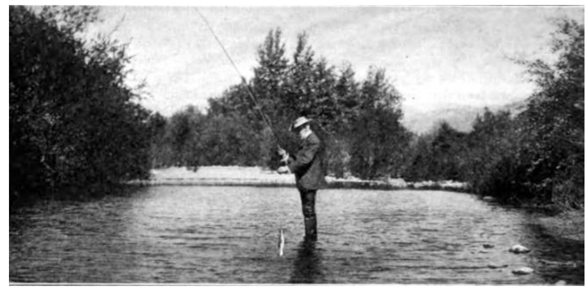
Steelhead are the anadromous, or ocean-going, form of the species *Oncorhynchus mykiss.* Historically, these fish were the only abundant salmonid species that occurred naturally within the coast ranges of South-Central California (Jordan and Evermann 1896, 1923, Jordan and Gilbert 1881). Steelhead entered the rivers and streams draining the Coast Ranges from Point Sal to the U.S. Mexican Border during the winter and spring, when storms produced sufficient runoff to breach the sandbars at the rivers' mouths and provided fish passage to upstream spawning and rearing habitats. These fish and their progeny were sought out by recreational anglers during the winter, spring and summer fishing seasons (Alagona *et al*. 2011, Swift *et al.* 1993, Nehlsen, *et al.*, 1991, Shapovalov *et al.* 1981, Capelli 1974, Boydstun 1973, Fry 1973, 1938, Combs 1972, Shapovalov and Taft 1954, Kreider 1948, Hubbs 1946, Snyder 1913). The ethnographic and archaeological evidence regarding the role of *O. mykiss* in Native American culture is currently limited and subject to varying interpretation by investigators (Hosale 2010, Lightfoot and Parrish, Glassow *et al*. 2007, Gobalet *et al*., 2004, Hildebrandt 2004, Hudson and Blackburn 1982, Horne 1981, Swezey and Heizer 1977, Spanne 1975, Tainter 1975).



Steelhead Angler, Big Sur River. c. 1940s.

Following the dramatic rise in South-Central California's human population after World War II and the associated land and water development within coastal drainages (particularly major dams and water diversions), steelhead abundance rapidly declined, leading to the extirpation of populations in many watersheds and leaving only sporadic and remnant populations in the remainder (Boughton *et al.* 2005, Good *et al.* 2005, Helmbrecht and Boughton 2005, Busby *et al.* 1996). While the steelhead populations declined sharply, most coastal watersheds retained populations of the non-anadromous life history form of the species (commonly known as resident or rainbow trout), often in the upper reaches of watersheds within national forest lands that were more protected from the impacts of human development. In response to the dwindling native populations of anadromous and related non-anadromous resident *O. mykiss*, and in an effort to meet the burgeoning demand for recreational fishing opportunities, the California Department of Fish and Game expanded an extensive put-and-take stocking program (Dill *et al*. 1997, Leitritz 1970, Butler and Borgeson 1965). This program was aimed principally at recreational anglers, and not intended or expected to address the underlying causes of the decline of the anadromous runs in South-Central California. As conditions in South-Central California coastal rivers and stream continued to deteriorate, put-and-take trout stocking became more focused on suitable manmade reservoirs.

Since the listing of South-Central California Coast steelhead as threatened in 1997, the California Department of Fish and Game has ceased stocking hatchery reared fish in the anadromous waters of South-Central California (California Department of Fish and Game and U.S. Fish and Wildlife Service 2010). However, a substantial portion of the upper watersheds, which contain the majority of historical spawning and rearing habitats for anadromous *O. mykiss*, remain intact (though inaccessible to anadromous fish) and protected from intensive development as a result of their inclusion in the Los Padres National Forest. Additionally, a significant amount of land within South-Central California coastal watersheds is protected by inclusion within regional parks and various military installations, including the upper Salinas watershed (including portions of Nacimiento and San Antonio Rivers) within the U.S. Army's Camp Roberts and Fort Hunter Liggett.



Juvenile Steelhead, Carmel River, 1907.

The National Marine Fisheries Service's (NMFS) responsibility and goal is to prevent the extinction of steelhead in the wild and ensure the long-term persistence of self-sustaining, and ultimately harvestable, wild populations of steelhead within the SCCCS DPS by addressing those factors limiting the species' ability to survive and reproduce in the wild. The species can be removed from the list of federally-protected threatened and endangered species only after this goal has been reached.

Recovery of steelhead will require reducing threats to the long-term persistence of wild populations, maintaining multiple interconnected populations of steelhead across the diverse habitats of their native range, and preserving the diversity of steelhead life history strategies that allow the species to withstand natural environmental variability—both intra-annually and over the long-term.

An effective steelhead recovery program will require the implementation of a series of coordinated recovery actions that:

- ❑ Prevent steelhead extinction by protecting existing populations and their habitats.
- ❑ Maintain current distribution of steelhead and restore distribution to

previously occupied areas that are essential for recovery.

- Increase abundance of steelhead to viable population levels, including the expression of all life history forms and strategies.
- Conserve existing genetic diversity and provide opportunities for natural interchange of genetic material between and within metapopulations.
- Maintain and restore suitable habitat conditions and characteristics for all life history stages so that viable populations can be sustained naturally.
- Refine and demonstrate attainment of recovery criteria through research and monitoring.

Preventing the extinction of steelhead has long term implications for all *O. mykiss* populations (Boughton *et al.* 2007b, 2006). Steelhead have evolved an ability to search out and use a wide variety of ever-changing habitats over millennia. The loss of steelhead would initiate a process of irreversible cumulative extinctions of other native *O. mykiss* trout populations in the region because the evolutionary innovations that are the product of anadromy could no longer be naturally transmitted among the remaining resident *O. mykiss* populations. Because of the naturally dynamic and unstable environment of South-Central California, the remaining resident *O. mykiss* populations would likely continue on the path of gradual differentiation and perhaps even speciation (Hoelzer *et al*. 2008), but with a vastly reduced ability to innovate and survive in a changing environment., thus increasing their chance of extirpation.

1.2 South-Central California Coast Steelhead Listing History

After NMFS completed a comprehensive status review of all West Coast steelhead populations (Busby *et al.* 1996), SCCCS populations were proposed for listing by NMFS as an threatened Evolutionarily Significant Unit (ESU) on August 9, 1996 (61 FR 56138). An ESU is composed of a group of conspecific populations that are substantially reproductively–isolated from other conspecific populations, and that possess important elements of the evolutionary legacy of the species which are expressed genetically and phenotypically that have adaptive value (56 FR 224, Waples 1998, 1995, 1991a, 1991b). The South-Central Coast Steelhead ESU was formally listed as threatened on August 18, 1997 (62 FR 43937). The original ESU boundaries during the first listing of 1997 were from the Pajaro River (Monterey County) south to (but not including) the Santa Maria River (San Luis Obispo County). During the time between the initial listing and a subsequent re-listing in 2006, NMFS adopted the DPS designation for steelhead to replace the ESU designation to be consistent with the listing policies and practices of the U. S. Fish and Wildlife Service. A DPS designation (61 FR 4722) uses similar but slightly different criteria from the ESU designation for determining when a group of organisms constitutes a DPS under the Endangered Species Act (ESA). A DPS is a population or group of populations that is discrete from other populations of the same taxon, and significant to its taxon. A group of organisms is discrete if it is “markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, and behavioral factors.’’ While a group of organisms is discrete if it is “markedly separated from other populations of the same taxon” it does not have to exhibit reproductive isolation under the DPS designation.

Following a subsequent status review of West Coast steelhead populations in 2005 (Good *et al.* 2005), a final listing determination for the threatened SCCCS DPS was issued on January 5, 2006 (71 FR 834).

The final designation for the SCCCS DPS encompasses all naturally spawned steelhead between the Santa Maria River (inclusive) and the U.S.-Mexico border. Consequently, this DPS includes only those *O. mykiss* whose freshwater habitat occurs below impassible barriers, whether artificial or natural, and which exhibit an anadromous life history. Individuals that have originated in freshwater above impassable barriers and exhibit an anadromous life history are also considered as part of the DPS when they are within waters below the most downstream impassable barriers.

1.3 Designated Critical Habitat

The ESA requires NMFS to designate critical habitat for all listed species. Critical habitat is defined as specific areas where physical or biological features essential to the conservation (recovery) of the species exist and may require special management considerations or protection. For recovery planning and implementation purposes, these physical or biological features can be viewed as the set of habitat characteristics or conditions that are the end goal of many recovery actions.

When designating critical habitat, NMFS considers certain habitat features called "Primary Constituent Elements" (PCEs) that are essential to support one or more life history stage(s) of the listed species (50 CFR 424.12b). PCEs considered essential for the conservation of the SCCCS DPS are those sites and habitat components that support one or more life stages and contain physical or biological features essential to survival, growth, and reproduction. These PCEs include:

- **Freshwater spawning sites** with sufficient water quantity and quality as well as adequate substrate (*i.e.*, spawning gravels of appropriate sizes) to support spawning, incubation and development.
- **Freshwater rearing sites** with sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions and allow development and mobility; sufficient water quality to support growth and development; food and nutrient resources such as terrestrial and aquatic invertebrates and forage fish; and natural cover such as shade, submerged and overhanging large wood, log jams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- **Freshwater migration corridors** free of obstruction and excessive risk of predation with adequate water quantity to allow for juvenile and adult mobility; cover, shelter, and holding areas for juveniles and adults; and adequate water quality to allow for survival.
- **Estuarine areas** that provide uncontaminated water and substrates; food and nutrient sources to support growth and development; and connected shallow water areas and wetlands to conceal and shelter juveniles. Estuarine areas include coastal lagoons that are seasonally stable, predominantly freshwater-flooded habitats that remain disconnected from the marine environment except during high streamflow events, and tidally-influenced estuaries that provide a dynamic shallow water environment.

- **Marine areas** with sufficient water quality to support growth, development and mobility; food and nutrient resources such as marine invertebrates and forage fish; and nearshore marine habitats with adequate depth, cover and marine vegetation to provide shelter.

The final critical habitat designation for the SCCCS DPS was issued on September 2, 2005 (70 FR 52488). A total of 1,240 miles of stream habitat and 3 square miles of estuarine habitat were designated as critical habitat from the 28 watersheds within the range of this DPS. Critical habitat for the SCCCS DPS includes most, but not all, occupied habitat from the Pajaro River in Monterey County to Arroyo Grande Creek in southern San Luis Obispo County, but excludes some occupied habitat based on economic considerations and all military lands with occupied habitat. The stream channels with designated critical habitat are listed in 70 FR 52488. A review of the current critical habitat designations may result in modifications of the current critical habitat designations, including the addition of unoccupied habitat which exhibit PCEs.

1.4 The Recovery Planning Process

The ESA, as amended (16 U.S.C. 1531 *et seq*.), mandates that NMFS develop and implement recovery plans for the conservation of listed species. The SCCCS DPS was listed as threatened in 1997 under the ESA. The development and implementation of a Recovery Plan for the SCCCS DPS is considered vital to the continued persistence and recovery of steelhead in this region.

NMFS has established a South-Central California Coast Steelhead Recovery Planning Area for the purposes of developing this Recovery Plan and guiding the implementation of actions to recover this species. The SCCCS Recovery Planning Area extends from the Santa Maria River south to the Tijuana River at the U.S.-Mexico border and includes those portions of coastal watersheds that are at least seasonally accessible to steelhead entering from the ocean and the upstream portions of some watersheds that are currently inaccessible to steelhead due to man-made barriers. NMFS' Southwest Region (SWR) Protected Resources Division (PRD) in Long Beach, California is responsible for the development of the recovery plan for the SCCCS DPS.

The Recovery Plan serves as a guideline for achieving recovery goals by describing the biological criteria that the listed species (and individual populations) must exhibit, and the recovery actions that must be taken to meet these criteria. Although recovery plans provide guidance, they are not regulatory documents. However, the ESA envisions recovery plans as the central organizing tool for guiding the recovery of listed species. Recovery plans also provide guidance to federal agencies fulfilling their obligations under Section 7(a)(1) of the ESA, which 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 proactive measures to achieve species recovery, recovery plans provide a context and framework for implementing other provisions of the ESA, including consultations on federal agency activities under Section 7(a)(2) and the development of Habitat Conservation Plans (HCPs) in accordance with Section 10(a)(1)(B).

Recovery plans are also intended to be used to inform local, state, tribal and non-governmental entities and individuals who may wish to participate in the conservation and recovery of the species, or who are engaged in activities that may adversely affect that species. Successful implementation of a recovery plan depends upon the cooperation of stakeholders and planning and regulatory entities.

Pursuant to Section 4(f) of the ESA, a recovery plan must be developed and implemented for species listed as threatened or endangered, unless it is found that such a plan will not promote the conservation of the species. A recovery plan must include the following:

- Objective, measurable criteria, which, when met, will allow delisting of the species (see Chapter 6, Steelhead Recovery Goals, Objectives & Criteria);

- A description of site-specific management actions necessary for recovery (see Chapters 9 through 13, Biogeographic Population Groups); and

- Estimates of the time and cost to carry out the recommended recovery measure (see Chapters 9 through 13, Biogeographic Population Groups, Recovery Action Tables).

Past recovery plans for other listed species have generally focused on the abundance, productivity, habitat, and other life history characteristics of a species. While knowledge of these characteristics is important for making sound conservation management decisions, the long-term sustainability of a threatened or endangered species can only be ensured by alleviating the threats that are contributing to the decline of that species or impeding its recovery. Therefore, the identification of such threats is a key component of any recovery program (National Marine Fisheries Service 2010a).

The Interim Endangered and Threatened Species Recovery Planning Guidance document (National Marine Fisheries Service 2010a) recommends "…*using a threats assessment for species with multiple threats to help identify the relative importance of each threat to the species' status, and, therefore, to prioritize recovery actions in a manner most likely to be effective for the species' recovery*." This Recovery Plan uses this recommended approach to identify and prioritize threats to the SCCCS DPS. The prioritized threats are then used to guide the identification of specific recovery actions. Chapter 4, Current DPS-Level Threats Assessment, summarizes the threats across the DPS and Chapters 9 through 13 provide a summary of the threats assessments within each of the five BPGs of the DPS. The threats assessment methodology is discussed in Appendix D, South-Central California Coast Steelhead Recovery Planning Area Threats Assessment (CAP Workbooks) Methodology.

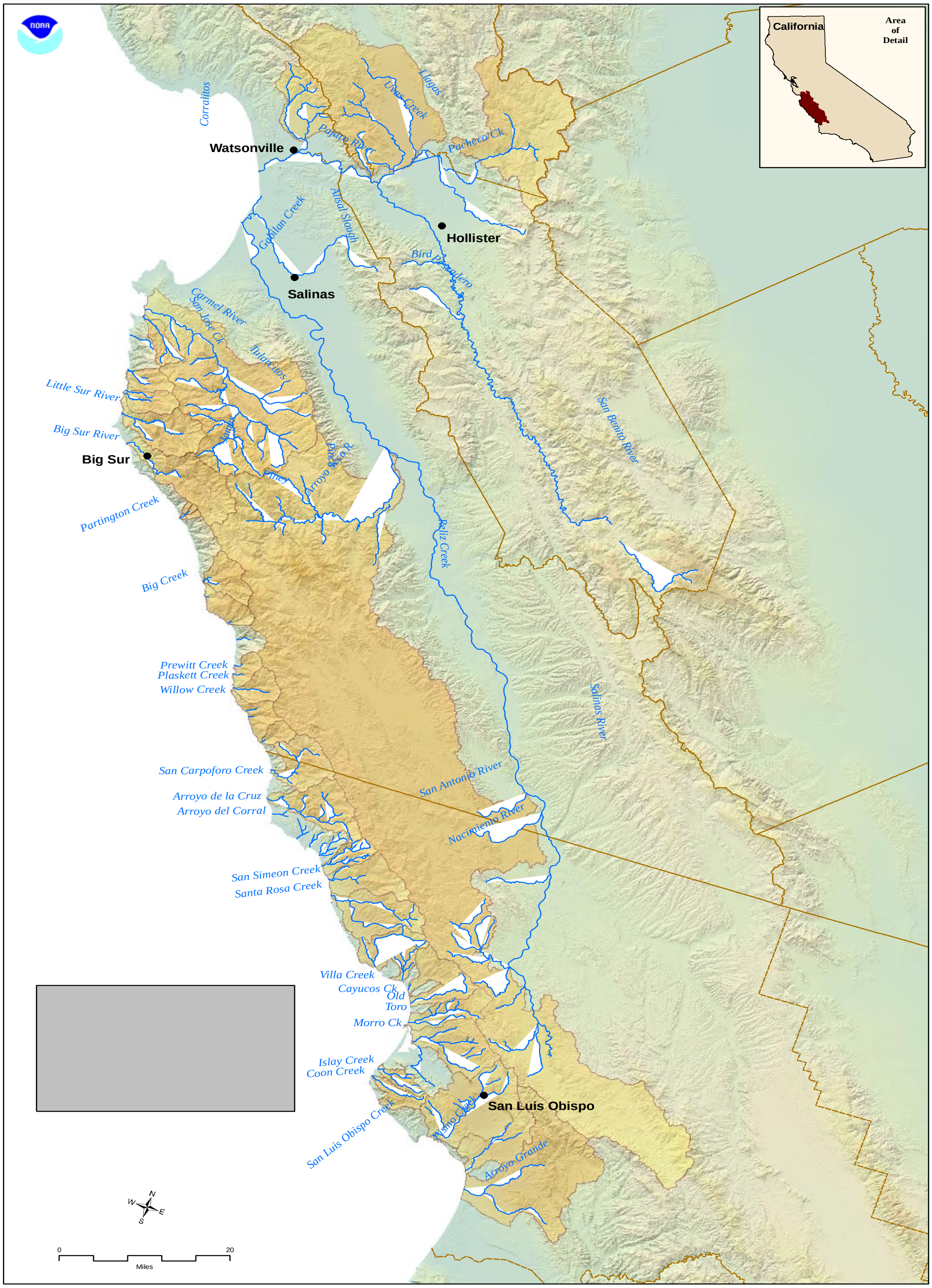


Figure 1-1. South-Central California Coast Steelhead Recovery Planning Area. Boundaries of Recovery Planning Area extend beyond the current distribution of the listed species

1.4.1 South-Central/Southern California Steelhead Technical Recovery Team

As part of its recovery planning efforts, NMFS Southwest Region (SWR) assembled a team of scientists with a wide variety of expertise in biological and physical sciences to provide technical assistance to the recovery planning process for South-Central California Coast steelhead; this group is known as the Technical Recovery Team (TRT). NMFS' intent in establishing the TRT was to seek geographic and species-specific expertise to develop a scientific foundation for the recovery planning. The TRT produced and published a number of Technical Memoranda, which provide a description of the unimpaired historic populations within the Recovery Planning Area (Boughton *et al.* 2006), and identified viability criteria for anadromous *O. mykiss* in the SCCCS DPS (Boughton *et al*. 2007b). Additionally, NMFS's Southwest Science Center produced and published a number of additional Technical Memoranda dealing with potential over-summering habitat in the region (Boughton and Goslin 2006), the reduction of the South-Central range limit of anadromous *O. mykiss* (Boughton *et al*. 2005), research and monitoring (Boughton 2010b), and recovery strategies in a changing environment (Boughton 2010a). Finally, NMFS's Southwest Science Center undertook a number of genetic investigations in an attempt to identify the population structure of the SCCCS DPS, and provided scientific review of local and regional recovery efforts (Clemento *et al.* 2009, Pearse and Garza 2008, Girman and Garza 2006; see also, Nielsen *et al*. 2001, 1994c).

1.4.2 Public Participation

Local, state, and federal support of recovery planning by those whose activities directly affect the listed species, and whose actions will be most affected by recovery requirements, is essential to the successful implementation of any recovery plan. NMFS supports and participates in collaborative efforts to develop and implement recovery plans by engaging local communities, state and federal entities, and other stakeholders.

As part of the recovery planning process, NMFS published a notice of intent to prepare a Recovery Plan for the species in the Federal Register and conducted a series of Recovery Planning Workshops to solicit information on threats and recovery actions as part of the development of the Recovery Plan for the SCCCS DPS. Public workshops were held in Arroyo Grande and Carmel, California in April 2007, and in San Luis Obispo and Carmel, California in June 2007.

At these workshops, NMFS provided a general overview of the:

- ❑ federal recovery planning process;
- ❑ preliminary timeline for NMFS Recovery Plan development;
- ❑ current understanding of steelhead populations and their habitats;
- ❑ threats assessment process and the threats identified by NMFS; and

NMFS also received public input on potential recovery actions.

Following the overview, workshop participants were separated into smaller, facilitated breakout groups to identify threats to specific steelhead populations and their habitats. In the final set of workshops, breakout groups identified potential recovery actions for specific populations and habitats. Information obtained from these workshops was used in the development of a formal threats assessment analysis using The Nature Conservancy's Conservation Action Planning (CAP) threats assessment methodology, and the identification of a full suite of recovery actions based on those threats. See Appendix D, South-Central California Coast Steelhead Recovery Planning Area Threats Assessment (CAP) Workbook Methodology.

NMFS has also established a web page to provide ongoing updates and information to the public about the recovery planning process, access to Recovery Plan materials and implementation of recovery actions. The home web page for NMFS SWR salmonid recovery planning is accessible at: http://swr.nmfs.noaa.gov/recovery/index.htm. The web page for recovery planning and implementation for the SCCCS DPS (including the Recovery Plan, related NOAA Technical Memorandum, and Threats Assessment summaries) can be found at: http://swr.nmfs.noaa.gov/recovery/So_Cal.htm.

Finally, recovery of the species cannot occur without public involvement in the implementation process. NMFS encourages the efforts of watershed groups dedicated to improving watershed ecosystem conditions. NMFS believes it is critically important to base steelhead recovery efforts on the many federal, state, regional, local, and private conservation efforts already underway throughout the region. Local support of the Recovery Plan by those whose activities directly affect the listed species, and whose actions will be most affected by recovery efforts, is essential. NMFS therefore supports and participates in locally-led collaborative efforts to develop projects and plans, involving local communities, state and federal entities, and other stakeholders. NMFS anticipates that watershed groups and private entities can utilize the information and recommendations provided in this Recovery Plan to further refine and develop recovery actions to abate threats and meet recovery objectives.

2. Steelhead Biology and Ecology

"[W]e must constantly keep in mind that variation, i.e., deviation from the norm, is one of the most marked characteristics of animal life. And of the vertebrates, the trout are among the most variable of all. Further, of the trout the steelhead is one of the most variable forms. . . . As an example, in the coastal streams most fish migrate in their first year, third, fourth, or fifth years, or do not migrate at all."

Leo Shapovalov and Alan C. Taft,
Life Histories of Steelhead Trout and Silver Salmon, 1954

2.1 SPECIES TAXONOMY AND LIFE HISTORY

Oncorhynchus mykiss is one of six Pacific salmon in the genus *Oncorhynchus* that are native to the North American coast. O. *mykiss*, along with other species of Pacific salmon exhibit an anadromous life history, which means that juveniles of the species undergo a change that allows them to migrate to and mature in salt water before returning to their natal rivers or streams (*i.e.,* streams where they were spawned) to reproduce.

Two principal steelhead recovery objectives are to increase abundance of steelhead and to preserve the expression of their diverse life history strategies. A schematic illustration of the various life history strategies that occur in the SCCCS Recovery Planning Area is shown in Figure 2-1. The figure is best understood by tracing the various pathways a freshwater juvenile may follow. Those pathways may remain entirely within freshwater ecosystems or transition between freshwater, estuarine and marine ecosystems. The use of these different environments confers advantages or disadvantages to the survival and reproductive success of the individual depending on the conditions of those environments. Even though neighboring watersheds can differ, a viable population of steelhead may contain individuals expressing many, if not all, the diverse life history strategies exhibited by the species. See discussion below in Section 2.6, South-Central California Coast Steelhead Freshwater Life Cycle Habitat Use.

Steelhead are a highly migratory species. Adult steelhead (Figure 2-2) spawn in coastal watersheds; their progeny (Figure 2-3) rear in freshwater or estuarine habitats prior to migrating to the sea. Within this basic life history pattern, the species exhibits a greater variation in the time and location spent at each life history stage than other Pacific salmon within the genus *Oncorhynchus* (Hayes *et al*. 2011a, 2011b, Quinn 2005, Hendry *et al.* 2004).

The life cycle of steelhead generally involves rearing in freshwater for one to three years before migrating to the ocean and spending from one to four years maturing in the marine environment before returning to spawn in freshwater. The ocean phase provides a reproductive advantage because individuals that feed and mature in the ocean grow substantially larger than freshwater residents, and larger females produce proportionately more eggs; however, the freshwater phase provides protected rearing environment, relatively free of competition and predators. This life history strategy is referred to as "fluvial-anadromous". Out-migration to the ocean (*i.e.,* emigration) usually occurs in the late winter and spring. In some watersheds, juveniles may rear in a lagoon or estuary for several weeks or months prior to entering the ocean. The timing of emigration is influenced by a variety of factors such as photoperiod, streamflow, temperature, and breaching of the sandbar at the river's mouth. These out-migrating juveniles, termed smolts (Figure 2.4), live and grow to maturity in the ocean for two to four years before returning to freshwater to reproduce (Jacobs *et al.* 2011, Borg 2010, Haro *et al*. 2009, Leder *et al.* 2006, Quinn 2005, Davies 1991, Groot and Margolis 1995, 1991, Northcote 1958).

The ocean phase of steelhead has not been studied extensively, though marine migration studies of other species of *Oncorhynchus* have encountered only isolated specimens of *O. mykiss* and as a result it is believed that the species does not generally congregate in large schools like other Pacific salmon of the genus *Oncorhynchus* (Grimes *et al*. 2007, Aydin *et al.* 2005, Burgner *et al*. 1992, 1980, Groot and Margolis 1991, Meyers *et al.* 1996, Hartt and Bell 1985). Consequently, the movement patterns of steelhead at sea are poorly understood. Some anadromous salmonids have been found in coastal waters relatively close to their natal rivers, while others may range widely in the North Pacific (Quinn 2005, Quinn and Myers 2005, Meyers *et al.* 1996, Groot and Margolis 1991, Burgner *et al*. 1992, 1980).

Returning adults may migrate from several to hundreds of miles upstream to reach their spawning grounds. The specific timing of spawning can vary by a month or more among streams within a region, occurring in winter and early spring, depending on factors such as run-off and sand bar breaching (Jacobs *et al.* 2011, Fukushima and Lesh 1998, Shapovalov and Taft 1954). Once they reach their spawning grounds, females use their caudal fin to excavate a nest (redd) in streambed gravels where they deposit their eggs. After fertilization by the male, the female covers the redd (often during construction of additional upstream redds) with a layer of gravel, where the embryos and alevins incubate within the gravel. Hatching time varies from about three weeks to two months depending on water temperature. The young fish emerge from the gravel two to six weeks after hatching. Adult steelhead do not necessarily die after spawning and may return to the ocean, sometimes repeating their spawning migration one or more times. It is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle *et al. 2008*, Moyle 2002). The frequency of repeat spawning among SCCCS DPS populations has not been investigated, and it is therefore unknown how it may differ from other populations, or the role repeat spawning plays in the population dynamics in South-Central California. Additional details regarding this species' life history can be found in Quinn (2005), Bjornn and Reiser (1991), Barnhart (1986, 1991), and Shapovalov and Taft (1954).

This species may also display a non-anadromous life history pattern (*i.e.,* a "freshwater-resident" strategy). It has been common practice to refer to non-anadromous individuals that complete their entire life history cycle (incubating, hatching, rearing, maturing, reproducing, and dying) in freshwater as rainbow trout, while referring to those emigrating to and maturing in the ocean as steelhead. However, this terminology does not capture the complexity of the life history cycles exhibited by native *O. mykiss*. Individuals can complete their life history cycle completely in freshwater, or they can migrate to the ocean after one to three years, and spend two to four years in the marine environment before returning to freshwater rivers and streams to spawn.

Additionally, "rainbow trout" which have completed their life history cycle entirely in freshwater sometimes produce progeny which become anadromous and emigrate to the ocean and return as adults to spawn in freshwater. Conversely, it has also been shown that steelhead may produce progeny which complete their entire life cycle in freshwater. This switching of life history strategies has been demonstrated by studying the microchemistry of *O. mykiss* otoliths (small inner ear bones), where time spent in marine and fresh waters can effectively be tracked by the presence or absence of certain ocean-derived elements in the bone tissue (Zimmerman 2005). Zimmerman and Reeves (2000) used this technique to uncover occasional life history switching in *O. mykiss* populations in Oregon. O. *mykiss* in the SCCCS Recovery Planning Area have not yet been examined in this way, but various lines of evidence (*e.g.*, inland resident fish in systems such as the upper Old Creek and Arroyo Grande Creek exhibiting smolting characteristics, river systems producing smolts with no regular access for adult steelhead) indicate that switching between freshwater and anadromous life cycles is likely occurring (M. Capelli, personnel communication,). The cues that trigger this phenomenon are unknown, but may be linked to environmental variation (Satterthwaite *et al.* 2012, 2010, 2009, Hayes *et al.* 2011b, Sogard *et al.* 2011). For example, juvenile residency can be strongly influenced by the hydrologic cycle in South-Central California, where extended droughts can cause juveniles to become land-locked and therefore unable to reach the ocean (Boughton *et al*. 2009, 2006).

Lastly, there is a third type of life history strategy displayed by *O. mykiss* that is referred to as "lagoon-anadromous." Bond (2006), working at a study site in northern Santa Cruz County, has recently shown that each summer a fraction of juvenile *O. mykiss* over-summered in the estuary of their natal creek. Like South-Central California estuaries, this estuary was cut off from the ocean during the summer by the formation of a sandbar spit, creating a seasonal lagoon. Bond (2006) showed that many juveniles grow fast enough after their first year of lagoon rearing to migrate to the ocean, and most enter the ocean at a larger size than the same year class fish rearing in freshwater habitats of the stream system. Larger size generally enhances survival in the ocean, and the lagoon-reared fish represented a large majority of the returning adult spawning population (Hayes *et al.* 2008, Bond 2006). Steelhead populations in the SCCCS Recovery Planning area have not been investigated to determine whether or to what extent they may exhibit this life history strategy, though estuarine conditions in many basins are similar those which have been investigated and documented in Central Coast basins.

Closely related to these life history strategies is the use by steelhead of a wide variety of habitats over their lifespan, including river mainstems, small montane tributaries, estuaries, and the ocean. Steelhead move between these habitats because each habitat supports only certain aspects of what the fish require to complete their life cycle. Different populations frequently differ in the details of the times and habitats that they utilize while pursuing the general pattern of the anadromous life cycle; these differences can reflect the evolutionary response of populations to environmental opportunities, subject to a variety of biological constraints that are also a product of evolution.

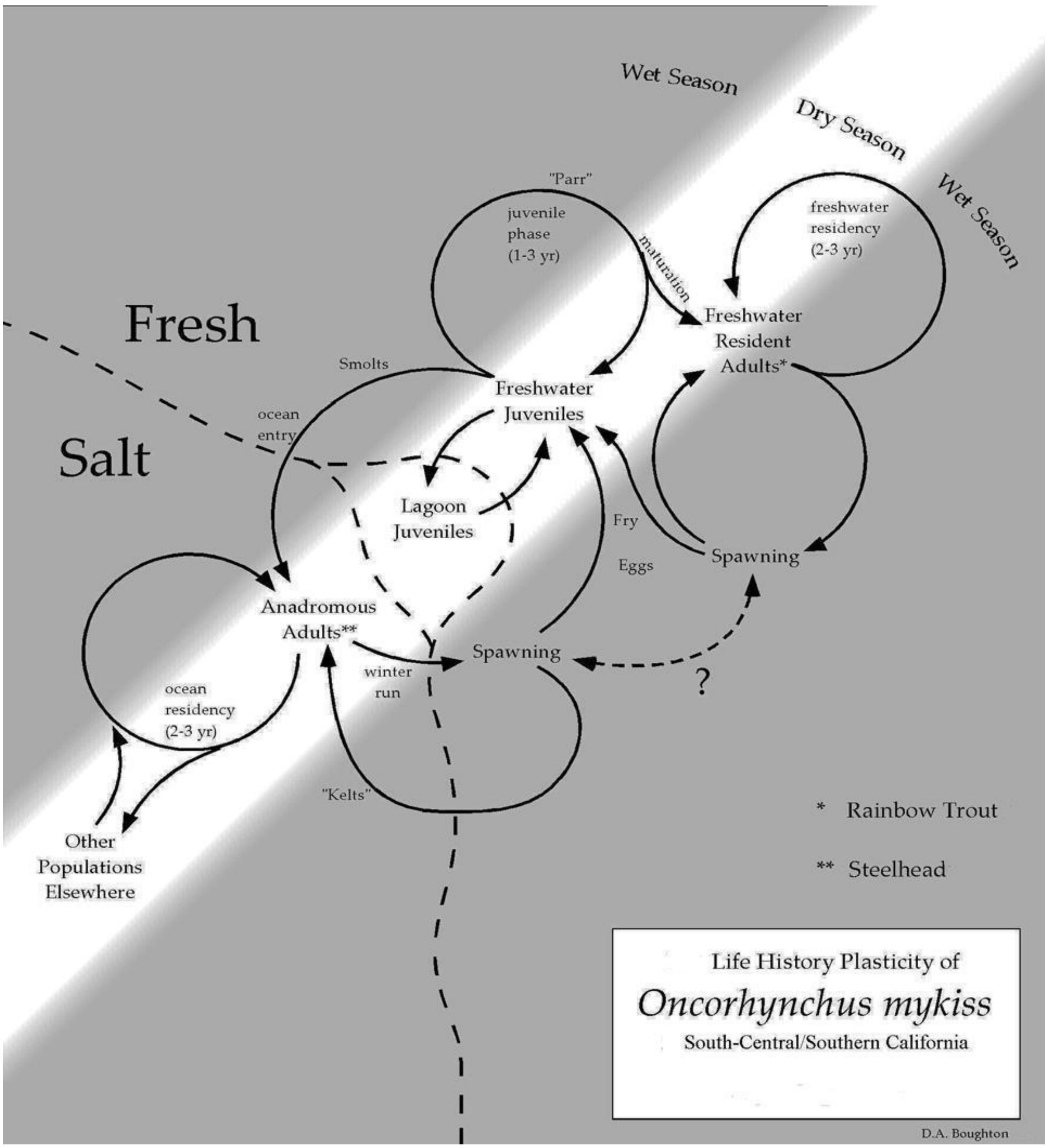


Figure 2-1. Summary of the various life history strategies exhibited by South-Central California Coast *O. mykiss* and the life stage specific terminology.

Within each of the three basic life history strategies (fluvial-anadromous, freshwater-resident, and lagoon-anadromous), there is additional variation, including examples of finer-scale habitat switching, such as multiple movements between lagoon and freshwater habitats in the course of a single summer in response to fluctuating habitat conditions; and also so-called "adfluvial" populations that inhabit freshwater reservoirs but spawn in tributary creeks (Hayes *et al.* 2011a, 2011b, 2008, M. Capelli, personnel communication).

Figure 2-2. Adult Steelhead (*O. mykiss)* (approx. 76 cm), Uvas Creek, Pajaro River, Monterey County, 2012.

Figure 2-3. Juvenile *O. mykiss* (approx. 10 cm), Trout Creek, Salinas River, Monterey County, 2008. (Courtesy Jenna Voss)

Figure 2-4. Steelhead smolts (approximately 19 cm), Arroyo Seco, Salinas River, Monterey County, 2011 (Courtesy Monterey County Water Resources Agency)

2.2 SPECIES FRESHWATER DISTRIBUTION AND POPULATION STRUCTURE

Differences between the historical and current distributions of South-Central California Coast steelhead illustrate their present threatened status. Many anadromous populations have become extirpated, particularly near the southern extent of their range (Boughton *et al.* 2006, 2005, Boughton and Fish 2003, Augerot 2005). Individual anadromous populations within this SCCCS Recovery Planning Area have been severely reduced or in some cases extirpated (Table 2-1, Figure 2-5). Some smaller watersheds may have originally supported only sporadic steelhead runs, or intermittent resident populations that experienced repeated local extinctions and recolonizations by anadromous immigrants in dry and wet cycles, respectively. This aspect of the freshwater distribution and population structure of *O. mykiss* has not been extensively studied, and as a result is not well understood (Boughton *et al*. 2006).

NMFS conducted an extensive *O. mykiss* population survey (targeted primarily at juveniles) in 2002 of most of the coastal watersheds within the South-Central California Coast Steelhead (SCCCS) Recovery Planning Area (Boughton and Fish 2003). Of the 46 watersheds in which steelhead were known to have occurred historically, between 37 and 43 percent were still occupied by either resident fish or steelhead (a range was reported for the occupancy estimate because several watersheds could not be surveyed). Three watersheds were considered vacant of steelhead because they were dry, 17 were considered vacant due to the presence of impassible barriers to all known spawning habitat, and six were considered vacant because the survey found no evidence of *O. mykiss*. Seventeen watersheds with no known historical record of steelhead occurrence were surveyed (primarily for juveniles); none of these were found to be occupied during the 2002 survey (Table 2-1, Figure 2-5).

One of the objectives of this Recovery Plan is to maintain the current distribution of steelhead and restore distribution to a variety of previously occupied areas. Fish-passage barriers appear to have played a large role in watershed-wide extirpations of steelhead; however, in many cases, ancestors of sea-run steelhead continue to persist as resident populations above barriers in these same stream systems, and in some cases produce progeny that emigrate downstream, past the barriers to the ocean as smolts. In an investigation of the contraction of the southern range limit of *O. mykiss*, it was found that the majority (68%) of anadromous population extirpations were associated with anthropogenic barriers which restricted the use of upstream habitats for spawning and rearing by the anadromous form of *O. mykiss.* Between 58% and 65% of these stream systems maintain *O. mykiss* populations, either above or below the anthropogenic barriers (Boughton *et al.* 2005). Land use practices have also contributed significantly to the reduction in steelhead distribution, particularly in mainstem habitats such as the Pajaro and Salinas Rivers and Pismo and Arroyo Grande Creeks within the Interior Coast Range and San Luis Obispo Terrace BPGs.

These resident populations could include fish that are considered naturally persistent residents, descendants of steelhead that have been blocked from downstream emigration by barriers (including irregular or inadequate flows to the ocean) and have been forced to adopt a resident life cycle strategy (*i.e.,* “residualized” populations), or in some cases perhaps progeny of stocked *O. mykiss* found above barriers to steelhead migration (Boughton *et al.* 2005).

Table 2-1. South-Central California Coast watersheds historically occupied by populations of steelhead (listed from north to south). Several watersheds with historical populations now have barriers that block migration to portions of the watershed.[1]

BASIN	EXTANT?
Pajaro River	Yes
Salinas River	Yes
Carmel River	Yes
San Jose Creek	Yes
Malpaso Creek[2]	Yes
Garrapata Creek	Yes
Rocky Creek	Yes
Bixby Creek	Yes
Little Sur River	Yes
Partington Creek	Yes
Big Creek	Yes
Vicente Creek[2]	Yes
Mill Creek	Yes
Prewitt Creek	Yes
Plaskett Creek	Yes
Willow Creek - Monterey	Yes
Alder Creek	Yes
Villa Creek Monterey	Yes
Salmon Creek	Yes
San Carpoforo Creek	Yes
Arroyo de la Cruz	Yes
Little Pico Creek	Yes
Pico Creek	Yes
San Simeon Creek	Yes
Santa Rosa Creek	Yes
Villa Creek – SLO	Yes
Cayucos Creek	Yes
Old Creek	Negative obs.[3]
Toro Creek	Dry[4]
Morro Creek	Yes
Chorro Creek	Yes
Los Osos Creek[2]	Yes
Islay Creek	Yes
Coon Creek	Yes
Diablo Canyon	Yes
San Luis Obispo Creek	Yes
Pismo Creek	Yes
Arroyo Grande Creek	Yes

[1] A watershed includes all of the tributaries and main-stem which share a common outlet to the ocean.
[2] Data from: Becker, *et al. 2008,* Boughton *et al. (2005),* Sleeper *(2002),* Titus *et al*. *(2010), M. Capelli, NOAA-NMFS, personal communication (2007-2012),* M. Larson, California Department of Fish and Game, personal communication (2007-2011),.
[3] "Negative obs." means juveniles were not observed during a spot-check of best-occurring summer habitat in 2002; however, such spot observations should not be interpreted as definitive determinants of absence of O. mykiss. Toro Creek has an adfluvial population above of *O. mykiss* above Whale Rock Reservoir.

[4]"Dry" indicates the stream had no discharge in anadromous reaches during the summer of 2002; because of the high variability of the hydrologic regime, such spot-checks do not necessarily reflect the potential suitability of such reaches for migration, spawning, or rearing of *O. mykiss*.; however, such an assumption may not be warranted since rearing juvenile steelhead can make use of ephemeral reaches (Boughton *et al. 2009).* See Boughton *et al. (2005)*. The California Department has previously report juvenile *O. mykiss* in upper Toro Creek in 1997.

Several reports describe the historical steelhead populations of the SCCCS Recovery Planning Area (Boughton *et al*. 2005, Boughton and Goslin 2006, Boughton *et al*. 2006). Using this information, the TRT proposed a structure for steelhead of the SCCCS Recovery Planning Area composed of five BPGs (Table 2-2). The division of steelhead populations into Biogeographic Population Groups (BPG) utilized two basic rules: First, populations were sorted into a coastal super-group and an inland super-group, based on whether or not the most potential freshwater habitats lay on an ocean-facing watershed subject to marine-based climate inversion and orographic (*i.e.,* lifting) precipitation from offshore weather systems. Second, within the coastal and inland super-groups, populations were sorted into groups defined by contiguous areas with broadly similar physical geography and hydrology. The combinations of these physical characteristics represent differing natural selective regimes for steelhead populations utilizing the individual watersheds. These differing physical characteristics have led to life history and genetic adaptations that can enable the populations to persist in the widely varying and distinctive habitat regimes represented by the five BPGs. The purpose of delineating the BPGs is to guide recovery efforts across the SCCCS Recovery Planning Area to ensure the preservation and recovery of the range of natural diversity of the SCCCS Recovery Planning Area. From north to south, these BPGs are known as: Interior Coast Range, Carmel River Basin, Big Sur Coast, and San Luis Obispo Terrace (Figure 2-5).

Table 2-2. Ecological characteristics of BPGs in the South-Central California Coast Steelhead Recovery Planning Area (originally Table 4 in Boughton *et al*. 2007b).

South-Central California Coast Steelhead ESU					
	Ecological Characteristics				
Population Group	**Migration Corridor**	**Migration reliabilit**[1]	**Summer Climate Refugia**[1]	**Intermittent Streams**	**Winter Precipitation**
Interior Coast Range[2]	Long alluvial valleys	Moderate/Low	Montane	Many	Mostly <75 cm (highlands) [3]
Carmel River Basin	Medium Valley	Moderate	Marine+ Montane	Some	30 – 90 cm3
Big Sur Coast	Short, steep	High	Marine	Few	75 – 135 cm
San Luis Obispo Terrace	Coastal Terrace	Moderate	Marine +Montane	Some	60 – 90 cm (highlands)

[1] Inferred reliability under an un-managed flow regime.
[2] The inclusion of the Pajaro River population in this group is debatable, since much of its best freshwater habitat currently occurs in the redwood forest at the southern end of the Santa Cruz Mountains – ecologically quite different from the chaparral watersheds of the other eat-slope populations
[3] Except in the Santa Cruz Mountains of the Pajaro system, which are wetter.

The separate watersheds comprising each BPG are generally considered as individual *O. mykiss* populations (*i.e.,* one watershed = one population of steelhead). Thus, single BPGs encompass multiple watersheds and multiple *O. mykiss* populations. However, many coastal watersheds in several of the BPGs (*e.g.*, Big Sur Coast and San Luis Obispo Terrace BPGs) are relatively small, and may be capable of supporting only small steelhead runs. The basis for the persistence of independent steelhead populations in these small watersheds is uncertain and further research is needed. (See Chapter 13, South-Central California Coast Steelhead Research, Monitoring, and Adaptive Management). The TRT (Boughton *et al.* 2007b) proposed that at least three scenarios (not necessarily mutually exclusive) are plausible:

1. Some of the populations in the coastal BPGs, though small, may be exceptionally stable and sustain the continued presence of steelhead in neighboring watersheds via adult dispersal between watersheds (an independent population supporting one or more dependent populations, thus forming a metapopulation).
2. Adult dispersal between neighboring watersheds within a coastal BPG may be common enough to knit together the steelhead in individual watersheds into a small number of "trans-watershed" populations (an independent population comprised of the fish from two or more neighboring streams, thus forming a metapopulation).
3. The populations in the smaller coastal basins (*e.g.,* in the Big Sur Coast and San Luis Obispo Terrace BPGs) may be dependent upon occasional or frequent adult dispersal pulses from populations in the larger inland basins (*e.g.,* Interior Coast Range or Carmel River Basin BPGs.)

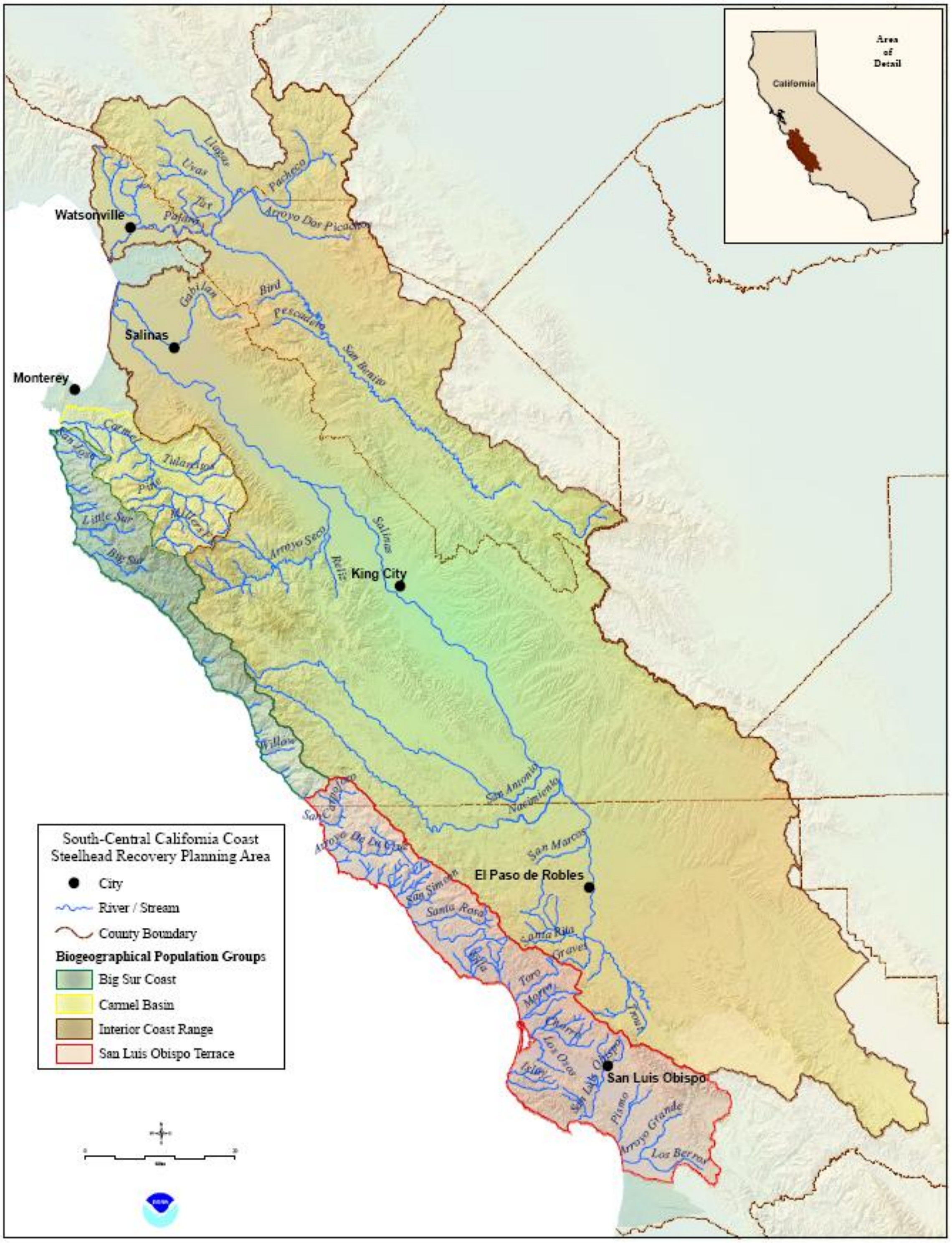


Figure 2-5. Biogeographic Population Groups (BPGs) in the South-Central California Coast Steelhead Recovery Planning Area (after Boughton *et al*., 2007b).

In characterizing the historic, pre-European settlement population structure of the SCCCS Recovery Planning Area, the TRT: 1) identified the original anadromous *O. mykiss* populations and attempted to determine which ones were still extant; 2) delineated the potential unimpaired geographic extent of each population on a watershed scale; 3) estimated the relative potential viability of each population in its (hypothetical) unimpaired state; and 4) assessed the potential demographic independence of each population in its (hypothetical) unimpaired state Boughton and Goslin 2006, Boughton *et al.* 2006, Helmbrecht and Boughton 2005). This analysis entailed a consideration of available historical and current data on the distribution and abundance of *O. mykiss*, new genetic data, landscape data, climate data, and stream discharge data. However, data limitations, particularly a lack of long-term run-size data, prevented the TRT from providing definitive characterizations of pre-European or current anadromous *O. mykiss* populations, including the geographic extent of individual populations, their intrinsic viability, or demographic independence. For a discussion of the constraints imposed by limited relevant data see Boughton and Goslin (2006) and Boughton *et al*. (2006). See Appendix B, Watershed Intrinsic Potential Rankings, Appendix C, Composition of SCCCS Recovery Planning Area Steelhead BPGs.

2.3 SPECIES ABUNDANCE

One of the recovery objectives for steelhead is to increase abundance of steelhead, including the expression of all life history forms and strategies. Current documented population abundances are extremely small; but the run size for most watersheds continues to be poorly characterized. Additionally, the presence of steelhead in watersheds is often sporadic. The status of steelhead populations along the West Coast was assessed in 1996 by the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) Biological Review Team (BRT) (Busby *et al*. 1996). In 2002 NMFS conducted an extensive survey of the geographic distribution of *O. mykiss* within south-central and southern California (Boughton and Fish 2003). Of the 36 watersheds that historically supported anadromous runs, between 86 percent and 94 percent continue to be occupied by native *O. mykiss* (a range of occupancy was reported because several basins could not be accessed). Occupancy was also determined for 18 basins with no historical record of anadromous *O. mykiss*; three of these basins (Los Osos, Vicente, and Villa creeks) were found to be currently occupied by *O. mykiss*. As a follow-up West Coast Status review Good *et al*. (2005) reported three new significant pieces information for the SCCCS DPS: 1) an updated time-series data regarding adult spawner counts at San Clemente Dam on the Carmel River; 2) NMFS' 2002 assessment of the geographic distribution of *O. mykiss* within its historic range (see above); and 3) changes in harvest regulations for *O. mykiss.*

The status of the steelhead within California was subsequently reviewed by Helmbrecht and Boughton (2005), and again in 2011 (Williams *et al*. 2011). The following summarizes the findings from these status reviews:

The steelhead populations in this region have declined dramatically from estimated annual runs totaling 27,000 adults near the turn of the century to approximately 4,740 adults in 1965 to several thousand total adults, with a large degree of inter-annual variability (Busby *et al*. 1996, Good *et al*. 2005, Williams *et al.* 2010). However, this run-size estimate is based on information from only five major watersheds bearing steelhead (Pajaro, Salinas, Carmel River, Little Sur, and Big Sur Rivers) located in the northern portion of the SCCCS Recovery Planning Area. Run-size estimates from coastal and inland watersheds south of the Big

Sur have generally not been estimated or recorded. Additionally, available run-size estimates represent only average annual estimates, and do not describe the wide annual variation in run-size that would be expected in a region with a highly variable climate and habitat conditions.

The BRT further noted that information was available to compute a trend for adult escapement for only one stock within the DPS – the Carmel River above San Clemente Dam. These Carmel River data indicate a significant decline of 22 percent per year from 1963 to 1993, with a recent average 5-year adult count of only 16 adult spawners recorded at San Clemente Dam. The BRT believed that general trends in the SCCCS DPS could be inferred from this early-1960 to early-1990 escapement data. The BRT also noted that the relationship between anadromous and non-anadromous *O. mykiss*, including possibly residualized populations upstream of impassible dams, while unclear, was likely to be important in the management of this species.

The Carmel River data are the only time-series data for the SCCCS DPS. Data collected since the 2005 BRT status review indicates that the abundance of anadromous *O. mykiss* spawners in the Carmel River has increased. Continuous data have been collected for the period from 1988 through 2012 (however these counts are incomplete because fish spawning below San Clemente Dam are not included). Counts from the start of the 1988-2002 period included three consecutive years with no fish reported (*i.e.,* in 1988, 1989, and 1990). A pen rearing program was established for juvenile *O. mykiss* using facilities at the Monterey Bay Steelhead Trapping Program and the Granite Canyon Marine Lab; fry from the artificially spawned adults were released above San Clemente Dam in the early 1990's. Steelhead counts increased from a single adult reported in 1991, to 775 adults reported in 1997, with a maximum of 881 adults reported in 2002. The BRT noted that the rapid increase in the number of returning adult anadromous *O. mykiss* spawners to the Carmel River could be attributed to a combination of factors, including improved freshwater conditions, improved resilience of populations, high stray rates, or ability of resident *O. mykiss* to produce smolts. The BRT also noted that while some component of the increase is probably due to improved ocean conditions during this period, it should not be assumed that comparable increases have occurred in other watersheds for the SCCCS DPS. However, the reported annual count (May 2009) of adult steelhead show a significant decrease: 95 fish at San Clemente Dam, and 21 fish at Los Padres Dam. These counts compare to average counts of 429 and 129 fish at San Clemente Dam and Los Padres Dam, respectively, since the end of the last drought in 1991 (Williams et al. 2011). The most recent (2011-2012) counts for the Carmel River indicate 470 adults at the San Clemente Dam, and 175 adult the Los Padres Dam, (Monterey Peninsula Water Management District 2012).

Since the listing of South-Central California steelhead, there have been increased efforts made to make periodic observations of adults as well as more systematic monitoring on a few watersheds with recently constructed fish passage facilities or active restoration efforts. For example, the Pajaro, lower Salinas River and the Carmel Rivers.

Finally, the BRT reported that the California Department of Fish and Game (CDFG) has prohibited sport harvest in the ocean (incidental ocean harvest is rare), and imposes significant angling restrictions within the anadromous waters of the SCCCS DPS (*e.g.,* restrictions on timing, location, and gear used for angling). However, CDFG continues to allow summer trout fishing in significant parts of the Salinas River system (*i.e.,* upper Arroyo Seco, Nacimiento River above barriers, upper Salinas

River, Salmon Creek, and the San Benito River in the Pajaro River system with zero bag limits. Additionally, a few other creeks have summer catch-and-release regulations. While there is indirect evidence that such fishing pressure has resulted in minimal or no mortality to *O. mykiss*, the reduction in risk to listed *O. mykiss* cannot be estimated quantitatively from the existing data because the natural abundance of *O. mykiss* is not quantitatively known.

In summary, while a majority of watersheds historically supporting *O. mykiss* are still occupied (often with individuals currently able to express only a resident life history strategy), steelhead run sizes have been sharply reduced. The three watersheds most likely exhibiting the largest annual anadromous runs (*i.e.*, Pajaro, Salinas, Carmel) have experienced declines in run size of 90 percent or more. Present population trends within individual watersheds that continue to support steelhead runs are generally unknown, and may vary widely between water-years. Available run-size estimates for all watersheds represent only average annual estimates that likely include wide annual variations expected in a region with a highly variable climate. However, these averages are extremely small, and raise the question of how such small runs of anadromous fish persist (potentially either by dispersal from some source population, and/or by consistent production of smolts by local populations of freshwater, non-anadromous *O. mykiss*. The consensus of the most current BRT was that the status of the SCCCS DPS has not changed appreciably in either direction since publication of the initial status review (Busby *et al.* 1996), and that SCCCS DPS is still in danger of extinction (Williams *et al*. 2011).

2.4 SPECIES GENETIC STRUCTURE AND DIVERSITY

A recovery objective for steelhead is to restore and conserve genetic diversity and interchange of genetic material between and within populations. Since the late 1990s, a number of genetic studies have been conducted to elucidate the structure of *O. mykiss* populations within the SCCCS Recovery Planning Area (Martìnez, *et al*. 2011, Clemento *et al.* 2009, Pearse and Garza 2009, Girman and Garza 2006, Nielsen 1999, 1994, Nielsen *et al.* 2001, 1997, 1994c). These studies have provided useful insights into the historic distribution of the species, as well as the potential influence of past (and current) stocking practices within the watersheds historically occupied by native *O. mykiss*. Berg and Gall (1988) surveyed steelhead populations throughout California. They discovered considerable variability among California populations, but did not discern a clear geographic pattern to the variation. Busby *et al.* (1996) also reported a high level of genetic variability in California coastal populations, including four from the SCCCS Recovery Planning Area. Busby *et al.* (1996) also reported an allozyme allele fixed in some populations but entirely absent in others, which is unprecedented in anadromous salmonids, except when comparing populations at the extreme ends of their ranges.

Sundermeyer (1999) examined five microsatellite loci from fourteen populations of *O. mykiss* in the Pajaro River. Most of these populations were found to be closely related to two populations from the San Lorenzo River which is immediately north but outside of the SCCCS Recovery Planning Area, and the source of hatchery-reared *O. mykiss* planted in the Pajaro River system. Native non-anadromous *O. mykiss* above barriers to upstream migration were less closely related to the San Lorenzo populations that those *O. mykiss* located below barriers. The *O. mykiss* from four locations above barriers to upstream migration (Llagas, upper Uvas, Bodfish, and Dos Picachos Creeks) were the mostly distantly related from the San Lorenzo River fish, and from each other.

Recent genetic investigations have shed light on the relationship between steelhead and the *O. mykiss* above barriers within the SCCCS Recovery Planning Area. Girman and Garza (2006) and Clemento *et al.* (2009) reported that above-barrier *O. mykiss* were more closely associated with below-barrier populations than to populations from other watersheds; that they were more related to the fish below the barrier than to any other geographically proximate populations. In addition, their results supported the idea that planted hatchery fish from other watersheds have had no detectable influence on the genetics of above-barrier populations. These results indicate that the above-barrier populations are not the descendants of hatchery fish. They are most likely the descendants of contiguous *O. mykiss* populations, because most of these areas have historical accounts of steelhead populations prior to construction of the barriers (Becker *et al.* 2008, Swift *et al*. 1993, Benke 2002, 1992, Hubbs 1946, Jordan and Gilbert 1881). While the fish that remain above barriers do not have an opportunity to interbreed with adult steelhead, they can, and in some cases do, produce progeny that emigrate downstream past the barriers to the ocean as smolts.

2.5 HABITAT CHARACTERISTICS OF THE SOUTH-CENTRAL CALIFORNIA COAST STEELHEAD RECOVERY PLANNING AREA

The major steelhead bearing watersheds in the SCCCS Recovery Planning Area include the Pajaro, Salinas, Carmel, Little and Big Sur Rivers (Good *et al*. 2005, Busby *et al*. 1996,). South of the Big Sur Coast, several major drainages and a number of smaller streams also supported runs of anadromous *O. mykiss* (of unknown size and frequency); these include the San Carpoforo, Arroyo de la Cruz, Pico and Little Pico, San Simeon, Santa Rosa, San Luis Obispo, Pismo, and Arroyo Grande Creeks (Titus *et al*. 2010, Becker *et al.* 2008, Swift *et al.* 1993).

Significant portions of the upper watersheds within the SCCCS Recovery Planning Area are contained within Los Padres National Forests. These forests are managed primarily for water production and recreation, with limited grazing and oil, gas, and mineral production (United States Forest Service, 2005a, 2005b, 2004, Berg *et al*. 2004, Stephenson and Calcarone 1999). Additionally, a significant amount of land within the SCCCS Recovery Planning Area is protected within military installations, and in the southern portions, within large scale regional parks. Urban development is centered in coastal areas and inland valleys, with the most expansive and densest urban development located within the Pajaro, Carmel, and Salinas River valleys. (Kier Associates and National Marine Fisheries Service 2008a, 2008b, Hunt & Associates 2008a, Keeley 1993, Hornbeck 1983; Lantis *et al*. 1981, Lockmann 1981).

The SCCCS Recovery Planning Area is comprised of geologically young mountainous topography with a number of inland valleys and coastal terraces. The geomorphology (*i.e.,* the shape and composition of the land surface) is strongly influenced by tectonic activity and various other signs of stress (*e.g.*, highly folded and faulted rocks of varying types), including metamorphic formations (*i.e.,* rocks that have changed under pressure and heat over time). The Coast Ranges (consisting of the Diablo, Temblor, and Santa Lucia Mountains) are made up of sedimentary formations (*i.e*., sediment deposited out of the air, ice, and/or water flows), granitic formations (*i.e.,* formed from cooled magma), and the widespread Franciscan formation (comprised of sandstones derived from erosion of volcanic highlands into deep marine basins). The legacy of tectonic activity and other physical stresses has created the steep slopes and unconsolidated rock formations that characterize this region. These geologic factors combined with an active, annual fire-cycle and intense winter storms have created spatially complex and frequently unstable river and stream habitats to which anadromous fishes and other aquatic species have adapted through evolutionary processes (Boughton *et al*. 2006, Sugihara *et al*. 2006, Norris and Webb 1990, Faber *et al*. 1989, Endler 1986, 1977, Felton 1965, Mayr 1963).

The SCCCS Recovery Planning Area is characterized by ten broad native terrestrial plant communities within the Californian floristic province: Estuarine Wetlands, Beach and Dunes, Riparian Forests, Coastal Prairie, Coastal Sage Scrub, Oak Woodlands, Chaparral, Valley Grasslands, Vernal Pools, and South Central California Conifer Forests (Barbour, *et al*. 2007, Holland 1996, Ferren *et al*. 1995, Sawyer and Keeler-Wolf 1995, Hickman 1993). Upland areas of the northern portion of the SCCCS Recovery Planning Area are dominated by a mix of Chaparral, Valley Grasslands, Oak Woodlands, and South-Central California Conifer Forests. Upland areas of the southern portion of the SCCCS Recovery Planning Area are dominated by South-Central Coastal Scrub, Valley Grassland, Oak Woodland, and South Central California Conifer Forests. Both of these upland areas are subject to catastrophic wildfires (Sugihara *et al.* 2006, Keeley 2006). Riparian forests consist of deciduous species. Large segments of the valley grasslands and riparian forests have been converted for agricultural, residential, and a variety of other commercial land-uses (Berg *et al*. 2004, California Department of Fish and Game 2003, Stephenson and Calcarone 1999, Holland 1996, Kreissman 1991, Mayer and Laundenslayer 1988, Warner and Hendrix 1984, Capelli and Stanley 1984). However, the interior uplands within the four U.S. National Forests are largely undeveloped, and a number of large parks, preserves, and greenbelts have been created in recent years on non-Federal lands.

The climate in the California floristic province is Mediterranean, with long dry summers and short, sometimes intense cyclonic winter storms. Rainfall is restricted almost exclusively to the late fall, winter months and early spring months (November through May. The California floristic province is subject to an El Niño/La Niña weather cycle which can significantly affect winter precipitation, causing highly variable rainfall between years. Additionally, there is a wide disparity between winter rainfall from north to south, as well as between coastal plains and inland mountainous areas. Mean annual precipitation ranges along the coast (north to south) from 32 to 24 centimeters (cm) per year, with larger variations (24-90 cm/year) from the coast inland (west to east) due to the orographic effects of the various mountain ranges. Fog along the coastal areas is typical in late spring and summer, extending inland along coastal reaches with valleys extending into the interior. This fog has been shown to moderate conditions for rearing *O. mykiss* in these lower, coastal reaches. South-Central California also experiences seasonally high, down slope winds during the early fall and winter that blow through the mountain. These winds, which can reach 40 miles per hour, are warm and dry and can severely exacerbate brush or forest fires, especially under drought conditions (Mastrandrea *et al*. 2009, Miller and Schlegel 2006, Haston and Michaelsen 1997, Philander 1990, Leipper 1994, Ryan and Burch 1992, Hornbeck 1983, Karl 1979, Felton 1965).

River flows vary greatly between seasons, and can be highly "flashy" (rapidly increased flows with high volume but short duration) during the winter season, changing by several orders of magnitude over a few hours in response to winter storms. Snow accumulation is generally small and of short duration, and does not contribute to peak run-off in most years. Baseflows in some river reaches can be influenced significantly by groundwater stored and transported through faults and fractured rock formations. Many rivers and streams naturally exhibit interrupted baseflow patterns (alternating channel reaches with and without perennial surface flow) controlled by geologic formations, and a strongly seasonal precipitation pattern characteristic of a Mediterranean climate. Water temperatures are generally highest during summer months, but can be locally controlled by springs, seeps, and rising groundwater, creating micro-aquatic conditions suitable for salmonids (Boughton, *et al*. 2007a, Faber *et al.* 1989, Mount 1995, Jacobs 1993, Reid and Wood 1976).

Within the SCCCS Recovery Planning Area steelhead habitat occurs in chaparral ecosystems which differ in significant ways from steelhead habitats found in snow-fed and/or conifer-lined ecosystems in the Sierra Nevada or North and Central Coasts of California. From the perspective of steelhead ecology, it is useful to divide these chaparral ecosystems which dominate the SCCCS Recovery Planning Area into two categories: coastal basins draining directly westward into the ocean, and inland basins set back from the coast, often separated from it by extensive mountain ranges. The inland basins are relatively few, large, and have a terrestrial climate whereas the coastal basins tend to be small, numerous and a heavily marine-influenced climate. These differences (and others that result from them, such as the reliability of suitable summer temperatures) likely impose different sorts of limiting factors on steelhead populations. Coastal basins are often characterized by a "mountain-terrace" system, in which a broad coastal terrace is backed by a steeper mountain range. These types of systems occur along the southern coast of Santa Luis Obispo County. The mountains harvest orographic rain from incoming storm systems, creating flashy streamflows that carve out well-shaded step-pool systems in the uplands, and braided gravel-bed streams and pool-riffle systems in the terraces. They also produce seasonal lagoons at the interface of the stream with the ocean. Each of these parts of the stream system produces habitat for a particular life stage of steelhead. Due to the movement of water, sediment and fish, stream systems function as integrated wholes with steelhead acting as effective strategists using the entire suite of resources provided them by the coastal and inland basins of the SCCCS Recovery Planning Area.

2.6 SOUTH-CENTRAL CALIFORNIA COAST STEELHEAD FRESHWATER LIFE CYCLE HABITAT USE

Steelhead spend a majority of their life in the ocean, but must enter freshwater to reproduce. Understanding the interaction between steelhead and their freshwater habitats is critical for effective steelhead recovery and management. Many of the naturally limiting factors described in this section that affect the growth and survival of juvenile steelhead in their freshwater phase are exacerbated by the artificial modification freshwater habitats and watershed processes that create and sustain these habitats. The freshwater habitats used by steelhead within the SCCCS Recovery Planning Area occur in two types of watersheds featuring distinctly different environmental regimes. One type is the series of rivers that flow through hot inland valleys and cut through coastal ranges to the sea. These watersheds have warm seasonal climates and are in coastal rain shadows. The other freshwater habitats are the small, steep coastal watersheds with higher rainfall, lower air temperatures, and a greater proportion of perennial streams (Boughton *et al*. 2006, Boughton *et al.* 2007b).

The *O. mykiss* life cycle can be conceptualized as a biological network in which environmental opportunities can be represented as a set of linkages:

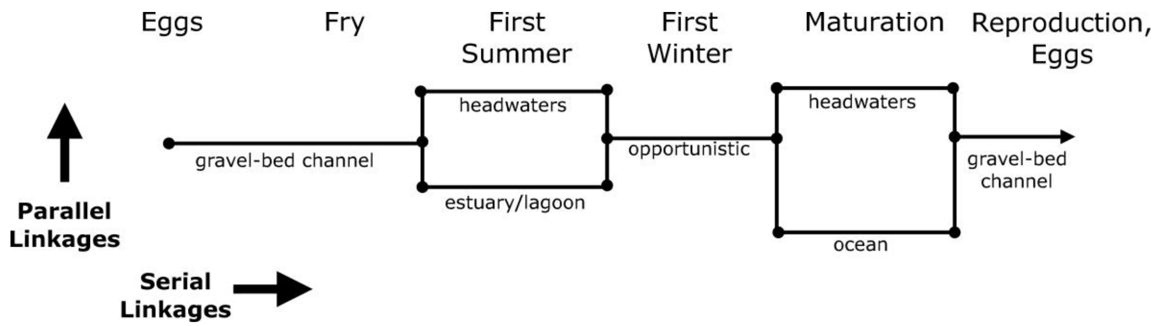


Figure 2-6. South-Central California Coast *O. mykiss* Life Cycle Habitat Linkages (Schwing *et al.* 2010, after Boughton).

The sequence of habitats required for the fish to complete the egg-to-egg life cycle involves a series of linkages, the loss of any of which prevents the completion of the life cycle. While serial linkages are a source of vulnerability, some of the linkages can be realized through alternative pathways: for example, over-summering in different sorts of thermal refugia, such as tributary headwaters or seasonal lagoons/estuaries next to the ocean; or maturation in freshwater versus the ocean. These alternative pathways in the network increase the resilience of the population to extirpation, because if one pathway fails in a particular year, some members of the population can still complete their life cycle by pursuing an alternative pathway.

The following provides a more detailed discussion of the freshwater life cycle phases of steelhead and the environmental factors that control the successful transition between freshwater life cycle phases prior to entering the ocean life cycle phase (Schwing, *et al.* 2010, after Boughton, *et al*. 2006).

Spawning Migration. Steelhead passage limitations arising from periodic drought (or longer term climate change) is one of the principal limiting factors affecting adult steelhead (Boughton *et al.* 2006). Steelhead are iteroparous (*i.e.*, can reproduce more than once), and, to realize the evolutionary benefits of repeat spawning, must have an opportunity to both enter and exit the stream system. The migration of steelhead into freshwater spawning and rearing streams is strongly associated with higher winter and spring flows which provide a continuous hydrological connection between the ocean and upstream spawning and rearing habitats. Some large steelhead adults in this domain may remain in freshwater after spawning, and can become trapped in deep residual pools in the summer (M. Capelli, personal communication). This sort of trapping is probably a function of the precise timing, duration, and magnitude of storms in a given winter. Periodic droughts further constrain migration opportunities during dry periods, and may have a bigger effect on repeat-spawning, which requires both an in- and out-migration opportunity in a given year, followed by an in-migration opportunity a year or two later. Finally, spawning efforts may be abrogated by one or more successive high flow events following spawning that erodes the spawning redds and exposes or flushes recently laid eggs out of the redd, exposing them to predation, or terminating the incubation process prematurely.

Initial Spring Feeding. The development and hatching of *O. mykiss* eggs is controlled by temperature and dissolved oxygen, which is itself influenced by flow rates, ambient air temperature, riparian cover, and groundwater input. Following the hatching and emergence from spawning gravels juvenile *O. mykiss* (fry) either stay near the redds from which they were hatched and establish territories, or disperse to favorable feeding areas (Boughton *et al.* 2009, Quinn 2005). Rainfall and runoff conditions conducive to adult upstream migration and spawning are also conducive to initial rearing conditions for the first spring growth of juvenile steelhead. As flows drop later in the spring and summer, rearing fish may move out of initial rearing reaches, or may continue to reside in deeper pools, where they may be trapped between temporary dry reaches of stream channel until the following winter rains reconnect perennial reaches.

An increase in rearing temperatures, either as a result of inter-annual, seasonal variability or longer-term climatic changes will likely produce warmer conditions during early rearing. If temperatures stay below about 17^{0} Celsius, a warming or an increase in week-scale variability of temperature can increase the growth rate of salmonids if food is abundant. But it would also increase metabolic demand and thus reduce growth if food is limiting (Boughton *et al*. 2007b, Smith and Li 1983, Brett 1971). Consequently, the effect of warmer conditions on growth is crucially dependent on per-capita food availability, which in turn depends on a host of other factors, such as primary productivity of the stream network, biomass of terrestrial insects caught in stream drift, and stream geomorphology as it affects the territorial dynamics of juvenile *O. mykiss*.

First Rearing Summer. The hot, rain-free summers of South-Central California require that juvenile *O. mykiss* retreat for the summer to sections of the stream network that do not dry up or overheat too much. Regionally, there are two alternative mechanisms for maintaining thermal refugia: the temperature lapse rate (*i.e.,* the decrease in temperature with an increase in altitude), which maintains cool, montane uplands, and the ocean heat sink, which maintains cool conditions proximate to the coast. In many small coastal basins, these two mechanisms merge geographically, whereas in inland basins the operation of these mechanisms may be separated by a long stretch of dry or warm channel that enforces a summer-long barrier to movement. Numerous tributaries draining various mountain ranges provide a high level of redundancy in the montane thermal refugia.

Probably as important as air temperature in maintaining cool water is protection from sunshine, which in summer is often the single biggest source of heat flux into a stream (Hannah *et al.* 2008, Evans *et al*. 1998). Wind effects can also be significant (Bogan *et al*. 2003). In coastal areas, fog and onshore winds provide shade and cooling wind, respectively. In the montane refugia, the closed tree canopy appears necessary to maintain suitably cool conditions (Leipper 1994, D. Boughton, unpublished data). Therefore, the resilience of montane thermal refugia to current inter-annual seasonal or longer-term climatic changes is probably highly dependent on the resilience of the closed tree canopy.

Mountain refuges appear more vulnerable than the coastal refuges to thermal increase (Snyder *et al*. 2002), perhaps because the latter are buffered by the ocean. An alteration of fire regime, flood regime, and/or sediment may eliminate the closed riparian canopy by burning trees, increasing the depth to the water table, or destroying trees via debris flows or floods (Bendix and Cowell 2010b, May and Gresswell 2004, Bendix and Hupp 2000). The water table can be lowered not just by increased sediment deposition, but also by decreased summer base flows, driven by lowered rainfall or greater evaporative demand of plants (Tague *et al*. 2009).

Lowered summer water tables may not just indirectly affect rearing juveniles via alteration of riparian trees; it may also affect the fish directly by reducing the summertime surface flow, and eliminating it entirely in dry parts of the rain shadow or in reaches with deep alluvium (*i.e.* response stream reaches). The gravel-bedded reaches used for spawning tend to have deep alluvium, and therefore can be especially vulnerable to loss of surface flow or incomplete riparian shading (Boughton *et al*. 2009). Timing is important for young-of-the-year development in gravel-bedded channels followed by retreat into "hydro-thermal" refugia once growth and size permits; large amounts of juvenile movement and stranding are commonly observed in South-Central California (see for example, Shapovalov 1944).

Groundwater inputs and heat-exchange with the channel-bed can serve to buffer daily and annual temperature fluctuations in a stream (Hannah *et al*. 2004, Tague *et al*. 2008). In a stable climate the ground stores heat seasonally (absorbing heat in summer and supplying heat in winter), but should have an annual net flux close to zero (Bogan *et al*. 2004). Decreased base flows during the summer may actually help the ground (channel-bed) buffer stream temperatures more effectively, by increasing the surface area of the bed-water interface, relative to the volume of water in the stream and the air-water surface area. The magnitude of such a buffering is not known, and would also probably shrink the amount of fish habitat and feeding opportunities for rearing juvenile fish.

The coastal thermal refugia are closely tied to the heat dynamics of the ocean and maritime air, and thus to the future pattern of seasonal upwelling and winds along the coast. Many tributaries and the lower sections of mainstems fall within the climatic influence of the marine inversion layer that develops in summertime. Except for the mainstems, many of these coastal streams also benefit thermally from the temperature lapse rate in the coastal mountains, as well as receiving large doses of orographic precipitation in the wintertime - the converse of the rain shadow-starved streams in more inland areas. This band of steelhead-hospitable coastal terrain is probably significantly more resilient to climate change than inland areas, and highly productive per unit of habitat. However, it is a very narrow band and so its total productivity may be limited.

Each stream system terminates at the coast with some type of estuary-lagoon system. In South-Central California, seasonal lagoons currently tend to form each summer when decreased streamflows allow marine processes to build a sand berm at the mouth of each system. Juvenile steelhead over-summer in these lagoons, where they often grow so rapidly that they can undergo smoltification at age 1 and enter the ocean large enough to experience enhanced survival to adulthood (Hayes *et al*. 2008, Bond 2006). Both effects should increase the resilience of the steelhead component of *O. mykiss*. In contrast, juveniles over-summering in some montane thermal refugia display very little or no growth during the summer (Sogard *et al*. 2009, Hayes *et al.* 2008, Boughton *et al*. 2007a, Bond 2006) .

Fall and Winter Feeding. Steelhead rearing ecology during the fall and winter is less documented, but likely is under fewer constraints than early life history or over-summering phases. Baseflows rebound in many creeks as the weather cools in September and October, and sections of channel that were dry during the summer months begin flowing again, even before the first rains of the fall. This is due to reduced evaporative demand by riparian plants. (Initial rainstorms of fall have relatively little effect on stream flows, as most precipitation gets absorbed into the ground). The cooling of the weather and the rebounding of baseflows releases over-summering fish that were trapped in small residual pools and thermal refugia, so that a relatively small number of fish potentially gain access to a large extent of stream habitat (Boughton *et al*. 2009).

In some areas of South-Central California, this time of the year is marked by peak emergence of aquatic arthropods and inputs into streams of terrestrial arthropods, suggesting the opening of increased feeding opportunities to the fish that survived the summer. Arthropod productivity appears sensitive to local geologic and vegetative factors (Rundio 2009), but where it occurs it may allow juvenile steelhead to transform relatively warm temperatures into opportunities for rapid growth (Rundio and Lindley 2008). If these opportunities occur in sparsely populated intermittent creeks, the conditions are conducive to potential rapid growth into large smolts.

The timing of these peaks of productivity and growth opportunities is likely to be modified by current inter-annual as well as longer climatic changes. Because warmer autumns would increase metabolic costs as well as well as scope for growth (Boughton *et al*. 2007a), the impact on *O. mykiss* growth and survival could be either negative or positive, depending on a sensitive balance of factors. Compared to fall feeding, winter-feeding and growth is presumably more constrained by cooler temperatures, less arthropod production, and disturbances associated with high-flow events.

Smolting and Outmigration. Intensive studies of steelhead populations in the redwood systems of Santa Cruz County indicate that most *O. mykiss* become smolts and migrate to the ocean at age 2 or 3, but a small proportion smolt at age 1 (Hayes *et al*. 2011, Sogard *et al*. 2009, Hayes *et al*. 2008, Shapovalov and Taft 1954). Since larger size at ocean entry greatly increases ocean survival (Hayes *et al*. 2008, Bond 2006, Ward *et al*. 1989), smolting at age 1 is probably only a viable strategy for fish that have achieved unusually rapid growth during their first year (Satterthwaite *et al*. 2009). Bond (2006) has shown that fish over-summering in lagoons can achieve such growth. It is possible that rapid growth can be achieved in other habitats as well (see for example, Casagrande 2012, 2010, Moore 1980), but most studies have shown growth to be slower in upland tributaries.

Quantitative data on growth and life history are not yet available for the chaparral and coastal terrace systems of the SCCCS Recovery Planning Area. It is likely that age at smolting of individual fish is based on locally adapted "decision rules", including also a "decision" as to whether to smolt at all versus maturing in freshwater. Local adaptation is likely to be dominated by a tradeoff between ocean mortality and the much greater fecundity that fish can realize by growing to a larger size in the ocean (Satterthwaite *et al*. 2009). Since ocean survival appears so strongly sensitive to size at ocean entry, the balance of anadromous versus freshwater-resident fish may be sensitive to juvenile growth rates. As noted above, warmer temperatures offer the possibility of either reducing or accelerating juvenile growth, depending on food availability, which itself may respond inter-annual and longer climatic effects on precipitation, riparian vegetation, and life cycle patterns sensitive to temperature, and nonlinear food-web dynamics.

An increase in the frequency, intensity, or duration of multi-year droughts would further limit migration opportunities for smolts. Loss of surface flow appears to occur more commonly in the deep alluvium of downstream reaches rather than in headwater tributaries (Boughton *et al*. 2009). Additionally, the sandbar barriers at the mouths of estuaries sometimes fail to breach in dry years, so drought would probably have greater impacts on migrating smolts (and migrating adults) than on the *O. mykiss* maturing in headwater tributaries (Jacobs *et al*. 2011). The loss of opportunity would force a higher proportion of fish to adopt a freshwater-maturation strategy rather than the anadromous strategy. Since freshwater residents are significantly less fecund than steelhead, the resulting population would be less resilient to extirpation, and gene flow among populations by straying steelhead would also be reduced. All these outcomes would tend to reduce the capacity of *O. mykiss* populations to recover from and adapt to changing conditions.

Subsequent Years in Freshwater; Maturation in Freshwater. The majority of juvenile *O. mykiss* that do not smolt their first year must again cycle through stages of spring-feeding, over-summering, and fall and winter feeding, although at a larger body size. Most of these fish probably smolt at age 2 or 3 or adopt the freshwater-resident strategy, maturing and eventually spawning in a suitable section of the stream network; the proportions adopting these pathways (*i.e.,* either multiple pre-smolts rearing years or freshwater maturation and reproduction) are unknown and probably sensitive to both growth and survival at all stages of life history (Satterthwaite *et al*. 2009).

The over-summering stage probably poses the greatest constraints. Compared to young-of-the-year, older fish appear to require deeper water for over-summering (Spina 2007, Spina *et al.* 2005, Spina 2003, Spina and Johnson 1999), and thus may be more restricted to the parts of the watershed that provide well-shaded perennial pools of sufficient depth. These appear to be concentrated in headwater streams well-fed by orographic precipitation, where baseflows are stable, riparian canopies are relatively complete, and geomorphic processes produce an abundance of pools (Boughton *et al*. 2009, Harrison and Keller 2006). The pool-forming mechanisms in these uplands are highly variable, involving self-formation of step-pools, scour around large boulders that roll off hillsides, and rock outcrop which create force-pools.

The upland habitats used by older juvenile fish are a subset of the upland habitats used by the fish initially in their first summer. Consequently, vulnerabilities to repeated inter-annual seasonal changes (and longer-term climate changes) are similar to those described previously (*e.g*., loss of baseflow, loss of riparian cover). Additional factors influencing productivity of upland habitats relied upon by rearing fish for multiple years are: (1) a lower level of redundancy, due to the more restricted distribution of high-quality pool habitat; (2) the vulnerability of pools to being transiently filled by fine sediments following wildfires; and (3) the long-term robustness of step-pools and bedrock force-pools, which should tend to re-scour after being filled, and are presumably resilient to a broader range of conditions compared to the reaches further downstream (Chin *et al*. 2009, Montgomery and Buffington 1997).

In summary, while freshwater habitats provide important spawning and rearing opportunities to steelhead, the inherent instability of these habitats can limit productivity depending on the pre-smolting growth patterns of individual fish, the pattern of rainfall, run-off, and input of sediments from natural hill-slope and channel erosion processes (accelerated, including its unique fish and wildlife resources by periodic wildfires).

3. Factors Contributing to Decline and Federal Listing

"Steelhead on the west coast of the United States have experienced dramatic declines in abundance during the past several decades as a result of human-induced and natural factors. The scientific literature is replete with information documenting the decline of steelhead populations and anadromous salmonid habitats. There is no single factor solely responsible for this decline."

Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead under the Endangered Species Act, 1996

3.0 INTRODUCTION

When evaluating a species for protection under the ESA, the law provides that the Secretary of Commerce must consider whether any one (or more) of five listing factors affect the species. Listing factors deal with those aspects of the species' biology or habitat that affect the level of threat to the species' continued persistence. The ESA requires that in developing recovery plans for listed species, each of the factors which contributed to the species' listing as threatened or endangered be addressed in the recovery actions identified in recovery plans.

The five listing factors are:

1. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range
2. Over-Utilization for Commercial, Recreational, Scientific, or Educational Purposes
3. Disease and Predation
4. Inadequacy of Existing Regulatory Mechanisms
5. Other Natural or Human-Made Factors Affecting Continued Existence

NMFS' listing determinations regarding the SCCCS DPS (71 FR 834, January 5, 2006, 68 FR 15100, March 28, 2003, 62 FR 43937, August 18, 1997, 55 FR 24296, June 15, 1990), and supporting technical reports (*e.g.*, Boughton *et al.* 2005, Good *et al.* 2005, Busby *et al.* 1996, National Marine Fisheries Service 1996a) have provided a detailed discussion of the factors affecting steelhead at the time of listing. There was no single factor responsible for the decline of South-Central California Coast steelhead; however, of those factors identified, the destruction and modification of habitat and natural and man-made factors had been recognized as the primary causes for the decline of the SCCCS DPS.

This chapter summarizes the factors identified at the time of the listing of the species. All of these factors are still prevalent and widespread. As a result, there have been few changes to the factors affecting the species since the time of original listing. The following chapter, Chapter

4, discusses the current threats facing the SCCCS DPS and represents our current understanding of how the listing factors continue to affect the species.

3.1 FACTOR 1: Present or Threatened Destruction, Modification or Curtailment of Habitat or Range

South-Central California Coast steelhead declined in large part as a result of a wide variety of human activities, including, but not limited to, agriculture, mining, and urbanization activities that have resulted in the loss, degradation, simplification, and fragmentation of habitat. Water storage, withdrawal, conveyance, and diversions for agriculture, flood control, domestic, and hydropower purposes have greatly reduced or eliminated historically accessible habitat. Modification of natural flow regimes by dams and other water control structures have resulted in increased water temperatures, changes in fish community structures, depleted flow necessary for migration, spawning, rearing, flushing of sediments from spawning gravels, and reduced gravel recruitment. The substantial increase of impermeable surfaces as a result of urbanization (including roads) has also altered the natural flow regimes of rivers and streams, particularly in the lower reaches.

Nacimiento Dam, Nacimiento River

In addition to these indirect effects these structures have also resulted in increased direct mortality of adult and juvenile steelhead. Land-use activities associated with urban development, mining, agriculture, ranching, and recreation have significantly altered steelhead habitat quantity and quality. Associated impacts of these activities include: alteration of stream bank and channel morphology; alteration of ambient stream water temperatures; degradation of water quality; elimination of spawning and rearing habitats; fragmentation of available habitats; elimination of downstream recruitment of spawning gravels and large woody debris; removal of riparian vegetation resulting in increased stream bank erosion; and increased sedimentation input into spawning and rearing areas resulting in the loss of channel complexity, pool habitat, suitable gravel substrate, and large woody debris.

Flood Control Work –Carmel River Estuary

In addition, a significant percentage of estuarine habitats have been lost, with an average of 66 percent of estuarine habitat remaining across the SCCCS Recovery Planning Area. The condition of these remaining wetland habitats is largely degraded, with many wetland areas at continued risk of loss or further degradation. Although many historically harmful practices have been halted, much of the historical damage remains to be addressed, and the necessary restoration activities will likely require decades. Many of these threats are associated with most of the larger river systems such as the Pajaro and Salinas Rivers, and many also apply to the smaller coastal systems such as San Jose, San Simeon, Santa Rosa, San Luis Obispo, Pismo, and Arroyo Grande Creeks (National Marine Fisheries Service 1996a).

Wetland Fill – Pismo Creek Estuary

3.2 FACTOR 2: Over-Utilization for Commercial, Recreational, Scientific, or Educational Purposes

Steelhead populations traditionally supported an important recreational fishery throughout their range. Recreational angling for both winter adult steelhead and summer rearing juveniles was a popular sport in many coastal rivers and streams until the mid-1950s. Recreational angling in coastal rivers and streams for native steelhead increased the mortality of adults (which represent the current generation of brood stock) and juveniles (which represent the future generations of brood stock) and may have contributed to the decline of some naturally small populations but is not considered the principal cause for the decline of the species as a whole. During periods of decreased habitat availability (*e.g.*, drought conditions or summer low flow when fish are concentrated in freshwater habitats), the impacts of recreational fishing or harassment on native anadromous stocks have been heightened.

Angling for both adults and juveniles in those portions of coastal rivers and streams accessible to anadromous runs from the ocean is permitted under the CDFG's angling regulations, though the CDFG imposes significant angling restrictions within the anadromous waters of the SCCCS DPS (*e.g.*, restrictions on timing, location, and gear used for angling); however, no Fishery Management and Evaluation Plan has been approved by NMFS. The CDFG continues to allow summer trout fishing in significant parts of the Salinas River system (*i.e.*, upper Arroyo Seco, Nacimiento River above impassable barriers), Salmon Creek, and the San Benito River in the Pajaro River system with zero bag limits. Additionally, a few other creeks have summer catch-and-release regulations (California Department of Fish and Game 2011a).

Steelhead are not targeted in commercial fisheries. High seas driftnet fisheries in the past may have contributed slightly to a decline of this species in local areas, although steelhead are not targeted in commercial fisheries and reports of incidental catches are rare. Commercial fisheries are not believed to be principally responsible for the large declines in abundance observed along most of the Pacific coast over the past several decades.

While there is indirect evidence that such fishing pressure has resulted in minimal or no mortality to *O. mykiss*, the reduction in risk to listed *O. mykiss* cannot be estimated quantitatively from the existing data because the natural abundance of *O. mykiss* is not quantitatively known. However, poaching or harassment remains potential forms of unauthorized take of South-Central California Coast steelhead.

NMFS had previously concluded that recreational harvest is a limiting factor for South-Central California Coast steelhead (Good *et al.* 2005, Busby *et al.* 1996, National Marine Fisheries Service 1996a).

3.3 FACTOR 3: Disease and Predation

Infectious disease is one of many factors that can influence adult and juvenile steelhead survival. Specific diseases such as bacterial kidney disease, Ceratomyxosis, Columnaris, Furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, Erythrocytic Inclusion Body Syndrome, and whirling disease among others are present and are known to affect steelhead and salmon (Noga 2000, Wood 1979, Rucker *et al*. 1953). Very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases for steelhead. Warm water temperatures, in some cases can contribute to the spread of infectious diseases (Belchik *et al.* 2004, Stocking and Bartholomew 2004). However, studies have shown that native fish in unimpaired native habitat tend to be less susceptible to pathogens than hatchery cultured and reared fish (Buchanan *et al*. 1983).

Introductions of non-native aquatic species (including fishes and amphibians) and habitat modifications (*e.g.*, reservoirs, altered flow regimes, *etc*.) have resulted in increased predator populations in numerous river systems, thereby increasing the level of predation experienced by native salmonids (National Marine Fisheries Service 1996a). Non-native species, particularly fishes and amphibians such as large and smallmouth basses and bullfrogs have been introduced and spread widely. These species can prey upon rearing juvenile steelhead (and their conspecific resident forms), compete for living space, cover, and food, and act as vectors for non-native diseases (Marks *et al.* 2010, Scott and Gill 2008, Fritts and Pearsons 2006, Bonar *et al.* 2005, Dill and Cordone 1997).

***O. mykiss* – San Carpoforo Creek**

Artificially induced summer low-flow conditions may also benefit non-native species, exacerbate spread of diseases, and permit increased avian predation. NMFS concluded that the information available on these impacts to steelhead did not suggest that the SCCCS DPS was in danger of extinction, or likely to become so in the foreseeable future, because of disease or predation. It is recognized, however, that small populations such as South-Central California Coast steelhead can be more vulnerable to extinction through the synergistic effects of other threats, and the role of disease or predation may be heightened under conditions of periodic low flows or high temperatures characteristic of steelhead habitats within the SCCCS Recovery Planning Area.

Finally, the introduction of a variety of non-native plant and animal species can alter ecosystems and related food-webs in complicated and subtle ways that can have unpredictable, long term impacts on native organisms (Cucherousset and Olden 2011, Davis 2009, Lockwood *et al*. 2007, Bonar 2005, Sax *et al.* 2005, Bossard 2008, Gamradt *et al.* 1997, Gamradt and Kats 1996, Williamson 1966, Elton 1958).

3.4 FACTOR 4: Inadequacy of Existing Regulatory Mechanisms

3.4.1 Federal Mechanisms

At the time of listing, several principal federal regulatory and planning mechanisms affected the conservation of steelhead populations within the SCCCS Recovery Planning Area (National Marine Fisheries Service 1996b, 1997a). These included: 1) land management practices within the four U.S. National Forests within the SCCCS Recovery Planning Area (Los Padres, Angeles, San Bernardino, and Cleveland); 2) the regulation of dredging and the placement of fill within the waters of the United States by the U.S. Army Corps of Engineers (USACE) through the Clean Water Act (CWA) Section 404 Program; 3) the regulation of dredging and the placement of fill within the waters of the United States through the CWA section 401 water quality certification regulations; 4) the Federal Emergency Management Agency (FEMA) administration of a Flood Insurance Program which strongly influences the development in waterways and floodplains; and 5) inadequate implementation of the CWA sections 303(d)(1)(C) and (D) to protect beneficial uses associated with aquatic habitats, including fishery resources, particularly with respect to non-point sources of pollution (including increased sedimentation from routine maintenance and emergency flood control activities within the active channel and floodplain).

For example, the USACE's program is implemented through the issuance of a variety of Individual, Nationwide and Emergency permits. Permitted activities should not "cause or contribute to significant degradation of the waters of the United States." A variety of factors, including inadequate staffing, training, and in some cases regulatory limitations on land uses (e.g., agricultural activities) and policy direction, resulted in ineffective protection of aquatic habitats important to migrating, spawning, or rearing steelhead. The deficiencies of the current program are particularly acute during large-scale flooding events, such as those associated with El Niño conditions, which can put additional strain on the administration of the CWA Section 404 and 401programs. Additionally, the USACE does not regulate most agricultural activities through administration of the 404 Program.

Similarly, the National Flood Insurance Program regulations allow for development in the margins of active waterways if they are protected against 100-year flood events, and do not raise the water elevations within the active channel (floodway) more than one foot during such flood events. This standard does not adequately reflect the dynamic, mobile nature of watercourses in South-Central California Coast, and the critical role that margins of active waterways (riparian areas) play in the maintenance of aquatic habitats. In addition, FEMA programs for repairing flood related damages (Public Assistance Program, Individual and Households Program, and Hazard Mitigation Grant Program) promote the replacement of damaged facilities and structures in their original locations, which are prone to repeated damage from future flooding, and thus lead to repeated disturbance of riparian and aquatic habitats important to migrating, spawning, or rearing steelhead.

3.4.2 Non-Federal Mechanisms

At the time of listing, several principal non-federal regulatory and planning mechanisms affected the conservation of steelhead populations within the SCCCS Recovery Planning Area (National Marine Fisheries Service 1997a, 1996b). These included: 1) administration of the California State Water Resources Control Board (SWRCB) water rights permitting system which controls utilization of waters for beneficial uses throughout the state; 2) state and local government permitting programs for land uses on non-federal and non-state owned lands; 3) administration of the Fish and Game Code Sections 1600-1603 (Streambed Alteration Agreements) program and 5957-5937 (regulation of dams); and 4) the lack of a Coast-Wide Anadromous Fish Monitoring Plan for California to inform regulatory actions such as angling restrictions. For example, the SWRCB water rights permitting system contains provisions (including public trust provisions) for the protection of instream aquatic resources. However, the system does not provide an adequate regulatory mechanism to implement the CDFG Code Sections 5935-5937 requirements for the owner of any dam to protect fish populations below impoundments. Currently the SWRCB's administrative policy implementing California Water Code Section 1294.4 applies only to northern California counties. Additionally, SWRCB generally lacks the effective oversight and regulatory authority over groundwater development comparable to surface water developments for out-of-stream beneficial uses.

The Section 1600 Lake or Streambed Alteration Agreements program is the principal mechanism through which the CDFG provides protection of riparian and aquatic habitats. Inadequate funding, staffing levels, training and administrative support have led to inconsistent implementation of this program, resulting in inadequate protection of riparian and aquatic habitats important to migrating, spawning and rearing steelhead.

Additionally, within the SCCCS Recovery Planning Area there is limited institutional organization specifically dedicated to steelhead recovery planning and implementation. Currently, the principal entities include the Tri-Counties Fish Team (which covers Ventura, Santa Barbara, and San Luis Obispo Counties and the state-wide organization, CalTrout; other portions of the SCCCS Recovery Planning Area are the focus of attention of individuals, watershed groups, or agencies with broader responsibilities or interests.

Finally, monitoring of stocks (particularly annual run-sizes) is essential to assess the current and future status of individual populations and the SCCCS DPS as a whole, as well as to develop basic ecological information of the steelhead populations of the SCCCS Recovery Planning Area. However, the Coast-Wide Anadromous Fish Monitoring Plan remains unfinished and funding for its implementation has not been identified and secured.

3.5 FACTOR 5: Other Natural or Human-Made Factors Affecting Continued Existence

This factor category encompasses two specific threats to the species identified at the time of listing: 1) environmental variability and 2) stocking programs. Similar to the other listing factors, these threats persist and recent information about environmental variability, including the effects of ocean conditions on the survival of salmonid populations and increases in wildfire occurrence and severity, indicate that the threat from "environmental variability" can be expected to increase. The current and future threat to species recovery from environmental variation is further discussed in Chapter 4, Current DPS-Level Threats Assessment, and 5, South-Central California Coast Steelhead and Climate Change.

3.5.1 Environmental Variability

Variability in natural environmental conditions has both masked and exacerbated the problems associated with degraded and altered riverine and estuarine habitats. Floods and persistent drought conditions have periodically reduced naturally limited spawning, rearing, and migration habitats.

California Wildfires (Courtesy NASA)

Furthermore, El Nino events and periods of unfavorable ocean-climate conditions can threaten the survival of steelhead populations already reduced to low abundance levels due to the loss and degradation of freshwater and estuarine habitats. However, periods of favorable ocean productivity and high marine survival can temporarily offset poor habitat conditions elsewhere and result in dramatic increases in population abundance and productivity by increasing the size and correlated fecundity of returning adults (National Marine Fisheries Service 1996a).

3.5.2 Stocking Programs

There are no steelhead production hatcheries operating in or supplying hatchery reared steelhead to the SCCCS Recovery Planning Area. However, up until the mid to late 1990's steelhead smolts derived from the San Lorenzo River were placed in the anadromous waters of the Pajaro and various tributaries (*e.g.*, Corralitos, Browns Valley, Uvas Creeks) as well as in the Arroyo Seco in the early 1990s. However, there is a small anadromous *O. mykiss* rearing operation on the Carmel River, and in the past there has also been an anadromous *O. mykiss* rearing operation on Old Creek, Garrapata Creek and a salmon rearing facility operated in connection with San Luis Obispo Creek. Additionally, CDFG maintains a stocking program of hatchery-derived non-anadromous *O. mykiss* in order to support put-and-take fisheries. These stockings are now generally conducted in non-anadromous waters, though fish may enter anadromous waters during spillage at dams. Until recently, CDFG has planted non-native steelhead in anadromous waters in the Nacimiento River, and there are reports of plantings in non-anadromous portions of the Pajaro River prior to the list of the SCCCS DPS (J. Ambrose, personal communication). Other non-native game species, such as smallmouth bass and bullhead catfish, are often stocked into anadromous waters by a variety of public and private entities (California Department of Fish and Game and Fish and Wildlife Service 2010, Leitritz 1970).

While these programs have provided seasonal fishing opportunities, the impacts of these programs on native, naturally-reproducing steelhead stocks is the subject of considerable discussion and active research (Berejikian 2011, Chilcote 2011, Tatara *et al.* 2011a, 2011b, Fraser 2008, Myers *et al.* 2004, California Department of Fish and Game and National Marine Fisheries Service 2001).

Competition, genetic introgression and disease transmission resulting from hatchery introductions may have the potential to reduce the production and survival of native, naturally-reproducing steelhead (Chilcote 2011, Hayes *et al.* 2004, Myers *et al*. 2004). However, genetic investigations of South-Central California Coast steelhead have not detected any substantial interbreeding of native with hatchery reared *O. mykiss* (Abadia-Cardoso *et al*. 2011, Christie *et al*. 2011, Clemento *et al.* 2009, Girman and Garza 2006).

Steelhead Rearing Facility — Carmel River

Stocking to support recreational angling within the SCCS Recovery Planning Area are now generally conducted in non-anadromous waters, though fish in some cases may escape into anadromous waters (California Department of Fish and Game and U.S. Fish and Wildlife Service 2010). Collection of native steelhead for hatchery broodstock purposes has the potential harm small or dwindling natural populations. However, artificial propagation can also, in some situations, play an important role in steelhead recovery through, among other means, preservation of individuals representing genetic resources which would otherwise be lost as a result of local extirpations. See Chapter 6, Steelhead Recovery Strategy, and Chapter 8, Summary of SCCCS DPS-Wide Recovery Actions.

4. Current DPS-Level Threats Assessment

"A widespread trend observed in this Steelhead Recovery Planning Area is severe to very severe degradation of habitat conditions along the mainstems of impaired watersheds, while the upper mainstem and tributaries retain relatively high habitat values for steelhead."

California Coast Steelhead Recovery Planning Area: Threats Assessment
Hunt & Associates 2008

4.0 INTRODUCTION

Anadromous *O. mykiss* in California face significant threats from water and land management practices that have degraded or curtailed freshwater and estuarine habitats, reducing the capability of the species to persist within most watersheds (Moyle *et al.* 2011, 2008). Extensive agricultural development in the Pajaro and Salinas River basins, as well as in segments of the Pismo, San Luis Obispo, and Arroyo Grande Creek basins, have significantly modified and degraded major steelhead-bearing watersheds, particularly their mainstems and estuarine habitats. In addition, given the current status of the species and the degraded condition of many freshwater and estuarine ecosystems, the persistence and recovery of the species may be further threatened by shifts in climatic and oceanographic conditions. See Chapter 5, South-Central California Coast Steelhead and Climate Change.

Table 4-1 summarizes the top-ranked[1] sources of threats across the SCCCS Recovery Planning Area. These were identified as part of the threats assessment performed for watersheds within each BPG. The threat sources with a "very high" or "high" severity ranking within the largest percentage of the watersheds within the SCCCS Recovery Planning Area were dams and surface water diversions, wildfires, and groundwater extraction. Urban development, levees and channelization, and other passage barriers also affect a large percentage of steelhead watersheds in the SCCCS Recovery Planning Area. Finally, while not captured in the threats assessment process that ranked the threats by threat source categories associated with Biogeographic Population Groups, the impacts of environmental variability, including projected changes in precipitation patterns and the consequences of fluctuations in ocean conditions play a significant role in the persistence and recovery of the SCCCS DPS; these are dealt with in Section 4.2.6 and Chapter 5, South-Central California Coast Steelhead and Climate Change.

This chapter provides an introduction to the threats assessment process and summarizes the results of NMFS' threats assessment at the DPS level. Summaries of the threats posed to individual BPGs are presented in the chapters devoted to each BPG.

[1] Threat sources were ranked in terms of the level of contribution and irreversibility of the stressors emanating from the threat source. See Appendix D for further information.

4.1 THREATS ASSESSMENT PROCESS

NMFS assessed the current and expected future threats to the species' persistence and recovery in a set of watersheds identified by the TRT and NMFS staff. This assessment was undertaken with the use of The Nature Conservancy's Conservation Action Planning (CAP) framework. This method and NMFS' application to the threats assessment for South-Central California Coast steelhead is further detailed in Appendix D, South-Central California Coast Steelhead Recovery Planning Area Threats Assessment (CAP Workbooks) method. Use of this method allows NMFS to organize the best available information and professional judgment on the threats facing the species into electronic workbooks that are programmed to summarize and track the information for use in identifying, developing and implementing recovery actions designed to address the identified threats. The threats assessment process is intended to be iterative so that new information can be incorporated as it becomes available or as periodic status reviews of the species occur (Kier Associates and National Marine Fisheries Service 2008a, 2008b, Hunt & Associates 2008a).

Current conditions of essential habitat elements for steelhead were assessed with information from a variety of sources including published and unpublished reports. The severity of threats to steelhead or their habitat was estimated and ranked. Based on the initial threats assessment, the threats and associated sources of those threats across the SCCCS Recovery Planning Area, within each BPG, and within specific watersheds, were identified. A listing of the individual watersheds that were evaluated in the CAP workbooks that were used to summarize threats at these scales can be found in Appendix D.

In addition to the CAP threats assessment process, NMFS considered the best available information regarding the impacts of predicted shifts in climate and the marine environment on the ability of the species to recover. These two threats are not easily addressed in the CAP workbooks and so are not reflected in the tables depicting the threats assessments results below. However, NMFS considered the threats posed by shifting climate and a varying marine environment when recommending a recovery strategy for the species and particular recovery actions. Steelhead will best be able to persist in changing environmental conditions through the recovery of well-distributed viable populations across the SCCS Recovery Planning Area able to support their different life stages and strategies. Recovery actions to address climate and marine environmental conditions are therefore embedded within recovery actions designed to achieve these objectives.

4.2 CURRENT DPS-WIDE THREATS ASSESSMENT SUMMARY

The following discussion presents the available information on the current and future threats faced by the species. The discussion is organized around a set of threat sources identified for each BPG in Chapters 9-12. The information presented in this chapter is a summary of the threats faced by the species across the SCCCS Recovery Planning Area. Specific information on threats within the different BPGs is presented in BPG-specific chapters 9-12 and associated appendices.

The general current conditions of 27 major watersheds within the SCCS Recovery Planning Area ranged from "Fair" to "Poor" at the northern and southern ends of the SCCCS Recovery Planning Area, whereas habitat conditions were generally rated as "Good" or "Very Good" in the central portion of the Recovery Planning Area within the Big Sur Coast and northern San Luis Obispo Terrace BPGS (See CAP Workbook summaries for more detailed information).

Table 4-1. High or Very High severity threat sources identified for the South-Central California Coast Steelhead Recovery Planning Area by BPG.

THREAT SOURCE*	Biogeographic Population Group (BPG)			
	Interior Coast Range	Carmel River Basin**	Big Sur Coast	San Luis Obispo
Dams and Surface Water Diversions	100%	100%	14%	50%
Groundwater Extraction	71%	100%	14%	58%
Levees and Channelization	43%	100%	0%	50%
Recreational Facilities	29%	100%	14%	25%
Urban Development	29%	100%	0%	25%
Roads and Culverts (Other Passage Barriers)	14%	100%	29%	8%
Agricultural Development	71%	0%	0%	67%
Non-Point Pollution	0%	0%	29%	33%
Mining	50%	0%	0%	0%

** Percentages indicate the proportion of all the watersheds in each BPG where the severity of a given threat source was identified as "High" or "Very High" as part of the CAP Workbook analyses. See individual BPG Threat Summaries in Chapters 9-12 for threats ranking in individual watersheds.*
*** The Carmel River is the only watershed within the Carmel River Basin Biogeographic Population Group.*

Many of the watersheds contain high-quality spawning and rearing habitat, but are compromised by one or more anthropogenic factors; for example, Salinas River (San Antonio, and Nacimiento Dams), Carmel River (San Clemente and Los Padres Dams, other passage barriers), and Pajaro River and tributaries (groundwater extraction, flood control, and diversions in the lower reaches) in the Interior Coast Range BPG. A widespread trend observed in the SCCCS Recovery Planning Area is severe to very severe degradation of habitat conditions along the mainstem of impaired watersheds, while the upper mainstem and tributaries (above and below dams) retain relatively high habitat values for steelhead. This is particularly evident in the Pajaro River, Salinas River, and Arroyo Grande Creek watersheds. Another DPS-level threat is impacts associated with wildland fires, including fire-fighting measures to control or extinguish them, and the post-fire measures to repair damages incurred in fighting wildland fires. (See for example, Cooper 2009, Capelli 2009, National Marine Fisheries Service 2008b, Finger 1997).

4.2.1 Dams, Surface Water Diversions, and Groundwater Extraction

Dams, surface water diversions, and groundwater extraction are common across the SCCCS Recovery Planning Area, especially on the larger rivers, such as the Pajaro, Salinas (and major tributaries, San Antonio and Nacimiento), and Carmel Rivers, but also Old, Pismo, and Arroyo Grande Creeks (California Department of Fish and Game 2011b, California Department of Water Resources 1988). Loss of surface flows or other passage impediments along the mainstem of the river adversely affect the productivity of important upstream tributaries otherwise providing spawning and rearing habitat for anadromous steelhead. Re-establishing or maintaining connections between the ocean and upper watersheds expands access to historically important spawning and rearing habitats, and improves the overall habitat conditions (amount and complexity) for steelhead, as well as the existing populations of native residualized *O. mykiss* that currently are isolated above dams and reservoirs.

San Clemente Dam –Carmel River

Dams also negatively affect the hydrology, sediment transport processes, and geomorphology of the affected drainages. In addition, dams and reservoirs frequently include recreational development for fishing and camping, which can introduce non-native predators and/or competitors (*e.g.*, largemouth and smallmouth bass, carp, crayfish, western mosquitofish) as well as promote trampling of the active channel, which potentially can lead to direct loss of redds (Muhlfeld *et al.* 20011a, 2011b, Johnson *et al.* 2008, Keefer 2008, Caudill *et al.* 2007, Dickens *et al.* 2007, Malcolm *et. al.* 2003, Williams and Bisson 2002, Brandt 2000, Pacific States Marine Fisheries Commission 1999, National Marine Fisheries Service 1996a, Roberts and White 1992).

4.2.2 Agricultural and Urban Development, Roads, and Other Passage Barriers

Human population density is high in some parts of the SCCCS Recovery Planning Area and development pressures in general are concentrated in the coastal terraces and middle and lower portions of watershed. Population density is a relative measure of intensity of land use and impacts to individual watersheds. Some of the watersheds in the Interior Coast Range BPG have been extensively developed for agriculture, which typically utilizes floodplains. In addition, the upland slopes in several of the watersheds in the San Luis Obispo Terrace BPG are extensively planted in orchard crops (California Department of Water Resources 1978).

Agricultural Activity –Pismo Creek

The typical pattern of urban and agricultural development focuses on the flatter portions of a watershed, typically within the floodplain and usually along the mainstem of the drainage and one or more tributaries, thereby magnifying potential impacts to steelhead even if most of the watershed remains undeveloped. Agricultural development on lower floodplains has resulted in channelization, removal of riparian vegetation, and simplification of channel structures, as well as the elevation of fine sediments and other types of pollution such as pesticides and fertilizers which can elevate nutrient levels and increase bio-oxygen demands. Public ownership of lands in the SCCCS Recovery Planning Area varies widely between watersheds but generally decreases southward. Although public ownership of these watersheds (U.S. National Forest and BLM lands, military reservations, *etc.*) can be extensive, these public lands are typically concentrated in the upper watersheds leaving the middle and lower watersheds subject to private development (Kier Associates and National Marine Fisheries Service 2008a, 2008b, Hunt & Associates 2008a, United States Army 2007, United States Forest Service 2005a, 2005b, 2004, National Marine Fisheries Service 1996a).

4.2.3 Flood Control, Levees, and Channelization

Urban and agricultural conversion of floodplain lands adjacent to the mainstem of rivers and streams frequently requires levees or other structures to protect these lands from flooding. The urban and agricultural reaches of a majority of the watersheds in the SCCCS Recovery Planning Area have been subjected to some degree of channelization and/or levee construction with the resulting loss or degradation of the riparian corridor and streambed. Flood control practices and associated channelization of streams and placement of levees impair the function and quality of stream habitats (Jeffres *et al*. 2008, Brown *et al.* 2005, National Marine Fisheries Service 1996a, Faber *et al.* 1989). Extensive channelization has occurred along the Pajaro River, and a number of its tributaries, as well as along the lower Salinas River which has been realigned, and long portions of the Carmel River, Pismo, San Luis Obispo, and Arroyo Grande Creeks (Kier Associates and National Marine Fisheries Service 2008a, 2008b, Hunt & Associates 2008a).

Channelization – Pajaro River

Habitat impairments for *O. mykiss* may include increased water temperature, incision of the streambed and loss of structural complexity and instream refugia (meanders, pools, undercut banks, *etc.*), complete loss of bed and bank habitat, increased sedimentation, turbidity, and substrate embeddedness, and excessive nutrient loading (Richardson, *et al.* 2010, Jeffres *et al.* 2008, Naiman *et al.* 2005, Newcombe 2003, National Research Council 2002, Naiman and Bilby 1998, Capelli and Stanley 1984, Warner and Hendrix 1984, Newcombe and McDonald 1991).

4.2.4 Non-Native Species

Non-native game species, such as large and smallmouth bass white bass, and bullhead catfish, are often stocked into both non-anadromous and anadromous waters by a variety of public and private entities. Additionally other non-native species such as striped bass have spread into some of the watersheds of the SCCC Recovery Planning Area from other areas. While these programs have provided seasonal fishing opportunities, the impacts of these programs on native, naturally-reproducing *O. mykiss* stocks are not well understood, though there is a potential adverse impact as a result of predation, disease, disruption of behavior or habitat displacement Cucherousset and Olden 2011, Davis 2009, Fraser 2008, Fritts and Pearsons 2006, Hayes *et al.* 2004, Noga 2000, Wood 1979, Dill and Cordone 1997, National Marine Fisheries Service 1996a, Rucker and Ordall 1953).

There are no production steelhead hatcheries operating in or supplying hatchery reared steelhead to the SCCCS DPS. However, there is an extensive stocking program of hatchery cultured and reared, non-anadromous *O. mykiss* (*i.e.,* rainbow trout) that supports a put-and-take fishery. Competition and disease transmission resulting from hatchery introductions have the potential to reduce the production and survival of native, naturally-reproducing steelhead, though genetic investigations of South-Central California Coast steelhead have not detected any substantial interbreeding of native with hatchery reared *O. mykiss* (Clemento *et al.* 2009, Girman and Garza 2006). These stockings are now generally conducted in non-anadromous waters.

However, California's steelhead stocking practices have distributed non-native steelhead stocks in many coastal rivers and streams in California (California Department of Fish and Game and U.S. Fish and Wildlife Service 2010). Because of problems associated with the practice of transplanting non-native steelhead stocks, CDFG developed its Salmon and Steelhead Stock Management Policy. This policy recognizes that such stock mixing can be detrimental and seeks to maintain the genetic integrity of all identifiable stocks of salmon and steelhead in California, as well as minimize interactions between hatchery and natural populations. To protect the genetic integrity of individual salmon and steelhead stocks, this policy directs CDFG to evaluate the stocks of each salmon and steelhead stream and classify it according to its probable genetic source and degree of integrity (McEwan and Jackson 1996). Additionally, CDFG has eliminated the stocking of hatchery cultured and reared fish in most coastal streams where steelhead have direct access from the ocean (California Department of Fish and Game and U.S. Fish and Wildlife Serviced 2010).

Striped Bass - Pajaro River (Courtesy Joel Casagrande)

In addition to the intentional introduction of non-native game species of fish, many other non-native species of wildlife and plant species have been introduced into the watersheds of South-Central California Coast which have the potential to displace native species, or adversely affect aquatic habitat conditions. Invasive plants such as the Giant reed *(Arundo donax)* and Tamarisk (*Tamarix* spp.) currently displace extensive areas of native riparian vegetation in major drainages such as the Salinas River and, in some cases, can reduce surface flows through the uptake of large amounts of groundwater. Non-native plant species such as water primrose (*Ludwigia uruguayensis*) can displace aquatic living space and, in extreme conditions, inhibit or block the instream movement of fish. Non-native plants can also reduce the natural diversity of insects that are important food sources for juvenile *O. mykiss* (Bell *et al.* 2009, Bossard *et al.* 2000, McKnight 1993).

4.2.5 Estuarine Loss

The mouths of most South-Central California Coast watersheds are characterized by one of several distinct types of estuaries formed by a combination of coastal topography, geology, and the hydrologic characteristics of the watershed (Jacobs *et al.* 2011, Ferren *et al.* 1995). Estuaries are used by steelhead as rearing areas for juveniles and smolts as well as staging areas for smolts acclimating to saline conditions in preparation for entering the ocean and adults acclimating to freshwater in preparation for spawning (Kier Associates and National Marine Fisheries Service 2008a, 2008b).

Estuarine Fill- Pajaro River

Because estuaries are located at the downstream end of coastal watersheds, and on relatively level coastal plains which are the most heavily urbanized portions of South-Central California, they have been subjected to a majority of the DPS-wide threats identified through the threats assessment. Estuarine functions have been adversely affected in a wide variety of ways (*e.g.*, degradation of water quality, modification of hydrologic patterns, changes in species composition). One indicator of the magnitude of the loss of estuarine functions is loss of wetland acreage, through a range of activities, including filling, diking, and draining. Approximately 75 percent of estuarine habitats across the SCCCS Recovery Planning Area have been lost and the remaining 25 percent is constrained by agricultural and urban development, levees, and transportation corridors highways and railroads (primarily in more extensively developed northern and southern portions of the SCCCS Recovery Planning Area). Grossinger *et al.* (2011), Kier Associates and National Marine Fisheries Service (2008a, 2008b), Dahl (1990), Ferren *et al.* (1995). In addition to the loss of overall acreage the habitat complexity and ecological functions of South-Central California Coast estuaries have also been substantially reduced as a result of the loss of shallow-water habitats such as tidal channel, the degradation of water quality through both point and non-point waste discharges and the artificial breaching of the seasonal sandbar at the estuaries mouth which can reduce and degrade steelhead rearing habitat. Estuarine habitat loss varies widely across BPGs, with the Pajaro and Salinas estuaries experiencing the largest physical modification and the estuaries along the Big Sur Coast (.e.g., Little Sur and Big Sur River) and the northern portion of the San Luis Obispo County coast (*e.g.,* San Carpoforo, Arroyo de la Cruz, and Little Pico Creek) the most physically intact, though they are impaired by reduced freshwater inflows and point and non-point waste discharges.. Table 4-2 provides an estimate of the relative loss of South-Central California Coast wetland estuarine acreage for some of the estuaries associated with steelhead populations in South-Central California Coast for which information was available. See Chapter 2, Steelhead Biology and Ecology for a discussion of the role of estuaries in the life history of steelhead.

Table 4-2. Estuarine habitat loss in component watersheds of the South-Central Coast Steelhead Recovery Planning Area by BGP.[1]

BPG	Watershed	Remaining Estuarine Habitat (% of historical habitat)
Interior Coast Range	Pajaro River	15
	Salinas River	10
Carmel River Basin	Carmel River	67
Big Sur Coast	San Jose Creek	10
	Garrapata Creek	100
	Bixby Creek	100
	Little Sur River	100
	Big Sur River	100
	Willow Creek	70
	Salmon Creek	100
San Luis Obispo Terrace	San Carpoforo Creek	90
	Arroyo de la Cruz	90
	Little Pico Creek	100
	Pico Creek	60
	San Simeon Creek	50
	Santa Rosa Creek	62
	Morro Creek	0
	Chorro and Los Osos creeks	83
	San Luis Obispo Creek	60
	Pismo Creek	30
	Arroyo Grande Creek	20

[1] Adapted from Kier Associates and National Marine Fisheries Service (2008a, 2008b).

4.2.6 Marine Environment Threats

Steelhead spend a majority of their life history cycle in the marine environment. Unlike the other anadromous Pacific salmon in the genus *Oncorhynchus*, steelhead do not die after entering freshwater to spawn, but may return to the marine environment and complete another year of ocean growth before returning to freshwater to repeat their reproductive cycle. Steelhead have not been observed in the marine environment in large aggregating schools with well-defined ocean migratory patterns. The incidental capture of steelhead in the marine environment as a by-catch of commercial fishing activities is uncommon. As a result of the apparent dispersal of single individuals or small groups in the marine environment, information on the movements, feeding habits, and predator-prey relationships of steelhead has not been extensively studied and is not well understood (Grimes *et al*. 2007, Aydin *et al.* 2005, Burgner *et al*. 1992, 1980, Groot and Margolis 1991, Hartt and Bell 1985). Table 4-3 outlines some of the metrics which are relevant to assessing conditions in the marine environment for both sub-adult and adult steelhead, though the actual conditions are either highly variable, or unknown.

Table 4-3. South-Central California Coast Steelhead Marine Environment Threats Assessment.

South-Central California Coast Steelhead Marine Environment Threats Assessment								
1. Sub-Adult Steelhead								
Category	**Key Attribute**	**Indicator**	**Poor**	**Fair**	**Good**	**Very Good**	**Current Indicator Status**	**Current Rating**
Landscape Context	Habitat Availability	Vegetation density in nearshore marine areas of CA – e.g., kelp/hectare	Low kelp density		High kelp density		Baseline data unavail-able	Variable
Landscape Context	Oceano-graphic Conditions	Ocean production index	Poor ocean conditions		Good ocean conditions			Variable
Condition	Fish Health	Condition of factor of sub-adult conspecifics collected in seines or other surveys	Data unavailable					Unknown
Condition	Fish Health	Incidence of disease/ parasitism in sub-adult conspecifics; salmon obtained from seine or other surveys	Baseline data unavailable					Unknown
Condition	Food Availability	Upwelling index	Poor ocean conditions		Good ocean conditions			Variable

Condition	Variability in Run Timing	Proportion of # of current vs. historic life history variations represented in domain	25% or less of historically known variation in run timing preserved in current runs	50% of historically known variation in run timing preserved in current runs	75% of historically known variation in run timing preserved in current runs	All historically known variation in run timing preserved in current runs		Unknown
2. Adult Steelhead								
Category	**Key Attribute**	**Indicator**	**Poor**	**Fair**	**Good**	**Very Good**	**Current Indicator Status**	**Current Rating**
Landscape Context	Oceano-graphic conditions	Ocean Production Index	Poor ocean conditions		Good ocean conditions			Variable
Condition	Fish Health	Condition factor of ocean-intercepted conspecifics	Data unavailable					Unknown
Condition	Fish Health	Incidence of disease/ parasitism in ocean-intercepted conspecifics	Baseline data unavailable					Unknown
Condition	Food Availability	Upwelling Index	Poor ocean conditions		Good ocean conditions			Variable
Condition	Variability in Run Timing	Proportion of # of current vs. historic life history variations represented in domain	25% or less of historically known variation in run timing preserved in current runs	50% of historically known variation in run timing preserved in current runs	75% of historically known variation in run timing preserved in current runs	All historically known variation in run timing preserved in current runs		Unknown

4.2.7 Natural Environmental Variability

Natural environmental variation has exacerbated the problems associated with degraded and altered riverine and estuarine habitats. See discussion in Chapter 2, Steelhead Biology and Ecology, Section 2.6. The current climate of the SCCCS Recovery Planning Area is classified as Mediterranean. This climatic regime is characterized by two distinct annual seasons, with a high degree of inter-annual and decadal variability: a long rainless season extending from May through November and a brief rainy season from December through March. Rainfall is associated with brief, but intense, cyclonic winter storms. This region is also subject to an El Niño/La Niña weather cycle which varies in length from seven to ten years. This large-scale weather pattern can significantly affect winter precipitation, causing highly variable rainfall and significant changes in oceanic conditions between years (McMullen and Jabbour 2010, Intergovernmental Panel on Climate Change 2007a, Changnon 2000, Philander 2004, 1990). In addition to these temporal climatic patterns, there is a wide disparity between winter rainfall from north to south, as well as between coastal plains and inland mountainous areas. Annual precipitation ranges along the coast (north to south) from 32 to 24 cm, with larger variations (24 – 90 cm) due to the orographic effects of the various mountain ranges, and well as El Nino-Southern Oscillation (Castello and Shelton 2004, Felton 1965).

River discharge, and therefore freshwater habitat conditions within South-Central California Coast watersheds, is strongly influenced by the intra- and inter-annual pattern of short-duration cyclonic storms (*e.g.*, frequency, timing, intensity, and duration). As a result, river discharge varies greatly between seasons, and can be highly "flashy" during the winter season, sometimes changing by several orders of magnitude over a few hours. Snow accumulation is generally small and of short duration, and does not contribute significantly to peak run-off. Base flows in some river reaches can be influenced significantly by groundwater stored and transported through alluvium, faults, and fractured rock formations. Many rivers and streams naturally exhibit interrupted base flow patterns (alternating channel reaches with perennial and seasonal surface flow) controlled by geologic formations, and the strongly seasonal precipitation pattern characteristic of a Mediterranean climate (Boughton *et al.* 2009, 2006, Holland 2001, Mount 1995, Jacobs, *et al.* 1993, Faber *et al.* 1989).

Over the course of their life cycle steelhead occupy both freshwater and marine environments. Freshwater habitats are critical for their reproductive phase, providing suitable habitat for the deposition, fertilization, and incubation of eggs in nests (redds) created by adults in spawning gravels. Freshwater habitats also provide a sheltered environment, relatively free of native predator species, and with suitable food sources, for rearing juveniles. Marine habitats are important for the growth and maturation of sub-adults, providing more abundant and appropriately sized food sources to support the large numbers of maturing fish emigrating from coastal watersheds of the South-Central California Coast Steelhead Recovery Planning Area, as well as fish originating from other coastal watersheds of the North Pacific Watershed (Quinn 2005, Moyle 2002). Both freshwater and marine environments are affected by weather and climatic conditions that vary on time scales ranging from hours to millennia. Despite the highly mobile nature of steelhead, and their ability to exploit freshwater and marine habitats in multiple ways, they remain vulnerable to natural changes in their environment.

4.2.8 Pesticide Use

The extensive use of pesticides for commercial agricultural purposes and there effects on anadromous salmonids has become an increasing area of concern (Baldwin *et al.* 2010, Macneale *et al.* 2010). Pesticide is a general term that refers to a wide range of chemicals (natural or anthropogenic in origin) or elements (such as copper sprays) used in an application with the intent to control or kill a pest species. Common classes of pesticides include insecticides, rodenticides, fungicides and herbicides. Pesticides may affect listed salmonids through direct or indirect means, via lethal or sub-lethal effects, over short time periods (acute effects) or longer time periods (chronic effects) or through the alteration of critical habitat components resulting in harm to the listed salmonids (Baldwin *et al.* 2010, Macneale *et al.* 2010). Adjuvants to pesticide active *ingredients*, such as surfactants or spreaders, may also cause or contribute to these effects (Laetz 2009).

Pesticides may also benefit listed salmonids, when used properly, in projects that protect or restore habitat functions such as the removal of non-native species (California Department of Pesticide Regulation 2012b, Zhang and Goodhue 2010). Several of the watersheds within the SCCC Recovery Planning (*e.g.*, Pajaro, Salinas, Santa Rosa, and Arroyo Grande) have been developed extensively with commercial agriculture, particularly row crops which are subjected to regular applications of a variety of pesticides. The nature and extent of the short and long-term effects of these pesticides on particular populations of steelhead within the SCCC Recovery Planning Area has not been extensively studied, and consequently is not well known. NMFS is working with the EPA at the national level to address EPA's responsibilities under the ESA during the process of registering or reregistering pesticide active ingredients for use under the Federal Insecticide, Fungicide, and Rodenticide Act and for establishing water quality criteria for pesticides under the Clean Water Act. At the Regional level, NMFS works with the State of California and EPA Region IX to assess these water quality criteria as they are proposed. NMFS also works with numerous action agencies or organizations to review or help plan their pesticide application projects for protectiveness to ESA listed species and their habitats.

5. South-Central California Coast Steelhead and Climate Change

"The West Coast's salmon and steelhead populations have always been sensitive to the variability of the northeast Pacific climate-ocean system . . . So steelhead recovery as a form of human stewardship has to be judged over a broader timeline, with multi-year setbacks in population size considered to be a normal and expected event, and progress judged at the scale of multiple decades and even multiple human generations."

Dr. David A. Boughton, Chair, NOAA Fisheries South-Central/Southern California Steelhead Technical Recovery Team, 2010

5.0 INTRODUCTION

The addition of CO_2 and other greenhouse gasses to the atmosphere over the past two centuries, as a result of industrialization and changes in land use, has substantially altered the radiative balance of the Earth. Less of the energy entering the Earth's atmosphere as sunlight is being re-radiated to space, with the effect that the planet is currently heating up at a pace not seen in human history, and perhaps not for millions of years (Archer and Pierrehumbert 2011, Solomon *et al.* 2009, Archer 2007).

The potential physical effects of projected future climate changes are manifold and complex, varying in range and intensity, across various landscape scales and ecosystem types. The biological response is also complex, and with many species, including Pacific anadromous salmonids, uncertain. While South-Central California Coast steelhead have evolved a suite of historically effective adaptations to a highly variable environment (including multiple paths for completing their life cycle), the rapid rate of projected climate presents yet another challenge to their persistence. Recent assessments of global climate change and climate change in the United States summarize the general effects on ecosystems (Trenberth, *et al*. 2011, Johnstone and Dawson 2010, Cayan, *et al*. 2009, Dettinger, *et al*. 2009, Mastrandera *et al.* 2009, Medellin-Azuara *et al.* 2009, Shaw *et al.* 2009, Westerling *et al.* 2009, Backland *et al.* 2008, Bedworth and Hanak 2008, and Gutowski *et al*. 2008, Barbour and Kueppers 2008, Hanak and Moreno 2008, Hanak and Lund 2008, Luers and Mastrandrea 2008, Intergovernmental Panel on Climate Change 2007a, 2007b).

These general physical effects include: 1) warmer atmospheric temperatures; 2) rises in sea level due to ice cap melting and thermal expansion of ocean water; 3) acidification of ocean waters; 4) increased droughts (frequency, severity, and duration) coupled with more severe cyclonic storms (intensity and duration); 5) increases in the intensity, frequency and duration of wildland fires; 6) modification of a variety of watershed processes, including run-off, erosion, sedimentation, and a variety of hill-slope processes ranging from ravel to mass-wasting and debris flows; 7) increases in water temperatures in rivers and streams; and 8) alterations in stream morphology (*e.g.*, occurrence and distribution of sediments, pools, riffles, etc.) as a result of changes in the frequency and intensity of high-flow events.

A review of existing studies indicates that regional climate changes would drive ecosystem changes in diverse ways (Dawson *et al*. 2011, Schwing *et al.* 2010). The ability to model and forecast the effects of such changes on steelhead populations is likely to be quite limited due to limitations on the predictability of behavior of non-linear causal networks (Schindler *et al.* 2008). This problem is common to many threatened and endangered species, but is exacerbated for Pacific salmonids due to their requirements for a succession of different habitats over the course of their life history cycle. However, the environmental changes anticipated for South-Central California Coast steelhead are not as profound as other regions of California. For example, in the Central Valley anadromous fish populations dependent on snowmelt-fed river systems may undergo a conversion to rain-fed systems, or along the central and north coastal areas where coho populations which have a fixed life history strategy may be less adaptable to environmental changes than steelhead (Moyle *et al.* 2008).

The projected climate changes in South-Central California are expected to mainly intensify patterns that are characteristic of a semi-arid Mediterranean Climate (periodic droughts, intense cyclonic rainstorms, dry, hot summers) and to which South-Central Coast populations of steelhead appear to have already evolved a flexible, opportunistic survival strategy. An important factor for coastal populations is the continuing role of the ocean in moderating coastal climates due to its high heat capacity. Thus coastal steelhead populations, even in the South-Central portions of California, appear to have a more predictable future than inland populations which are vulnerable to faster and more extreme changes in climate (Boughton 2010a).

5.1 PROJECTED CLIMATE CHANGES

5.1.1 Terrestrial and Freshwater Environment

Geographically, California is situated at the transition between regions of net gain and net loss of water, and predicted future water availability is sensitive to model assumptions and emissions scenarios (Hayhoe *et al*. 2004). Climate models appear to make a median prediction of about 10% loss of precipitation statewide by 2100, under a low emissions scenario (Cayan *et al*. 2009). However, there is enough variability in the predictions that significantly drier or wetter futures are also reasonable expectations (Trenberth *et al*. 2011, Hayhoe *et al*. 2004, Leung *et al*. 2004, Snyder *et al*. 2002).

For California, the mid-century (2035- 2064) response to global climate change is consistent across scenarios: an annual maximum temperature increase of about +1.9° to +2.3°C for sensitive climate models, and 1°C less for the less sensitive model (Shaw *et al.* 2009). The statewide precipitation response is relatively small, ±4cm across the various scenarios and models, though more precipitation falls as rain rather than snow. Also, the snow melts sooner; and more is evaporated leading to lower soil moisture and streamflows (Null *et al.* 2010, Cayan *et al.* 2008a). The model simulations suggest that predictability is reasonably good at the 40-year time-scale, perhaps because global climate outcomes at this timescale are dominated not by positive atmospheric feedbacks, but by the inertial effect of the ocean, which acts as transient negative feedback that limits the pace of climate change (Baker and Roe 2009).

By 2100 the temperature scenarios diverge much more severely, about +2.5°C versus +4.2°C for the lower and middle-upper emission scenarios, respectively. Under the middle-upper emission scenario, the end-of-the-century also marks a period of unprecedented wildfires and significantly more erratic precipitation in the south-central and southern coastal regions, and the possibility of large decreases in mean precipitation (Shaw *et al.* 2009, Cayan *et al.* 2008a).

Perhaps more importantly, under the middle-upper emission scenario, the end-of-the-century marks a period of *accelerating* greenhouse gas emissions and climate change, whereas in the lower scenario it is a period of emissions *shrinking* toward zero and global change that is decelerating toward equilibrium (Solomon *et al.* 2009, Cayan *et al.* 2008a). Thus the changes projected under the middle-upper emissions scenario are the prelude for even faster changes in the 22nd Century, with no prognosis for stabilizing greenhouse gas concentrations and climate.

Regional climate projections for the south-central and southern California coast ranges suggest a future of longer, hotter summers, but with a potentially higher incidence of fog along the immediate coast, more extreme heat waves and droughts, but with perhaps more intense precipitation events in some areas (Karl *et al.* 2009, Cayan *et al*. 2008a, Snyder and Sloan, 2005, Snyder *et al.* 2002).

Climate change has the potential to profoundly affect both terrestrial and freshwater ecosystems in California (Maurer *et al.* 2010, Bakke 2008, Barbour and Kueppers 2008, Schindler *et al.* 2008). There are a number of potential negative effects on steelhead and their freshwater and estuarine habitats which are of particular significance. Many of these effects could be exacerbated by the human response to climate change, particularly as a result of the increase competition for limited freshwater supplies. These are summarized below (Schwing *et al.* 2010).

Rainfall and Runoff. Steelhead depend on adequate rainfall and run-off during their migratory seasons to both enter and emigrate from coastal watersheds. In South-Central California adequate stream flow is not only necessary for adults to reach upstream spawning areas and juveniles to emigrate to the ocean, but also to breach the sand bar, which seasonally forms at the mouth of most coastal rivers and streams, to allow entrance to and emigration from the watershed (Jacobs *et al.* 2011, Maurer 2006, Quinn 2005).

Rivers and riparian areas (and associated wetland areas) make up less than one percent of the landscape in arid regions such as South-Central California. These highly productive ecosystems are embedded within upland systems with much lower productivity. The primary driver of terrestrial hydrologic systems is precipitation. Most of the United States experienced increases in precipitation and stream flow and decreases in drought during the second half of the past century. However, there are indications that increases in the severity and duration of droughts have increased in the western and southwestern United States. The full effects of these changes on aquatic organisms such as *O. mykiss* are not well understood (Schwing *et al.* 2010).

Groundwater. Groundwater is an important source of surface flows during dry periods in many South-Central California Coast watersheds. Groundwater can therefore contribute to sustaining suitable over-summering juvenile rearing conditions in mainstem and tributary habitats. Surface flows can be maintained as a result of the intersection of a high groundwater table or through the transmission of water through geologic fault systems. The effects of climate change on groundwater systems have not been as extensively studied as have the effects of climate change on surface water systems. One recent investigation in the Santa Ynez Mountains of California suggests that an increase in the biomass of watersheds dominated by chaparral is likely to increase with the increase of atmospheric CO_2 and atmospheric temperature, leading to reductions in summer stream flow (Tague *et al.* 2009). Other Global Climate Models (GCMs) projecting a decrease in vegetative cover could lead to an increase in summer stream flow (Boughton 2010a).

Water Temperature. Increased minimum atmospheric temperatures and warmer spring and summer temperatures have led to increased stream temperatures in most of the continental Unites States. Increased stream temperatures likely will have both direct and indirect adverse impacts on juvenile *O. mykiss.* These include subjecting the species to physiological stress, and altering the aquatic environment through such modifications as reducing dissolved oxygen levels or increasing the growth of algae and rooted aquatic vegetation. Elevated stream temperatures can also favor the proliferation of non-native warm water species that can compete for living space, and also prey on native *O. mykiss*, particularly juveniles. Changes in water temperature are most likely to occur during low-flow periods that coincide with over-summering rearing juvenile *O. mykiss*. Stream temperature increases have already begun to be detected across the United States, though no comprehensive analysis similar to streamflow trends has been conducted. An increase in the incidence of coastal fog could moderate these effects in some coastal areas (Wenger *et al.* 2011, Johnstone and Dawson 2010, Mantua *et al.* 2010, Keefer 2009, Schindler *et al.* 2008, Daufresne and Boet 2007, Battin 2007, Mohseni and Eaton 2003, Mohseni et al. 1999a, 1999b, Eaton and Schaller 1996).

Wildland Fire. Chaparral is the predominant vegetation type within the SCCS Recovery Planning Area. Wildfires are a natural phenomenon essential for the periodic renewal of chaparral plant communities (Sugihara *et al.* 2006, Davis and Borchert 2006). In addition, wildfires can have at least temporary major impacts on freshwater habitats of anadromous and non-anadromous *O. mykiss.* These effects range from increasing the erosion, transportation, and deposition of massive amounts of fine sediments into watercourses containing coarser-grained spawning gravels to destroying riparian vegetation and facilitating the spread of non-native plant and animal species. The frequency and size of wildfires is expected to increase as a result of increases in atmospheric temperatures (Bell *et al.* 2009, Westerling and Bryant 2008, Westerling *et al.* 2009, Lenihan *et al*. 2006, Miller and Schlegel 2006).

Santa Ana winds and human-triggered ignitions play important roles in the fire regime of South-Central California chaparral and scrubland forests. These seasonal, hot, dry winds occur primarily during the fall and winter and are driven by large-scale patterns of atmospheric circulation resulting from high pressure over the Great Basin, coupled with low pressure off the coast of South-Central California that drives dry air toward the coast. These winds can reach 40 miles per hour and can spread fires rapidly, sometimes burning 115 square miles of chaparral and shrub vegetation per day (Ryan and Burch 1992). Using GCMs, Miller and Schlegel (2006) predict that the total number of annual Santa Ana wind events would not change over the next 30 years, though one of the General Climate Model simulations showed a shift in the seasonal cycle, with fewer Santa Ana wind events occurring in September and more occurring in December. The potential implications of this shift for the fire regime are unclear (Davis and Borchert 2006, Keeley 2006, Keeley *et al.* 1999). Wildland fire impacts can be compounded by fire-fighting measures to control or extinguish wildland fires (*e.g.,* the use of fire retardants) as well as by post-fire measures to repair damages incurred in fighting wildland fires
(Capelli 2009, Cooper 2009, National Marine Fisheries Service 2008b, Finger 1997).

5.1.2 Marine Environment

Steelhead spend the majority of their lives in the marine environment, entering freshwater habitats for brief periods to reproduce and rear. While steelhead are subjected to the same basic oceanic conditions (*e.g.*, currents, water temperature, up-welling, abundance of prey base, predator-prey interactions, and water quality) as other anadromous Pacific anadromous salmonids, they may respond and be affected by such conditions differently because of their distinctive behavioral, physiological and other ecological characteristics. However, as with other anadromous Pacific salmon, conditions in the marine environment are crucial to the growth, maturation, mortality, and abundance of returning adult steelhead to their freshwater spawning habitats.

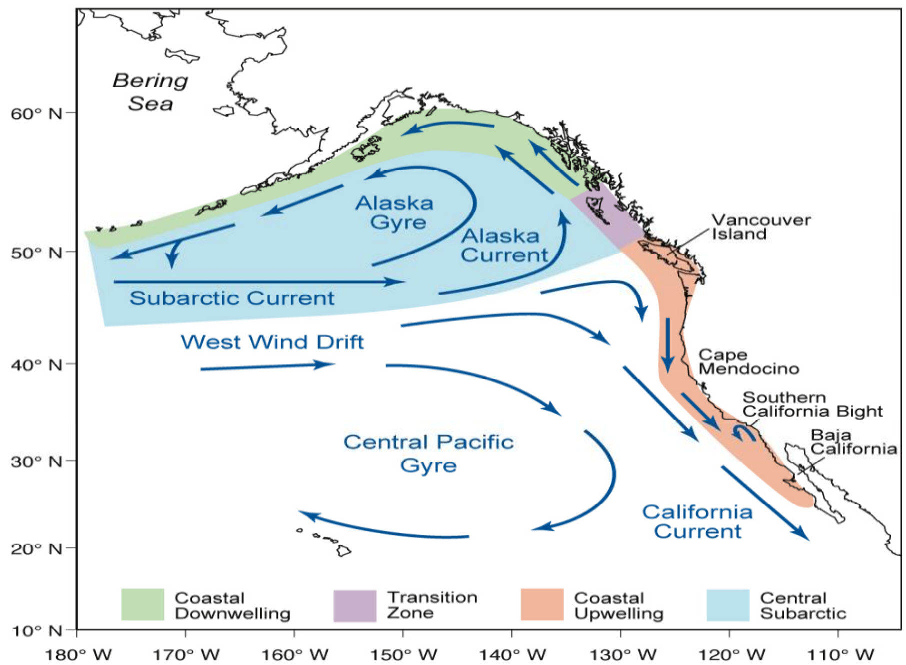


Fig. 5-1. Principle Ocean Currents in the North-East Pacific Ocean Affecting Coastal Waters of California (J. A. Barth, Oregon State University

California Current Ecosystem. The California Current Ecosystem (CCE) is one of eight large marine ecosystems within the jurisdiction of the United States. The northern end of the current is dominated by strong seasonal variability in winds, temperature, upwelling, plankton production and the spawning times of many fishes, whereas the southern end of the current has much less seasonal variability. Climate signals in this region are quite strong. During the past 10 years, the North Pacific has seen two El Niño events (1997/98, 2002/03), one La Niña event (1999), a four-year climate regime shift to a cold phase from 1999 until late 2002, followed by a four-year shift to warm phase from 2002 until 2006 (Schwing *et al*. 2010, Peterson and Schwing 2003, Mantua *et al.* 1997). However, because of the dearth of information on the marine phase of steelhead it is difficult to assess the biological response to projected climate driven changes in the CCE.

Climate-Induced California Current Ecosystem Responses

Numerous climate stressors (*e.g.*, warming, sea level rise, freshwater flow) impact productivity and structure throughout the CCE. The following provides a summary of these issues based upon the analysis developed as part of a NMFS framework for a long-term plan to address climate impacts on living marine resources (Schwing *et al.* 2010, Osgood 2008).

1. Future climate variability in the context of global climate change and a warmer planet

One of the likely consequences of global climate change will be a more volatile climate with greater extreme events on the intra-seasonal to inter-annual scales. For the CCE this will mean more frequent and severe winter storms, with greater wind mixing, higher waves and coastal erosion, and more extreme precipitation events and years, which would impact coastal circulation and stratification. Some global climate models predict a higher frequency of El Niño events; others predict that the intensity of these events will be stronger. If true, primary and secondary production will be greatly reduced in the CCE, with negative effects transmitted up the food chain, including to the Pacific anadromous salmonids (Trenberth *et al.* 2010, Mastrandrea *et al.* 2009, Karl *et al*. 2008, Bell and Sloan 2006, Benestad 2006, Bell *et al.* 2004, Trenberth 1999).

2. The extent and timing of freshwater input and its impact on the nearshore habitat of anadromous fishes

Variability in ocean conditions has substantial impacts on salmon survival and growth, and can be influenced in continental shelf waters by river runoff. Potential changes in rainfall and snow pack are likely to increase winter and spring runoff but decrease summer runoff. Climate models project the 21st century will feature greater precipitation in the Pacific Northwest, extreme winter precipitation events in California, and a more rapid spring melt leading to a shorter, more intense spring period of river flow and freshwater discharge. This will greatly alter coastal stratification and mixing, riverine plume formation and evolution, and the timing of transport of anadromous populations to and from the ocean (Maurer *et al*. 2010, 2006, Mantua *et al*. 2010, Poff *et al.* 2010, Barnett 2008, Kim *et al.* 2002).

The situation in South-Central California may be more complex, and difficult to model, because of the uncertainty surrounding the projected climate changes; further the response of South-Central California Coast steelhead to these climate driven changes is uncertain (Boughton 2010a, Boughton *et al.* 2006, 2007b).

3. The timing and strength of the spring upwelling transition and its effect on production and recruitment of marine populations

Coastal upwelling of cold water carries significant plankton and krill populations into coastal waters. These populations are an important food source for young Pacific anadromous salmonids entering the ocean to begin the marine phase of their life cycle. At present there is some evidence that coastal upwelling has become stronger over the past several decades due to greater contrasts between warming of the land (resulting in lower atmospheric pressure over the continent) relative to ocean warming (Bakun 1990). Regional climate models project that not only will upwelling-favorable winds be stronger in summer, but that the peak in seasonal upwelling will occur later in the summer (Snyder *et al.* 2003), delaying the availability of an important food source to juvenile Pacific anadromous salmonids. However, the winds may not be able to mix this light buoyant water or transport it offshore, resulting in the inability of cold nutrient-rich water to be brought to the sea surface.

Fig.5-2 Seasonal Coastal Upwelling Pattern Along the California Coast (Courtesy NOAA)

Thus, phytoplankton blooms may not be as intense, which may impact organisms up the food chain including Pacific anadromous salmonids (Roemmich and McGowan, 1995). Given that the future climate will be warmer, the upper ocean at the watershed scale will likely be, on average, more stratified. The result will be lower primary productivity everywhere (with the possible exception of the nearshore coastal upwelling zones).

4. Ocean warming, increased stratification and their effect on pelagic habitat

The vertical gradient in ocean temperature off California has intensified over the past several decades (Palacios *et al*. 2004). Areas with enhanced riverine input into the coastal ocean will also see greater vertical stratification. Generally warmer ocean conditions will cause a northward shift in the distribution of most marine species, and possibly the creation of reproductive populations in new regions. Existing faunal boundaries are likely to remain as strong boundaries, but their resiliency to shifts in ocean conditions due to global climate change is not known. The effects of any shift of pelagic species, particularly predator and prey species, on Pacific anadromous salmonids are unclear, but may vary with individual species such as steelhead (Lindley *et al.* 2007).

5. Changes in gyre strength, regional transport, and source waters to the California Current and their impact on species distribution and community structure

Observations of the biota of the California Current show that there are pronounced latitudinal differences in the species composition of plankton, fish, and benthic communities, ranging from cold water boreal sub-arctic species in the north to warm water subtropical species in the south.

Copepod biodiversity increases in coastal waters due to shoreward movement of offshore waters onto the continental shelf, which is caused by either weakening of southward wind stress in summer or strengthening of northward wind stress in winter.

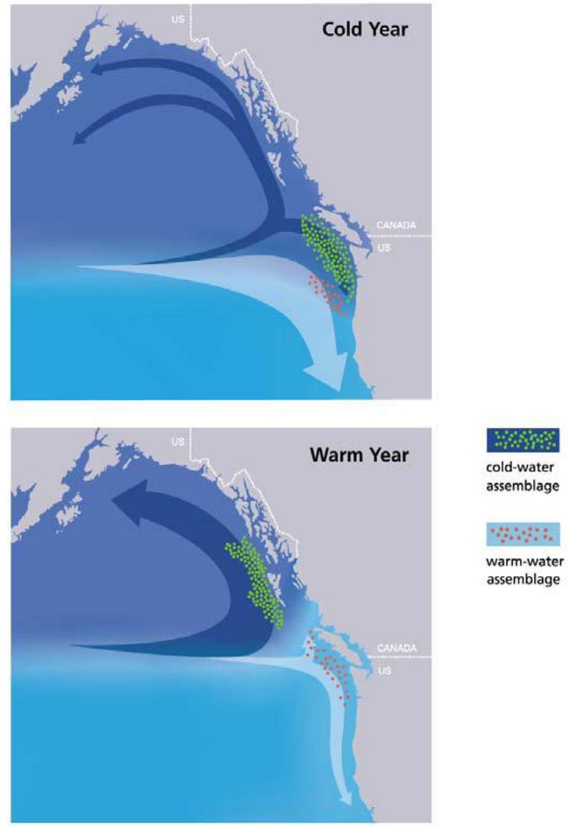


Fig. 5-3. Shift in Cold and Warm-Water Faunal Assembles During Pacific Decadal Oscillations and El Niño/La Niña/Southern Oscillations (Osgood 2008)

Regardless of the season, the source waters that feed into the California Current from the north and from offshore can exert some control over the phytoplankton and zooplankton species that dominate the current. The occurrence of low returns of Pacific anadromous salmonids when the Pacific Decadal Oscillation (PDO) is in a positive, warm-water phase, and high returns when the PDO is in a negative, cold-water phase suggests a mechanistic link between PDO sign change and the growth and survival of Pacific anadromous salmonids. However, for Alaska salmon, the typical positive PDO condition is associated with enhanced streamflows and nearshore ocean mixed-layer conditions favorable to high productivity (Mantua and Hare 2002, Mantua *et al*. 1997). Most climate models project roughly the same timing and frequency of decadal variability in the North Pacific under the impacts of global warming. However, combined with a global warming trend, the CCE is likely to experience more years of positive, warm phases (*i.e.*, periods of lower productivity).

Two other marine related effects of global climate change are relevant to steelhead as well as other Pacific anadromous salmonids: sea-level rise and ocean acidification.

Sea Level Rise. One of the several life history strategies exhibited by steelhead is the "lagoon-anadromous" strategy in which juveniles rear a portion of the year in the estuary of their natal river or stream. Studies in small coastal estuaries seasonally closed off from the ocean by sand bars have shown these areas to be productive rearing areas for *O. mykiss*, with juveniles growing fast enough to migrate to the ocean after their first year, and generally at a larger size than juveniles rearing in the freshwater portion of the stream system. Fish that enter the ocean at a larger size exhibit greater survival rates in the ocean, and thus tend to be disproportionately represented in the adult spawning population (Hayes *et al.* 2008, Bond 2006).

Changes in sea level, which have the potential to affect important estuarine habitats, have already been reported and are expected to continue. Researchers have projected that by 2035-2064 global sea level rise will range between 6-32 cm above 1990 levels, regardless of the emission scenarios used. However, between 2070-2100 the projected range of sea level rise varies between 11-54 cm to 17-72 cm depending on the emission scenario used (Cayan *et al*. 2009, 2008b, Pilkey and Young 2009, Raper and Braithwaite, 2006). This more recent analysis suggests a larger rise in sea level than previously projected by Hayhoe *et al*. (2004, Ewing 1989). A projected 1m rise in sea level would lead to the potential inundation of 65 percent of the coastal marshlands and estuaries in the continental United States. In addition to the inundation and displacement of estuaries/lagoons, there would be shifts in the quality of the habitats in affected coastal regions. Prior to being inundated, coastal watersheds would become saline due to saltwater intrusion into the surface and groundwater (Pilkey and Young 2009). A rise in sea level will most dramatically affect those estuaries which have been confined by surrounding development that prohibits their boundaries from naturally shifting in response to inundation. As discussed in Chapter 4 (Current DPS-Level Threats Assessment), estuarine habitat functions and habitat loss may be of particular importance to steelhead, though their role in South-Central California has been the subject of limited investigation.

Ocean Acidification. Another projected effect of climate change on the marine environment is acidification. As a result of increased anthropogenic CO_2 in the oceans since the industrial revolution, the pH of seawater has dropped from 8.2 to 8.1 (on a logarithmic scale, this represents a c. 26% increase in the concentration of H^+ ions). Estimated future increase in atmospheric CO_2 could result in a decrease in surface water pH of 0.3-0.4 by the end of the century, depending on the emission scenario used (Feely *et al.* 2008, Feely, *et al*. 2004). The effects of CO_2 concentration in the marine environment are not uniform, but are expected to vary with water depth, circulation and temperature, and in coastal waters with upwelling and freshwater input and nutrients (National Research Council 2010).

The reaction of CO_2 with seawater reduces the formation of calcium carbonate used in skeleton and shell formation of marine organisms, and can change many biologically important chemical reactions. The effects of ocean acidification will vary among organisms. As an example, ocean acidification has been shown to reduce the abundance of some carbonate forms, such as pteropods (Fabry *et al.* 2008). Because pteropods are an important food source for certain species of Pacific salmon (*e.g.*, sockeye, pink, and chum salmon), a reduction in pteropods can affect the marine growth of these species. One bioenergetics/food web model predicts that a 10% reduction in pteropod production would result in a 20% reduction in the growth of pink salmon (Aydin *et al.* 2005). Because of the lack of information on the marine phase of steelhead, it is unclear if pteropods or other carbonate forming prey constitute a signification portion of the diet of steelhead when in the marine environment. The significance of ocean acidification for steelhead and other anadromous salmonids may depend on the change of pH and carbonate equilibrium, its effect on pteropods and pelagic planktonic community structure, and the ability of juvenile and adults to modify their diets accordingly (Schwing *et al*. 2010). The long-term consequences of ocean acidification on marine ecosystems are poorly understood, but potentially significant (National Research Council, 2010). Because the marine life history phase of steelhead is not well understood, as noted above, the long-term consequences of ocean acidification for this species are even less certain (Nielsen and Ruggerone 2009, Meyers *et al*.1996).

5.2 CLIMATE INFLUENCES ON STEELHEAD

5.2.1 Steelhead Life Histories and Habitats

The intricate life history of salmonids as well as the complexity of their multiple aquatic habitats means that it is rare that an isolated environmental factor, or driver, is responsible for variability in a given population. Numerous climate stressors (*e.g.*, warming, sea level rise, freshwater flow) affect population productivity and structure throughout the habitats and life history stages of a species. To understand the implications of climate change for salmonids, it is useful to establish a conceptual framework that organizes this complexity (Schwing *et al.* 2010). Such a framework is reflected in the viability criteria and recovery strategy described in Chapters 6, Steelhead Recovery Goals, Objectives, & Criteria and 7, Steelhead Recovery Strategy, in this Recovery Plan which is based on the current climate conditions, and should provide guidance in the adaptive management of steelhead as the climate changes in the SCCS Recovery Planning Area.

The framework used here organizes complexity into four broad spheres: 1) the multiple life history pathways that are open to salmonids as a function of their adaptations and ecological tolerances; 2) the environmental opportunities that aquatic habitats offer to salmonids at each stage of their life history (Mobrand *et al*. 1997); 3) the suite of habitat-generating processes and stressor-pathways, by which climate (and other drivers) create, destroy, or maintain these aquatic habitats; and 4) the spatial connectivity and timing by which the other domains are knitted into a productive and viable salmonid population. This way of organizing the material allows a systematic treatment of each life stage, each habitat used by each life stage, and each way in which climate change potentially impacts each habitat-generating mechanism (Waples *et al.* 2010, 2008a, 2008b, Schindler *et al*. 2008).

5.2.2 Life History Pathways

The life history network described in Chapter 2, Sub-section 2.6 (South-Central California Coast steelhead Freshwater Life Cycle Habitat Use) can be related to the Viable Salmonid Population (VSP) concept of McElhany *et al*. (2000), where viability is measured in terms of four parameters: abundance, productivity, diversity, and spatial structure. Each link in a habitat network involves an interaction between a life history stage and a particular habitat, and has two attributes that emerge from this interaction: survival and capacity. The patterns of survival and capacity across the network translate to abundance and productivity, respectively, for the population as a whole, two of the four VSP parameters (Mobrand *et al*. 1997).

Diversity and spatial structure, the other two VSP parameters, emerge from the parallel linkages in the life history network. Diversity has two broad components: the diversity of pathways offered by the environment (habitat diversity), and the ability of the species to pursue those opportunities (phenotypic plasticity, generalist strategies, and genetic diversity). Spatial structure, the fourth VSP parameter, provides the physical space for parallel linkages to occur in greater numbers and larger capacities, thus increasing the overall resilience of the population.

Because climate is changing, it can be expected that steelhead populations will respond, along with other species, but in variable ways. In so far as evolution has raised steelhead populations to an adaptive peak, climate change will generally be expected to reduce the fitness of steelhead populations at least temporarily (Schwing *et al*. 2010).

The interactions between steelhead at distinctive phases in their life history and the habitat conditions characteristically associated with those life history phases should be the focus of future research into the effects of projected climate change on steelhead life histories and habitats.

5.2.3 Environmental Opportunities and Habitat Diversity

Environmental opportunities are times and places where physical, chemical and biological conditions support the survival, growth, migration and reproduction of anadromous salmonids. Some of these conditions are predictable or discernible, and some are not. Frequently the relatively predictable components are physical or possibly chemical conditions, traceable to the interaction of climate acting on a geologic template (Buffington *et al*. 2004). In freshwater habitats, these physical components of environmental opportunity are generally functions of variation along three axes: flow, channel morphology or substrate, and water quality - especially temperature (Beechie *et al*. 2010, Orr *et al*. 2008, Newson and Large 2006, Thorp *et al*. 2006, Stanford *et al*. 1996). In marine habitats, climate-related opportunities tend to be physically structured by water temperature, currents and circulation patterns, chemistry (especially acidification), and for the near-shore domain, sea level rise.

Climate largely shapes where in time and space anadromous salmonids can persist or flourish, within the constraints of past evolution and the geologic/topographic template. A change in climate means a change in the space and time where anadromous salmonids can persist and flourish; but these changes are filtered through a set of processes in the watershed, by which precipitation, elevated CO_2, and air-temperature patterns are converted into flow, and stream temperature patterns (Schwing *et al.* 2010).

5.2.4 Habitat-Forming Processes

The processes that convert climate patterns into spatial and temporal habitat for salmonids are sometimes called habitat-forming processes (Beechie and Bolton 1999). Salmonid habitats are generated by the operation of four broad process domains: watershed (or terrestrial), fluvial, estuarine, and marine domains (Montgomery 1999).

These functional domains can be further subdivided to make meaningful connections between climate processes, spatial and temporal habitat, and salmonid life history pathways. For example, the precipitation pulses from Pacific storm systems drive fluvial processes that tend to produce an ordered sequence of channel types from headwaters to the estuary (Montgomery and Buffington 1997). Some of these, such as step-pools and pool-riffle channels, play specific roles (rearing and spawning, respectively) in salmonid life history.

These broad processes can also be subdivided to indicate differential response to climate change. (Boughton *et al.* 2009, Davy and Lapointe 2007, Buffington *et al*. 2004, Moir *et al*. 2004, Kahler *et al*. 2001). For example, the fluvial domain can be divided into a sediment-transport domain and a response, or alluvial, domain downstream (Montgomery and MacDonald 2002). These are expected to have different sensitivities to changes in flow regime and sediment supply. Estuarine domains tend to be small interfaces between the much more extensive fluvial and marine domains; they thus exhibit a dynamism that is inherently responsive to alteration of either marine or fluvial dynamics (Jay *et al*. 2000).

As with the life history networks of anadromous salmonids, if multiple ecosystem processes produce the same sort of resource for a salmonid population, resiliency of the population tends to improve. Parallel linkages fall into two general categories: redundant pathways and alternative pathways (Edelman and Gally 2001, Tononi *et al*. 1999).

Redundant pathways are multiple instances of the same process providing the same outcome. For example, if headwater streams provide fish with thermal refugia during the summer, a stream system with multiple tributaries, each providing a refugium, is highly redundant. Redundancy provides resilience against small-scale disturbances, such as chemical spills (Nielsen *et al*. 2000) or wildfire. But redundant pathways tend to respond in a coordinated fashion to large-scale disturbances, such as droughts or heat waves, and thus provide little resilience to them because they would all tend to respond the same way.

Alternative pathways are different processes that produce the same physical conditions. For example, thermal refugia can be generated either by a headwater stream (via the temperature lapse rate), or by a coastal lagoon (via proximity to the ocean heat sink). Due to the large thermal mass of the ocean, coastal thermal refugia would probably be relatively resilient to heat waves, and may even be enhanced by them through onshore movement of fog. Alternative pathways are less likely than redundant pathways to exhibit a consistent response to a large-scale disturbances, and this can promote resiliency even more effectively than redundancy (Levin and Lubchenco 2008). Moreover, alternative pathways appear able to make living systems both more robust and more resilient to sustained directional change – such as climate change - not just disturbances (Whitacre and Bender 2010, Moritz et al. 2005, Carlson and Doyle 2002, Tononi *et al*. 1999).

5.2.5 Spatial Connectivity and Timing

The fourth element in this conceptual framework deals with the continuity of environmental opportunities for successive life stages of anadromous salmonids. The timing of fish movement from one habitat to another depends on whether environmental conditions in the habitats and migration corridors connecting them are suitable, and whether fish are at a suitable stage of development to require or be capable of the movement between habitats.

Rapidly changing climate may alter such opportunities by creating critical mismatches in development and habitat conditions to which anadromous runs are currently adapted. In principle, a river-ocean system could contain the full suite of habitats necessary for all life stages, but if the fish cannot reliably move from one habitat type to the next at the appropriate time in its life cycle, the system is unlikely to support a viable population.

Adult South-Central California Coast steelhead currently enter freshwater in the winter and late spring when flows are high and migrate to high elevation habitats that will be inaccessible to later in the season when flows are lower. The timing of these flows depends on precipitation. Following successful spawning and incubation fry emerge some time later, depending almost entirely on water temperature experienced while they are in the gravel. Growth and development to the smolt stage also depends upon temperature. Smolts typically enter the ocean from late winter to late spring, when feeding conditions are optimal due to seasonal upwelling supporting enhanced primary production. The timing of salmon life cycle stages has been shaped by centuries or millennia of climate conditions, and can be adversely affected by rapid climate change that alters the timing, rate, and spatial location of key physical and biological processes (Crozier *et al*. 2008).

5.3 RECOVERY PLANNING FOR SOUTH-CENTRAL COAST CALIFORNIA CLIMATE CHANGE

5.3.1 Core Principles

While some physical parameters of climate change are likely to be predictable, the response of ecosystems and hence the future conditions of steelhead habitats are much less predictable. This suggests that the over-arching strategy for dealing with climate changes will be to enhance the resilience of the steelhead metapopulations to respond to ecosystem changes, through forecasting and managing the physical envelope of the species according to a few core principles (see Boughton *et al.* 2010a for a discussion of these principles):

- Widen opportunities for fish to be opportunistic (*i.e.,* exploit a variety of habitat types)
- Maximize connectivity of habitats (i.e., within and between habitats)
- Promote the evolvability of populations and metapopulations (*i.e.,* the ability of a population to generate novel functions, through genetic change and natural selection, that help individuals of a population survive and reproduce)
- Maintain the capacity to detect and respond sustainably to ecosystem changes as they occur.

The viability criteria outlined in Chapter 6, Steelhead Recovery Goals, Objectives & Criteria, and the recovery strategy identified in Chapter 7, Steelhead Recovery Strategy, applied these core principles to the current climate regime, and should be applied to future climate regimes.

As a result, there will likely be a need to extend the results of the TRT. The following climate change related questions have already been identified by the TRT:

How will the climate trends alter the wildfire regime, and thus alter sedimentalogical and hydrological processes that affect the distribution of steelhead habitat?

Will different watersheds develop distinctly different wildfire regimes, with implications for habitat dynamics, carrying capacity, and viability?

What environmental factors maintain suitable creek temperatures during the summer, and will they moderate the response of stream temperatures to climate change?

Are there natural freshwater refugia that sustain *O. mykiss* during droughts longer than the generation time of the fish?

How are patterns of intermittency likely to respond to climate change, and where are suitable flows likely to intersect with suitable water temperatures under scenarios of climate change?

6. Steelhead Recovery Goals, Objectives & Criteria

"Recovery is the process by which listed species and their ecosystems are restored and their future safeguarded to the point that protections under the ESA are no longer needed. A variety of actions may be necessary to achieve the goal of recovery, such as the ecological restoration of habitat or implementation of conservation measures with stakeholders."

Endangered and Threatened Species Recovery Planning Guidance, National Marine Fisheries Service, 2010

6.1 DPS RECOVERY GOAL

The goal of this Recovery Plan *to prevent the extinction of South-Central California Coast steelhead in the wild and ensure the long-term persistence of viable, self-sustaining, wild populations of steelhead distributed across the South-Central California Coast Steelhead (SCCCS) Distinct Population Segment (DPS). It is also the goal of this Recovery Plan to re-establish a sustainable South-Central California Coast steelhead sport fishery*.

Recovery of the SCCCS DPS will require the protection, restoration, and maintenance of habitats of sufficient quantity, quality, and natural complexity throughout the SCCCS Recovery Planning Area so that the full range of all life history forms of *O. mykiss* (*e.g.*, switching between resident and anadromous forms, timing and frequency of anadromous runs, and dispersal rates between watersheds) are able to successfully use a wide variety of habitats in order to overcome the natural challenges of a highly variable physical and biological environment.

A **viable population** is defined as a population having a negligible risk (< 5%) of extinction due to threats from demographic variation, non-catastrophic environmental variation, and genetic diversity changes over a 100-year time frame. A **viable DPS** is comprised of a sufficient number of viable populations broadly distributed throughout the DPS but sufficiently well-connected through ocean and freshwater dispersal to maintain long-term (1,000-year) persistence and evolutionary potential (McElhany *et al*. 2000).

6.2 DPS RECOVERY OBJECTIVES

To ensure recovery of the SCCCS DPS, specific objectives are necessary to guide recovery efforts and to measure the species' progress towards recovery. Similarly, specific, measurable and objective criteria are also necessary to describe the recovery of the species.

Steelhead in South-Central California occupy a wide array of watersheds, some portions of which are severely degraded with highly modified natural watershed processes and streamflows. Under these degraded habitat conditions, steelhead populations in some watersheds have declined to very low numbers where they continue to persist. In other watersheds, populations have been extirpated, particularly near the southern end of the species' range. Existing threats constrain the species' current distribution to small, disjunct portions of its historic range and preclude it from expressing its full range of life history strategies in response to naturally varying habitat conditions. In order to recover, the species needs substantially higher numbers of returning adults, successful spawning and rearing in freshwater and estuarine environments, and successful emigration of juveniles to the ocean. To achieve these goals, it is essential to preserve and restore the species' existing habitat, as well as restore its access to historically important spawning and rearing habitats throughout the SCCCS Steelhead Recovery Planning Area. Individual watersheds, and in some cases groups of watersheds, must have the capacity to support self-sustaining populations of steelhead in the face of natural variation in environmental conditions such as droughts, floods, wildfires, variable ocean-rearing conditions, and long-term climate changes.

To recover steelhead, the following objectives have been identified:

- ❑ Prevent steelhead extinction by protecting existing populations and their habitats
- ❑ Maintain current distribution of steelhead and restore distribution to some previously occupied areas
- ❑ Increase abundance of steelhead to viable population levels, including the expression of all life history forms and strategies
- ❑ Conserve existing genetic diversity and provide opportunities for interchange of genetic material between and within viable populations
- ❑ Maintain and restore suitable habitat conditions and characteristics to support all life history stages of viable populations
- ❑ Conduct research and monitoring necessary to refine and demonstrate attainment of recovery criteria

6.3 RECOVERY CRITERIA

Prior to determining that a species has "recovered" and can therefore be removed from the List of Threatened and Endangered Species (*i.e.*, delisting) or have its protective status lowered from "endangered" to "threatened" (*i.e.*, down listing), certain criteria for recovery, related to the condition of the species and the status of the threats to the species, must be met. In the case of delisting the SCCCS DPS, biological recovery criteria regarding the abundance, productivity, spatial structure, and diversity of the populations within the DPS and the DPS as a whole, are the measures of recovery. Threats abatement criteria are indicators that key threats to the populations and DPS have been abated or controlled. Both types of recovery criteria will be used by NMFS to assess whether the species is recovering (moving towards meeting the criteria, and down listing may be appropriate) or has recovered (meets the criteria and delisting may be appropriate). Several of the criteria have not been established quantitatively because additional research is needed to define or refine them. For this reason, one of the six recovery objectives focuses on the research and monitoring needed to refine the criteria and directly measure whether steelhead populations are meeting the criteria. Given the species' condition and the severity of the threats to the species, however, it is clear that significant increases in population and DPS health and reductions in critical threat sources are needed.

The Technical Recovery Team (TRT) identified two different approaches to articulating viability criteria: 1) prescriptive criteria, which identify specific targets, generally expressed in quantitative terms, and 2) performance criteria, which identify standards for final performance, expressed in theoretical terms. In light of uncertainties regarding South-Central California Coast steelhead, quantitative prescriptive criteria must be precautionary, while performance criteria require the development of direct estimates of risk, and a quantitative account of uncertainty (Boughton *et al*. 2007b, 2006). Because of the uncertainty of the efficacy of the provisional prescriptive criteria, which are based on limited quantitative population data from South-Central California Coast steelhead, the Recovery Plan uses the performance based criteria until more specific prescriptive criteria are available.

6.3.1 Biological Recovery Criteria

The TRT developed general viability criteria for both individual steelhead populations and for the SCCCS DPS as a whole. These criteria describe characteristics of both individual populations and the DPS that if achieved would indicate that the DPS is viable, and therefore at a low risk of extinction over a specific period of time. [1] The population and DPS criteria are independent of anthropogenic effects in the sense that they must be met regardless of habitat conditions and human-caused threats. The time frame and related recommended criteria address the preservation of the evolutionary potential of the species (*i.e.*, existing genetic, phenotypic, and behavioral diversity) by ensuring that the DPS will persist over a long enough period of time to exhibit future evolutionary changes such as adaptation or diversification in response to environmental changes. Preserving the evolutionary potential of the species is an important component in ensuring the species' long-term viability.

The viability criteria recommended by the TRT provide guidance for judging recovery of steelhead populations and the SCCCS DPS given the current level of knowledge and understanding of the biology and ecology of South-Central California Coast steelhead. All of the recommended criteria carry varying levels of uncertainty depending on the amount of information available on steelhead in the SCCCS Recovery Planning Area. Given the high levels of scientific uncertainty, NMFS proposes to adopt many of the viability criteria as recovery criteria until such time as sufficient scientific information is available to refine the criteria for assessing population and DPS viability; additionally, these criteria will be reviewed when NMFS conducts 5-year status reviews.

[1] For a detailed discussion of the methods used by the TRT to develop the recommended viability criteria, see Boughton *et al*. 2007b.

Table 6-1. Biological Recovery Criteria for the South-Central California Coast Steelhead DPS.

POPULATION-LEVEL CRITERIA – Apply to Populations selected to meet DPS-level criterion D.1.1		
Criterion Type[1]	**Recovery Threshold**	**Notes**
P.1 Mean Annual Run Size	Run size is sufficient to result in an extinction risk of <5% within 100 yrs.	Monitoring run size will provide information on year-to-year fluctuations in the population necessary to determining the appropriate recovery threshold for individual populations. Research on the role of non-anadromous spawning fraction in stabilizing anadromous faction will also enable refinement of the minimum recovery threshold (see Boughton *et al.* [2007b] for discussion of steps in determination of threshold value for each viable population).
P.2 Ocean Conditions	Run Size criterion met during poor ocean conditions	"Poor ocean conditions" determined empirically, or size criterion met for at least 6 decades
P.3 Spawner Density	*Unknown at present*	Research needed
P.4 Anadromous Fraction[2]	N = 100% of Mean Annual Run Size	Requires further research (see note above)
DPS-LEVEL CRITERIA		
Criterion Type	**Recovery Threshold**	
D.1 Biogeographic Diversity	1. Biogeographic Population Group contains minimum number of viable populations: Interior Coast Range (4 populations); Carmel River Basin (1 population); Big Sur Coast (3 populations); San Luis Obispo Terrace (5 populations) (see Boughton *et al*. 2007b for detailed discussion) 2. Viable populations inhabit watersheds with drought refugia 3. Viable populations separated from one another by at least 68 km or as widely dispersed as possible[3]	
D.2 Life-History Diversity	All three life-history types (fluvial-anadromous, lagoon-anadromous, freshwater resident) be exhibited and distributed across each Biogeographic Population Group.	

[1] It is assumed that all spawner criteria represent escapement (*i.e*., unharvested spawning adults) rather than migrating adults that may be captured before having an opportunity spawn.
[2] The anadromous fraction is the percentage of the run size that must exhibit an anadromous life history to be counted toward meeting the mean annual run size criteria. However, the recovery strategy recognizes the potential role of the non-anadromous form of *O. mykiss* and includes recovery actions which would restore habitat occupied by the non-anadromous form, as well as reconnect such habitat with anadromous waters, and thus allow the anadromous and non-anadromous forms to interbreed, and the non- anadromous forms to potentially express an anadromous life history.
[3] This geographic separation is based on the maximum width of recorded historic wildfires; see additional discussion below under Section 6.3.1. 2

The population level criteria apply to certain populations in all of the BPGs.[2] Further research is needed to refine the population criteria in the BPGs; for example, data on the magnitude of natural population fluctuations could reveal that smaller mean run sizes would be sufficient to attain viability in some basins (Williams *et al.* 2011). Additionally, further research could refine the role of each of the BPGs in the recovery of the SCCCS DPS. At a minimum, all BPGs will need to achieve sufficient spatial structure and diversity (*i.e.,* two of the four criteria that define a viable DPS in the wild). Dispersal of steelhead between BPGs may be an important mechanism for maintaining viability of steelhead populations. In addition, preservation of the resident form of the species and habitats that support that life history form may be critical to conserving the genetic diversity of steelhead and providing stock that can re-establish and support the fluvial-anadromous and lagoon-anadromous life history strategies.

6.3.1.1 Discussion of Population-Level Recovery Criteria

Criterion P.1 – Mean Annual Run Size. There is substantial uncertainty regarding the mean annual run size that would represent viable anadromous *O. mykiss* populations throughout the SCCCS DPS. The TRT estimated a mean annual run size for the DPS using a method derived from Lindley's 2003 "random-walk-with-drift" model and quantitative field data for one anadromous *O. mykiss* population and 19 Chinook salmon populations in California's Central Valley for estimating variability in population growth estimates (Lindley 2007, 2003). The resulting criterion of 4,150 spawners per year provides for a 95 percent chance of persistence of the population over 100 years and applies to a generalized situation where there are no quantitative field data on specific local populations (Boughton *et al*. 2007b). Based on the irregular inter-annual patterns of precipitation, anecdotal accounts of highly variable spawning runs and the expectation that larger abundances buffer populations against the increased extinction risks that come with variations in freshwater and marine survival, it can be expected that an average of 4,150 spawners per year, persisting through a cycle of poor ocean conditions would be adequate to safeguard a population (see also discussion below, P.2 – Ocean Conditions). This target may be biologically feasible in larger watersheds within the SCCCS Recovery Planning Area, such as occur within the Interior Coast Range and Carmel River Basin BPGs), but may be too high for relatively small watersheds that may support viable populations at average run sizes well below 4,150 (Boughton *et al*. 2007b). Factors such as reliable access to spawning and rearing areas, a stable freshwater environment, the role of non-anadromous forms of *O. mykiss*, inter-watershed exchanges of anadromous forms of *O. mykiss*, or other factors, may play an important role in refining the population-level recovery criteria. Additionally, data on the magnitude of natural fluctuations in anadromous run sizes in individual watersheds may identify a smaller mean run size that is sufficient for viability in some basins (Williams *et al*. 2011).

The separate watersheds comprising each BPG are treated as individual steelhead populations for the purposes of meeting the run-size criterion. Because of uncertainty regarding the applicability of 4,150 spawners per year to many of the watersheds within the SCCCS Recovery Planning Area and the lack of current data to develop more refined criteria, this Recovery Plan proposes that performance-based run-size criteria be developed for different core populations throughout the DPS. Development of this criterion for each population would utilize a precautionary approach towards determining run sizes that provide for a 95 percent chance of persistence of the population over 100 years. In general, the 4,150 number can be thought of as an approximate upper bound

[2] See Chapter 2 and Table 2-2, Steelhead Biology and Ecology and Chapter 7, Recovery Strategy, for a discussion of these populations.

on what the ultimate viability targets will turn out to be, although there is a chance that development of a performance-based criterion would result in values higher than 4,150 spawners in some watersheds (Boughton *et al*. 2007b). This criterion will be reviewed during NMFSs periodic 5-year review of the Recovery Plan, and potentially during the Southwest Fisheries Science Center's 5-year status review updates for Pacific salmon and steelhead listed under the ESA.

Methods exist for estimating extinction risk through the use of time-series of spawner counts (Dennis *et al*. 2006, Lindley 2007, 2003, Holmes 2001). In general, about 20 years of data are necessary to obtain reasonable confidence in such estimates (Lindley 2007, 2003), though recovery to some level is necessary in some watersheds to have a sufficient number of spawners to refine viability criteria. The development of performance-based criteria requires an understanding of some key risk factors before settling on final viability targets, including: 1) the magnitude of year-to-year fluctuations in spawner abundance; 2) the magnitude and duration of poor ocean survival during poor ocean conditions; and 3) the ability or inability of rainbow trout to contribute progeny to steelhead populations and thereby bolster steelhead populations during periods of otherwise poor survival. These factors and the years of data collection required, highlight the critical need for immediate implementation of population abundance monitoring in key watersheds. However, some populations may currently have run sizes so low that obtaining accurate counts would be difficult because of the small sample size, or surveying may be detrimental because of the associated mortality associated with sampling techniques. Collecting useful data may not be practical until such populations have been recovered to some level, depending on the field methods used for monitoring. Boughton *et al.* (2007b) describe a decision tree for use in refining and establishing a viability criterion for mean population size.

Criterion P.2 – Ocean Conditions. Year-to-year variation in a population's survival and/or reproduction can cause large fluctuations in population growth rate irrespective of population size. Consequently, larger variance causes the number of fish to fluctuate more, increasing the chance of the population fluctuating to zero. A large mean population growth rate lowers this risk by shortening the recovery time from downward fluctuations, and a large mean population size keeps the population further away from zero to begin with (McElhany *et al*. 2000, Lande 1993, Foley 1997, 1994).

Variation in ocean conditions is known to have dramatic impacts on marine survival of Pacific salmonids (Mantua and Hare 2002, Mueter *et al.* 2002, Mantua, *et al.* 1997). A conservative working assumption is that salmonid ocean survival fluctuates widely and is connected with variations in ocean conditions. Periods of poor ocean conditions (as reflected in a significant increase in mean ocean mortality of *O. mykiss*) can last for multiple decades and may result in as much as a five-fold decrease in ocean survival of salmonids (Mantua *et al.* 1997). A population that meets the run-size criterion (P.1) during a period of good ocean survival is likely to decline to risky levels when ocean survival deteriorates for long periods. Therefore, a simple but effective criterion for ocean condition is that the run size criterion must be met during a period of poor ocean survival. This criterion could be met via two distinct strategies:

1. Monitor population size for at least the duration of the longest-period climate "cycle" (about 60 years according to Mantua and Hare [2002], though others question the notion of predictable cycles), or
2. Concurrently monitor population size and ocean survival, so that periods of low ocean survival can be empirically determined.

Data on ocean survival (derived from smolt counts combined with adult counts) should be useful for separating the effects of ocean cycles and watershed conditions on population growth. Investment in both smolt counts and adult counts allows an estimation of ocean survival as distinct from freshwater production and survival (with only adult counts, the vital rates in the two habitats are confounded and cannot be estimated separately). In addition, short-term improvements in run size due to watershed restoration could be distinguished from short-term improvement due to ocean cycles. The Coastal Monitoring Plan being prepared by NMFS and CDFG (Adams *et al.* 2011) provides for a series of "Life Cycle Monitoring Stations" which involve the monitoring of smolts and spawners to allow ocean survival to be estimated for specific watersheds; if fish from other watersheds have similar rates of ocean survival, these results could be extrapolated to address this issue for South-Central California Coast steelhead.

As performance-based run-size criteria are developed for populations within the SCCCS DPS, the methods and data used to develop those values may change the ocean conditions criterion or even preclude the need for such a specific criterion, though not the consideration of marine conditions. As discussed above, the magnitude and duration of poor ocean survival on the extinction risk of the population is a key factor to consider when developing the run-size criterion.

Criterion P.3 – Spawner Density. The distribution of adult or juvenile fish across a watershed can influence the viability of a population. If too thinly distributed, populations can decline as a result of the difficulty in locating mates, but may also reduce their vulnerability to localized catastrophes or environmental variations by occupying a broader range of habitats. If too densely packed within a limited spatial distribution, populations may be more vulnerable to unpredictable environmental events as all the members of the population experience the same conditions. The TRT concluded that a viability criterion related to the density of spawners (at some scale) in a population is warranted, particularly for populations that were historically large, but are unlikely to be recovered to those historic levels due to a risk that a thinly distributed population in such a watershed could meet the criterion for mean size, and yet not be viable. The TRT also found that the viability threshold should be high enough to ensure that fish generally inhabit good-quality habitats that promote the resilience of the population.

A potentially suitable threshold for both these purposes is the density at which intra-specific competition for redd sites becomes observable. For coho salmon (*O. kisutch*) this appears to be on average about 40 spawners per kilometer (one spawning pair per 50 meters of stream length), although individual streams vary considerably around this mean (Bradford *et al*. 2000). However, the TRT could not find data for deriving a corresponding steelhead criterion. The Coastal Monitoring Plan proposes to implement redd-counting for monitoring salmon and steelhead in the northern coastal area of California (Aptos Creek to the Oregon border). This should provide data that will be useful for deriving a specific spawner density criterion; also redd-counts could be made in the SCCCS Recovery Planning Area if it is necessary for developing specific South-Central California criterion, or as means of estimating the anadromous run-size in individual watersheds.

Criterion P.4 – Anadromous Fraction. Anadromous fraction is the mean fraction of reproductive adults that are anadromous (steelhead). Steelhead in the SCCCS Recovery Planning Area co-occur with rainbow trout. Elsewhere, steelhead have been observed to have trout among their progeny, and vice versa (Zimmerman and Reeves 2000). It is not known how often these transitions occur in South-

Central California Coast *O. mykiss*, or what factors bring them about, though clearly individual populations can have more than one life history type (Sogard *et al*. 2012, Hendry *et al.* 2004, 2004a). Depending on the rate of transition, a group of resident and anadromous fish may function as a single population; two completely distinct populations; or something in between.

Interchange between resident and anadromous fish groups would almost certainly lower the extinction risk of both groups, for the same two reasons that dispersal between separate steelhead populations reduces risk: 1) the existence of a "rescue effect" and 2) the possibility of recolonization (Hanski and Gilpin 1997, Foley 1997). The rescue effect would occur at low steelhead abundance, when input from the trout population prevents their complete disappearance. Recolonization occurs when steelhead disappear completely, but are regenerated by the trout population via "recolonization" of the steelhead niche (Hendry *et al.* 2004). These phenomena may have maintained steelhead in the Carmel River system, and possibly Salmon Creek and other South-Central California Coast watersheds, in recent times, since most contemporary steelhead runs appear far too small to be self-sustaining (Boughton *et al*. 2005). Unfortunately, lack of data on life history polymorphism prevents a reasonable estimate for the magnitude of the rescue effect, or for a viability threshold for anadromous fraction. Lacking such data, the precautionary criterion for anadromous fraction must assume that the rescue effect is negligible, and that anadromous fraction must be 100% - that is, when applying the population size criterion discussed previously, 100% of the spawners must be annual anadromous immigrants. Future research on this topic could be used to estimate a viability threshold that is more efficient than the precautionary "100% rule." One of the most useful scientific tools for addressing the interchange question involves otolith microchemistry but, as this technique requires lethal sampling of fish, a scientific collecting permit under section 10(1)(A) of the ESA would be required to authorize mortality using this methodology. Newer, non-lethal genetic techniques are also being explored (D. Pearse, personal communication). However, in populations where anadromous fish are currently quite rare, it will probably be necessary to recover run sizes somewhat before numbers are sufficient for useful ecological research.

6.3.1.2 DPS-Level Recovery Criteria

Criterion D.1 (.1, .2, and .3) – Biogeographic Diversity. This criterion contains three elements that address issues of redundancy and separation between populations and within-watershed conditions to provide for resilience against natural environmental events such as droughts and wildfires. The BPGs are an important component in the recovery of the SCCCS DPS and all BPGs must be restored to viability before the DPS as a whole can be recovered and eventually delisted. The delineation of BPGs was based on suites of basic environmental conditions (*e.g.,* large inland and short coastal stream networks in a range of climatic, terrestrial, and aquatic regimes). The recovery of multiple watersheds and populations in each BPG ensures that there are sufficient populations within the BPG and across the DPS to provide resiliency in the face of environmental fluctuations, and also that a variety of habitat types and conditions are represented (*e.g.,* different stream gradients and estuary size, complexity and function).

Recovery of the SCCCS DPS will require recovery of a sufficient number of viable populations (or sets of interacting trans-watershed populations) within each of the four BPGs to conserve the natural diversity (genetic, phenotypic, and behavioral), spatial distribution, and resiliency of the DPS as a whole.

Criterion D.2 – Life History Diversity. Essential to the recovery and long-term conservation of the SCCCS DPS is the preservation and restoration of all the life history forms and strategies the species has evolved to exploit the diversity and range of habitat conditions that are characteristic of South-Central California. These life history forms include the fluvial-anadromous, lagoon-anadromous, and freshwater life history patterns that can be exhibited by native *O. mykiss* throughout the SCCCS Recovery Planning Area. Achieving this goal will require a number of closely coordinated activities, such as further research into the diverse life history patterns and adaptations of steelhead to a semi-arid and highly dynamic environment including the ecological relationship between non-anadromous and anadromous populations; monitoring of existing populations; and the implementation of the habitat protection and restoration actions would allow focusing on management activities (*e.g.,* removal of physical or hydrologic migration barriers,) to produce the suite of conditions that promote the coexistence of the different life history forms. Research may indicate that not all life history forms may have to be present in all viable populations on a regular basis, but only periodically.

Criteria D.2 – Redundancy and Geographic Separation. Wildfires, droughts, and debris flows pose the greatest natural threats to entire populations. Preservation of the various life history forms of *O. mykiss* requires that not all viable populations in a BPG be extirpated as a result of a natural catastrophic event – this requires both a redundancy of populations and an effective separation of populations. To ensure the survival of a minimum number of viable populations in each BPG, recovered populations should be separated by a sufficient distance to minimize the likelihood that individual wildfires do not encompass the entire suite of watersheds in any BPG. To determine the level of redundancy of viable populations and spatial differentiation between populations necessary to withstand catastrophic wildfires, the expected geographic extent of a thousand-year wildfire was estimated, based on wildfire data from 1910 through 2003. Fire return times were estimated using standards methods, and the number of wildfires that might be expected to affect each BPG was estimated, based on the number of fire-starts per mile in each BPG. From this analysis it was determined that the number of viable populations necessary for each BPG was at least one viable population plus the maximum number of wildfires expected for the BPG, or the number of historic viable populations in the BPG, whichever was less. The minimum geographic distance between individual viable populations, to the maximum extent feasible, should be 42 miles to minimize the likelihood that the minimum number of viable populations would be extirpated by the same thousand-year wildfire event. The preservation of a necessary minimum number of viable populations within a BPG against droughts and debris flows is achieved through the redundancy and geographic separation prescribed to protect against wildfire risk (Boughton *et al.* 2007b).

6.4 THREATS ABATEMENT CRITERIA

The current threat regime that is impeding the ability of anadromous *O. mykiss* to recover must be addressed to meet the population and DPS-level recovery criteria described above. In addition efforts to reduce the threats facing the species must also take into consideration future threats to species recovery such as climate change, ongoing human population growth, and associated land and water developments. Basic threats abatement criteria identified below are used in tracking the success of recovery efforts. The identified existing and future threats fall within the categories of listing factors identified during the species listing process (see Chapters 9 through 12, sub-sections 9.4 – 12.4 for each BPG). Each of these factors must be addressed prior to making a determination that a species has recovered and no longer requires the protections of the ESA.

This Recovery Plan prioritizes recovery actions for the watersheds within the BPGs according to the role of the watershed in recovery of the species, the severity of the threat addressed by the action, and the listing factors addressed by the action. Each recovery action has been given a priority of 1 or 2 as defined in the NMFS Interim Recovery Planning Guidance (see box, below, for definitions) for purposes of providing general guidance in the implementation of individual recovery actions. Further, a priority 3 ranking has been assigned for all other recovery actions which do not meet the criteria used for priority 1 or 2 recovery actions. Each recovery action has also been qualified with an additional descriptor: A) if the action addresses the first listing factor regarding the destruction or curtailment of the species' habitat; or B) if the action addresses one of the other four listing factors (see Chapter 3, Factors Contributing to Decline and Federal Listing, for definition of listing factors). Where the recovery action addresses both types of listing factors, the descriptor is based on the principal listing factor addressed. Priority 1 recovery actions are necessary to prevent the extinction of the SCCCS DPS or an irreversible decline. Priority 2 actions are intended to avoid prejudicing the recovery of the DPS by ensuring that individual populations essential to recovery are not further degraded or lost. Priority 3 actions are the remainder of the full suite of actions necessary to address all the viability criteria identified for the full recovery of the DPS (including recovery of individual populations identified in Table 7-1).

Priority 1: Actions that must be taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2: Actions that must be taken to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction.

NMFS proposes that all watershed threats having a priority 1A or 1B recovery actions in core 1 and 2 populations be abated to a "low" level using the same threats assessment process used to establish threat levels for this plan.

In addition, for watershed threats with recovery actions ranked as either priority 2 or 3, the threat must be abated one level below its current threat ranking based on the ranking system used in the threats assessment (*e.g.*, abate from "high" to "medium," or "medium" to "low").

The application of these threats abatement criteria is illustrated in the example in Table 5-2. High-level (red) threats associated with high-priority (1A and 1B) recovery actions are abated to low (green) levels. However, high-level threats associated with secondary (2A and 2B) priority recovery actions need only be abated one threat level to medium (yellow).

Table 6-2. Example application of basic threats abatement criteria.

Threat	Current Threat Level	Recovery Action Rank	Target Abatement Level for Recovery
Culverts and Road Crossings (Passage Barriers)		1A	
Urban Development		1B	
Wildfires		1B	
Roads		2B	
Groundwater Extraction		2B	

The threats abatement criteria are linked to one or more of the listing factors identified for the SCCCS DPS. Only Listing Factor 2, Over-utilization, does not have specific threats abatement criteria identified, as changes in fishing regulations have already ameliorated the threat posed to the species from angling through the prohibition of angling in most anadromous waters within the SCCCS DPS. These threats abatement criteria are intended to ensure that:

- Viable populations have unimpeded access to previously occupied habitats (Listing Factors 1, 4, and 5).
- Freshwater migration corridors supporting viable populations meet the life history and habitat requirements of steelhead (Listing Factors 1, 3, 4, and 5).
- Watersheds supporting viable populations have habitat conditions and characteristics that support all life history stages (Listing Factors 1, 3, 4, and 5).
- Adequate funding, staffing, and training are provided to state and federal regulatory agencies to ensure the ecosystem and species protections of state and federal requirements are properly implemented and remain in place (Listing Factor 4).
- Standardized monitoring of populations and their habitats in each BPG across the SCCCS DPS evaluates the effectiveness of recovery actions and measures progress towards recovery (Listing Factors 4 and 5).

The threat source ranking for each component watershed is presented in BPG Chapters 9-12; a description of the CAP workbook methodology can be found in Appendix D.

7. Steelhead Recovery Strategy

"The aim of the Federal Species Act (ESA) is to recover species that would otherwise go extinct, and to that end it requires the Federal government to prepare recovery plans. A recovery plan outlines a strategy for lowering extinction risk to an acceptable level. . ."

NOAA Fisheries Technical Recovery Team, Population Characterization for Recovery Planning, 2006

7.0 INTRODUCTION

The biological recovery strategy is the approach undertaken to achieve the individual recovery criteria and objectives and, in turn, the ultimate recovery goal of de-listing the SCCCS DPS. The recovery strategy in this Recovery Plan identifies the core watersheds where recovery of viable populations is necessary to achieve the recovery goal and implement watershed-specific actions (*e.g.*, removal of migration barriers, modification of land-use practices, including agriculture, and protection and restoration of spawning and rearing habitats) that are necessary to reverse the effects of past and ongoing threats to population abundance, growth rate, diversity, and spatial structure of threatened steelhead within the SCCCS Recovery Planning Area. An integral element in this recovery strategy is the development and implementation of a research and monitoring program which will provide the additional information necessary to refine recovery criteria and objectives, as well as assess the effectiveness of recovery actions and the overall success of the recovery program.

Recovery of South-Central California Coast steelhead will require an effective implementation, as well as a scientifically sound biological recovery strategy. The framework for a durable implementation strategy involves two key principles: 1) solutions that focus on fundamental causes for watershed and river degradation, rather than short-term remedies; and 2) solutions that emphasize resilience in the face of an unpredictable future to ensure a sustainable future for both human communities and steelhead (Beechie *et al*. 2010, 1999, Boughton 2010a, Boughton *et al*. 2006, 2007b, Lubchenco 1998).

Implementation of this Recovery Plan will require a shift in societal attitudes, understanding, priorities, and practices. Many of the current land and water use practices that are detrimental to steelhead (particularly water supply and flood control programs) are not sustainable. Modification of these practices is necessary to both continue to meet the needs of the human communities of South-Central California and restore the habitats upon which viable steelhead populations depend. Recovery of steelhead will entail significant investments, but will also provide economic and other ecosystem and societal benefits. Restored, viable salmonid populations provide ongoing direct and indirect economic benefits, including recreational fishing, and other tourist related activities. A comprehensive strategic framework is necessary to serve as a guide to integrate the actions contributing to the larger goal of recovery of the SCCCS DPS. This strategic framework incorporates the concepts of viability at both the population and DPS levels, and the identification of threats and recovery actions for watersheds within each BPG.

7.1 ACHIEVING RECOVERY

For millennia, South-Central California Coast steelhead have successfully dealt with natural environmental fluctuations such as prolonged droughts, flash-floods, uncontrolled wildfires, sea level alternations, periodic massive influxes of sediment to the rivers and streams, and climate changes—natural environmental fluctuations which also currently challenge the human population of South-Central California (Waples *et al.* 2008a, 2008b).

Of the approximately 37 million people currently living in California, approximately 2.8 million live in the South-Central California counties of Santa Cruz, Santa Clara, Monterey, San Benito, and San Luis Obispo. As a result of this large human population, and related development, steelhead populations, along with other indigenous species of both animals and plants, have been severely reduced or extirpated in many coastal watersheds. Despite extensive landscape modifications, steelhead have continued to persist, in one or more of its several life history forms, in portions of many South-Central California watersheds, including some of the most highly urbanized.

Recovery of viable, self-sustaining populations of anadromous South-Central California Coast steelhead will entail the re-integration of these populations into the human configured landscape. Such re-integration will necessarily include an effort to restore habitats and operate the human built system in ways which conserve and better utilize land and water resources in mutually beneficial ways for South-Central California Coast steelhead and the current and projected human population. Uncertain future precipitation and associated wildfires will create challenges in maintaining traditional water supply and flood control structures such as dams, levees, and channelization. Engineered systems which control hydrological systems have often been overvalued, and frequently overwhelmed when their design parameters have been exceeded by natural forces (floods, droughts, wildfires, earthquakes, debris flows, *etc.*). Investments in more sustainable productive capital can at least partially offset these challenges while also providing more suitable habitat conditions for steelhead. Dedicating space for natural stream behavior via setback levees and underground or off-channel water storage are some of the ways to take advantage of the self-organizing capacity of natural systems. Such an approach can offer a more efficient mix of technological and natural capital, and is more likely to be a more economical, self-maintaining strategy (see for example, Mount 1995). Steelhead recovery that is based on watershed and river restoration has the potential to reconcile three conditions: steelhead viability, self-adjustment of stream systems, and the provision of ecological services for people.

Addressing these challenges therefore provides an opportunity to meet a wide variety of public policy objectives to ensure a sustainable future for the threatened South-Central California Coast steelhead, as well as other native riparian species, including a number of other federally listed species such as California red-legged frog, Least Bell's vireo, Arroyo toad, Tidewater goby, and the Western snowy plover that co-occupy the SCCS Recovery Planning Area.

Under present conditions, the viability of individual populations is more likely achievable by focusing recovery efforts on larger watersheds capable of sustaining larger populations, and DPS viability is more likely to be achievable by focusing on the most widely-dispersed set of such core populations capable of maintaining dispersal connectivity between South-Central California coastal watersheds.

Effective implementation of recovery actions will entail: 1) development of cooperative relationships and a shared vision with private land owners, special districts, and local governments with direct control and responsibilities over non-federal land-use practices to maximize recovery opportunities; 2) participation in the land use and water planning and regulatory processes of local, regional, State, and Federal agencies to integrate recovery efforts into the full range of land and water use planning; 3) close cooperation with other state resource agencies such as the California Department of Fish and Game, California Coastal Commission, CalTrans, and the California Department of Parks and Recreation, State Water Resources Control Board, and Regional Water Quality Control Boards to ensure consistency of recovery efforts; and 4) partnering with federal resource agencies, including the U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, U.S. Bureau of Reclamation, U.S. Bureau of Land Management, U.S. Army Corps of Engineers, U.S. Department of Transportation, U.S. Department of Defense, and the U.S. Environmental Protection Agency to utilize agencies' expertise and resources. To support all of these efforts, NMFS and its partners will need to provide technical expertise and public outreach and education regarding the role and value of the species within the larger watershed environment and the compatibility of sustainable development with steelhead recovery.

An implementation schedule describing time frames and estimated costs associated with individual recovery actions has been developed. Estimating time and total cost to recovery is challenging for a variety of reasons. These reasons include the large geographic extent of the SCCCS Recovery Planning Area; the need to refine recovery criteria; the need to complete watershed-specific investigations such as barrier inventories and assessments; the establishment of flow regimes for individual watersheds; and the review and possible modification of a variety of existing land-use and water management plans (including waste discharge requirements) under a variety of local, state, and federal jurisdictions. Additionally, the biological response of many of the recovery actions is uncertain, and achieving full recovery will be a long-term effort likely requiring decades, while addressing new stressors that emerge over time. However, NMFS estimated the costs associated with certain common restoration activities such as those undertaken as part of the California Department of Fish and Game Fisheries Restoration Grants Program. Appendix E, Habitat Restoration Cost References For Steelhead Recovery Planning, contains preliminary estimates for these categories of typical watershed and river restoration actions.

7.2 CORE POPULATIONS

The findings of the TRT (Boughton *et al*. 2007b, 2006) and additional review by NMFS indicate certain watersheds and the steelhead populations within those watersheds constitute the foundation of the recovery of the SCCCS DPS. (See Table 7-1). These watersheds exhibit the physical and hydrological characteristics (*e.g.,* large spatial area, perennial and reliable winter streamflow, stream network extending inland) that are most likely to sustain independently viable populations, and that are critical for ensuring viability of the DPS as a whole. Population viability is more likely achievable by focusing recovery efforts on larger watersheds in each Biogeographic Population Group capable of sustaining larger populations, and DPS viability is more likely achievable by focusing on the most widely-dispersed set of such core populations capable of maintaining dispersal connectivity (see Boughton *et al.* 2007b, 2006).

In Table 7-1 populations are identified as Core 1, Core 2, or Core 3.[1] The Core 1 populations are those populations identified as the highest

[1] The minimum number of recovered populations identified in Table 7.1 is comprised of a combination of Core 1, 2, and 3 populations.

priority for recovery actions based on a variety of factors, including: the intrinsic potential of the population in an unimpaired condition; the role of the population in meeting the spatial and/or redundancy viability criteria; the current condition of the populations; the severity of the threats facing the populations; the potential ecological or genetic diversity the watershed and population could provide to the species; and the capacity of the watershed and population to respond to the critical recovery actions needed to abate those threats. The weight given these factors in designating populations as either Core 1 or Core 2 may vary with individual watersheds. Generally larger watersheds with the highest intrinsic potential, such as the Salinas and Pajaro, have been designated Core 1 populations. However, smaller watersheds such as San Carpoforo or Arroyo de la Cruz Creeks which may contain high quality habitat but are not be subjected to existing or future threats similar to other comparable watersheds may be classified as Core 2 populations. This approach to designating Core Populations is intended to focus recovery efforts on populations which are essential to the recovery of the DPS as well as on watersheds which are have the highest need for recovery action. Core 1 populations form the nucleus of the recovery implementation strategy and must meet the population-level biological recovery criteria set out in Chapter 6, Steelhead Recovery Goals, Objectives & Criteria, Table 6-1. This set of Core 1 populations should be the first focus of an overall recovery effort; however, NMFS also recognizes that the timing of such efforts may be influenced by practical considerations such as the availability of funding, environmental review and permitting requirements, as well as willing and able partners. Core 2 populations also form part of the recovery implementation strategy and contribute to the set of populations necessary to achieve recovery criteria such as minimum numbers of viable populations needed within a BPG. Similar to Core 1 populations, Core 2 populations must meet the biological recovery criteria for populations set out in Table 7-1; while these populations are ranked slightly lower than Core 1 populations based on the factors noted above, NMFS recognizes that the timing of recovery actions on these populations may be influenced by practical considerations such as the availability of funding, environmental review and permitting requirements, and willing and able partners. While recovery actions on Core 3 populations are not assigned as high an implementation priority as Core 1 and 2 populations, these populations could be important in promoting connectivity between populations and genetic diversity across the SCCCS Recovery Planning Area, and therefore are an integral part of the overall biological recovery strategy.

Populations identified in Table 7.1 as Core 1 and 2 populations should meet the four population recovery criteria either as a single population or a group of interacting trans-watershed populations such as those that might exist in the Big Sur Coast and San Luis Obispo Terrace BPGs. Core 3 populations, because of their generally lower intrinsic potential, may function as part of an interacting trans-basin population, but do not meet all the population viability criteria as individual populations. Further research is needed to identify these interacting groups, and the population characteristics which they must exhibit to ensure viability of the DPS.

The TRT recommended that a critical component of the recovery strategy should be to secure the extant inland populations of the species: Interior Coast Range BPG (Pajaro and Salinas Rivers) and the Carmel Basin BPG (Carmel River). The number of original inland populations was small, large in spatial extent, and inhabited challenging environments. Due to low redundancy they are necessarily Core 1 populations in the sense described above. Yet the populations of the Interior Coast Range and Carmel Basin BPGs appear to have produced the largest run sizes in the SCCCS DPS during years of high rainfall and run-off (Boughton *et al.*, 2006, Good *et al.*, 2005). The extant habitat of these populations–especially the anadromous waters of the Pajaro, Arroyo Seco, and Salinas Rivers–merit high priority for immediate protection and restoration so that fish runs do not decline further. The low level of redundancy in these BPGs indicates that ongoing efforts to restore flows and fish passage in the Pajaro and Salinas Rivers are necessary steps to achieving DPS viability, as are efforts to improve flows and fish passage in the Carmel River Basin.

Table 7-1. Core 1, 2, and 3 *O. mykiss* populations within the South-Central California Coast Steelhead Recovery Planning Area. Core 1 populations are highlighted in bold face.

BPG	POPULATION	FOCUS FOR RECOVERY
Interior Coast Range	**Pajaro River watershed (all populations)**	**Core 1**
	Salinas River watershed (all populations)	**Core 1**
Carmel River Basin	**Carmel River**	**Core 1**
Big Sur Coast	**San Jose Creek**	**Core 1**
	Garrapata Creek	Core 2
	Rocky Creek	Core 3
	Bixby Creek	Core 2
	Little Sur River	**Core 1**
	Big Sur River	**Core 1**
	Big Creek	Core 3
	Limekiln Creek	Core 3
	Prewitt Creek	Core 3
	Willow Creek	Core 3
	Salmon Creek	Core 3
San Luis Obispo Terrace	San Carpoforo Creek	Core 2
	Arroyo de la Cruz	Core 2
	Little Pico Creek	Core 2

	Pico Creek	Core 2
	San Simeon Creek	**Core 1**
	Santa Rosa Creek	**Core 1**
	Villa Creek	Core 3
	Cayucos Creek	Core 3
	Toro Creek	Core 3
	Old Creek	Core 3
	Morro Creek	Core 3
	Morro Bay Estuary Chorro Creek Los Osos Creek	Core 2
	San Luis Obispo Creek **Pismo Creek** **Arroyo Grande Creek**	**Core 1** **Core 1** **Core 1**

**Note: If further research determines that individual populations are not viable, restoration of more closely spaced populations may be required to achieve the minimum number of viable populations for this BPG.*

Public and private groups should not be dissuaded from undertaking actions that alleviate threats to the species in Core 3 watersheds (or other steelhead bearing watersheds within the SCCCS DPS such as Big, Villa, Old, or Toro Creeks) because of their potential role in contributing to the overall abundance and diversity of the SCCCS DPS, as well as promoting connectivity between populations. While sufficient information regarding threats and the biology and ecology of the species is available to define an overall recovery strategy, there still remain questions regarding the ecology of the species (*e.g.*, function of certain habitats in the life history of the species, relationship between the anadromous and resident forms, rate of dispersal between watersheds). In light of this uncertainty, a prudent approach is to define a recovery strategy based on the existing information on Core 1 and 2 watersheds while recovery opportunities in Core 3 watersheds continue to be actively pursued as a precaution to reduce the risk of extinction. Therefore, while the Core 1 and 2 watersheds form the foundation for recovery of the SCCCS DPS, recovery actions to alleviate threats should be undertaken in other watersheds to complement this recovery implementation strategy.

7.3 CRITICAL RECOVERY ACTIONS

The recovery actions in this recovery strategy represent the critical elements for alleviating major threats to threatened steelhead in core watersheds. Recovery actions are also specified to address limited knowledge regarding the biology and ecology of the species, as well as its changing status within individual core watersheds.

Critical recovery actions should have the highest priority across the SCCCS DPS and within core watersheds to achieve recovery objectives and criteria. In the tables describing recommended recovery actions for populations within the DPS, these actions have received a priority ranking of

1. Opportunistically, other recovery actions may be implemented prior to these actions, but these actions are widely recognized in the scientific literature as addressing threats which have caused the wide-spread decline of steelhead throughout its natural range. See for, example, Moyle *et al.* (2011, 2008), Johnson *et al.* (2008), Caudill *et al*. (2007), Gustafson *et al.* (2007), Cooke *et al. (*2006), Boughton *et al.* (2005), Brown *et al.* (2005), Doyle *et al. (*2003), Williams and Bisson (2003), Hart *et al.* (2002), Bednarek (2001) Pejchar and Warner (2001).

A wide range of anthropogenic activities have contributed to the high extinction risk of the SCCCS DPS, and the significant of each activity varies considerably between watersheds. In some watersheds such as the Pajaro and Salinas, agricultural activities (and related flood control and water management practices have had a significant impact on steelhead habitat. However, two types of developments and activities generally pose the most widespread threats to the species: 1) impassable barriers, and 2) water storage and withdrawal, including groundwater extraction (see Chapter 4, Current DPS-Level Threats Assessment, Table 4-1). These threats affect basic life history phases of the species (egg-to-smolt survival and smolt-to-spawner survival) throughout the DPS and are key components of the risks posed to the species. Accordingly, this recovery strategy places a high priority on recovery actions that alleviate threats related to impassable barriers and water storage and withdrawal. Closely related to providing access to rearing habitats is the need to ensure that the ecological functions of those habitats are protected and, where impaired, are restored. The critical recovery actions to address these two threats within the Core 1 watersheds are listed below in Table 7-2. Additionally, land-use practices, including agricultural practices in the Pajaro, Salinas and Arroyo Grande watersheds have severely degraded mainstem and estuarine habitats and are identified as high threat sources with corresponding high priority recovery actions in each respective BPG, with corresponding high priority recovery actions in Tables 9-4 through 9-6, and Tables 12-4 through 12-13.

Regarding the effects of impassable anthropogenic barriers on threatened steelhead, the recovery objectives include restoring steelhead distribution to previously occupied areas and restoring genetic diversity and natural interchange within populations and metapopulations. One of the threats abatement criteria identified to meet these objectives is to allow the species sustainable natural access to historical spawning and rearing habitats. Historical habitats are often situated in protected areas such as U.S. National Forests, and exhibit essential characteristics such as suitable substrate, sustained base flows, and refugia such as pool habitats. Besides allowing access to historical habitats, dam modification provides additional ecological benefits that are essential to attaining the recovery objectives. Such benefits include maintaining genetic and ecological diversity, population abundance, growth rates, and buffering against natural and anthropogenic catastrophic disturbances (*e.g.*, wildfires, droughts, debris flows) though restoration of the natural spatial population structure of the SCCCS Recovery Planning Area. Mechanistic solutions to fish passage can be problematic for a variety of reasons, including: the limitations in the operations during high flows when fish are most likely to be migrating; periodic mechanical failures which result in migration delays, or lost migration opportunities; and the expense of personnel and equipment to maintain such operations. See for example, Keefer *et al*. 2008, Caudill *et al.* (2007), Pompeu and Martinez (2007), Oldani and Baigum (2002), Nemeth and Kiefer (1999), Cada *et al.* (1995, 1993), Colt and White (eds.) (1991), Fleming *et al. (*1991), Godinho *et al.* (1991), Lucas and Baras (2001). If barrier modification (including removal or breaching) is determined to be technically or otherwise infeasible, alternative approaches for providing effective passage of steelhead should be implemented. The selected alternatives should provide the full range of ecological benefits associated with barrier removal, breaching, or modification.

Water storage (including reservoirs and managed groundwater basins) and withdrawals (*e.g.,* groundwater pumping, surface-water diversions) can alter the pattern and magnitude of streamflow, with multiple adverse effects to steelhead habitats, including, but not limited to: reducing migratory conditions, degrading spawning and rearing habitat, facilitating the colonization by non-native species, and altering the physical and biotic habitat structure which supports the ecosystem upon which steelhead depend. See for example, Wegner *et al.* (2011, 2010), Marks *et al.* (2010), Poff and Zimmerman (2010), Poff *et al.* (2010, 1997), Annear *et al*. (2009), Instream Flow Council (2009), Olden and Naiman (2009), Lytle and Poff (2004), Bunn and Arthington (2002), Gibbons *et al.* (2001), Hatfield and Bruce (2000), Vadas (2000), Kraft (1992), MacDonald *et al*. (1989).

Recovery of the SCCCS DPS requires the restoration of steelhead distribution to previously occupied areas and the restoration of suitable habitat conditions and characteristics for all life history stages of steelhead. Threats abatement criteria identified to meet these objectives include the restoration and protection of these habitat conditions and characteristics. The essential recovery actions involve either halting the alteration of the pattern and magnitude of streamflow when such an option is available, or implementing measures (*e.g.,* operating criteria) to ensure that a more natural (*i.e.,* timing, frequency, duration, magnitude, and rate-of-change) streamflow is restored. There are many sites within core watersheds where past and present anthropogenic activities continue to alter the pattern and magnitude of streamflow and for which essential recovery actions are identified. In some situations, other actions to address impassable barriers may fully or partially eliminate threats to the pattern and magnitude of streamflow, thereby addressing two principal threats to the species: physical blockage of fish passage, and reduction or elimination of surface flows. The restoration of a more natural flow regime will also contribute toward restoring rearing habitats.

Regarding rearing habitats, rapid juvenile growth is one of the most effective strategies for successfully completing the early life history stages (fertilized egg to smolt) of the anadromous life history form, and ensuring survival during the ocean phase prior to return as spawning adults. Studies have demonstrated high growth rates in some seasonal lagoons, and possibly other freshwater habitats that provide suitable over-summering habitat (Hayes *et al.* 2011b, 2008, Casagrande 2012, 2010, Bond 2006, Smith 1990, Moore 1980). The identification, protection, and where necessary, restoration of such habitats is therefore another critical recovery action.

The high priority recovery actions identified in the Recovery Plan do not diminish the importance of continuing to undertake actions that, while not the focus of this recovery strategy, promote the restoration and maintenance of essential habitat functions for individual populations within the SCCCS Recovery Planning Area. Resource managers and stakeholders should continue to implement recovery actions that: 1) curb unnatural inputs of fine sediments to waterways, 2) promote the establishment and maintenance of streamside vegetation and flood-plain connectivity and function, and 3) encourage the formation and preservation of complex instream habitat. To reduce further degradation of habitat characteristics and condition in watersheds throughout the entire range of the DPS, local stakeholders should continue to undertake those actions that complement the essential recovery actions in Core 1 watersheds.

Finally, conservation hatcheries may contribute to the recovery of the SCCCS DPS in a variety of ways, including: (1) providing a means to preserve local populations faced with immediate extirpation as a result of catastrophic events such as wildfires, toxic spills, dewatering of watercourses, etc.; 2) preserve the remaining genotypic and phenotypic characteristics that promote life history variability though captive broodstock, supplementation, and gene-bank programs to reduce short-term risk of extinction; and 3) reintroduction of populations in restored watersheds.

Issues that should be considered prior to implementing a conservation hatchery program include: 1) conditions under which rescue, reestablishment or supplementation could be used effectively in wild steelhead recovery, 2) methods for rescue, reestablishment or supplementation, and 3) protocols for evaluating the effectiveness of such conservation hatchery functions over time. (See Chapter 8, Summary of DPS-Wide Recovery Actions, Sub-section 8.3 for additional discussion of the role of conservation hatcheries in steelhead recovery.) Conservation hatcheries and species' establishment program should not serve as surrogates for establishing and preserving essential habitat functions for threatened steelhead particularly where anthropogenic activities have created threats that constrain or eliminate habitat functions and values.

Table 7-2. Critical recovery actions for Core 1 *O. mykiss* populations within the South-Central California Coast Steelhead DPS.

BPG	POPULATION	CRITICAL RECOVERY ACTIONS
Interior Coast Range	Pajaro River	Implement operating criteria to ensure the pattern and magnitude[1] of groundwater extractions and water releases from Uvas Dam and Pacheco Dam to provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Physically modify[2] fish passage impediments, including Uvas Dam and Pacheco Dam to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Manage instream mining to minimize impacts to migration, spawning and rearing habitat.
	Salinas River	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases from the Salinas, Nacimiento, and San Antonio Dams to provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Physically modify fish passage impediments, including Salinas Dam and downstream passage impediments to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.
	San Antonio River	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions from San Antonio Dam to provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Physically modify fish passage impediments, including San Antonio Dam to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.
	Nacimiento River	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, from Nacimiento Dam to provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Physically modify fish passage impediments, including Nacimiento Dam to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.
Carmel River Basin	Carmel River	Implement alternative off channel water supply projects to eliminate or decease water extractions from the channel (including subsurface extractions), and implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, from San Clemente and Los Padres Dams to provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove fish passage impediments, including San Clemente and Los Padres Dams to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
Big Sur Coast	San Jose Creek	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.

	Little Sur River	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments, including dams and diversions, to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Manage roads to minimize sedimentation of spawning and rearing habitat. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
	Big Sur River	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
San Luis Obispo Terrace	San Simeon Creek	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage to allow steelhead impediments natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Manage instream mining to minimize impacts to migration, spawning and rearing habitat. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
	Santa Rosa Creek	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
	San Luis Obispo Creek	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments, including dams and diversions, to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
	Pismo Creek	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments, including dams and diversions, to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.
	Arroyo Grande Creek	Implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases, including bypass flows around diversions, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or modify instream fish passage impediments, including dams and diversions, to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream

		to the estuary and ocean. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats.

[1] "Pattern and magnitude" refers to timing, duration, frequency, magnitude, and rate-of-change.
[2] Physically modifying a dam may incidentally restore the natural or pre-dam pattern and magnitude of streamflow.

7.4 RESTORING STEELHEAD ACCESS TO HISTORICAL HABITATS THAT ARE CURRENTLY INACCESSIBLE AND UNOCCUPIED BY THE SPECIES

Steelhead are a highly migratory species, allowing them to move between marine and freshwater habitats to gain access to spawning and rearing habitats, and productive marine foraging areas (Quinn 2005). Much of this movement within freshwater habitats has been restricted by a variety of barriers to migration (California Department of Fish and Game 2011b; see Figures 7-1 and 7-2). Restoring steelhead access to historical spawning and rearing habitats (*i.e.*, areas upstream of introduced barriers that are currently unoccupied by anadromous *O. mykiss*) is an essential action for recovering threatened steelhead.

The following discussion summarizes the ecological rationale for this specific recovery action. Central to the rationale is the historical steelhead population structure and distribution, and the necessity of historical habitats for reducing extinction risk and increasing population growth rate (*i.e.*, the productivity of a population).

Unoccupied areas are essential for conserving threatened steelhead (Boughton *et al.* 2007b, 2006). The characteristics and condition of historical habitats must remain functional to support their intended conservation role for the species. Implementing these essential recovery actions will require removing or physically modifying anthropogenic barriers, which NMFS expects will generate questions regarding the feasibility of undertaking such activities. In response to such questions, we summarize information here that indicates barrier removal and physical modification would be feasible and successful (*i.e.*, would increase population growth rates).

Native steelhead historically existed in areas that are currently inaccessible.

Knowing where the species existed prior to the construction of migration barriers is essential for identifying the watersheds where restoring access to historical spawning and rearing habitats would be appropriate.

A review of the scientific and historical literature on the distribution of steelhead within the SCCCS Recovery Planning Area indicates that the species was widespread up until the mid-20th century. See for example, Becker *et al*. (2008), Boughton *et al.* (2007c), Boughton *et al.* (2005), Boughton and Fish (2003), Swift *et al.* (1993), Nehlsen, *et al.* (1991), Wells *et al.* (1975), Boydstun (1973), Fry (1973), Shapovalov *et al*. (1981), Combs (1972), Fry (1938, 1973), Kreider (1948), Hubbs (1946), Jordan and Gilbert (1881), and Jordan and Evermann (1896, 1923).

Investigation of the genetic structure of juvenile *O. mykiss* collected from freshwater habitats, including instream areas upstream of migration barriers within Core 1 populations, confirm that the present-day populations are dominated by ancestry of indigenous South-Central coastal steelhead (Clemento *et al.* 2009, Pearse and Garza 2008, Girman and Garza 2006, Nielsen *et al.*2001, 1997, 1994c). Populations of *O. mykiss* that exist upstream of introduced barriers are largely or entirely descended from relic *O. mykiss* populations ascending the watersheds historically. These findings as well as the intrinsic potential of certain watershed-specific populations for recovering this species support the high priority of restoring steelhead access to upstream spawning and rearing areas, especially within Core 1 populations (Boughton *et al*. 2007b, 2006, Boughton and Goslin 2006).

Restoring species access to historical habitats will reduce extinction risk and increase population growth rate.

Artificial migration barriers are a major cause of habitat loss and fragmentation within the

SCCCS Recovery Area, and have resulted in a high risk of species' extinction (Hunt & Associates 2008a, Boughton *et al.* 2005). Restoring steelhead access to historical habitats is necessary to reduce extinction risk to a level that is considered negligible over a 100-year period. See Figures 7-2 and 7-3.

Population extinction risk is related to the numerical abundance of the population, which itself is related to the extent that the species is distributed over space (*i.e.,* population spatial structure) and the degree to which diversity of life history traits is not restricted. Small populations with limited spatial structure are particularly susceptible to extinction, owing to their increased susceptibility to demographic and environmental fluctuations, and loss of genetic variability. Steelhead exhibit a suite of traits, such as anadromy, timing of spawning, emigration, and immigration, fecundity, age-at-maturity, and other behavioral, physiological and genetic characteristics. The variable of these characteristics reflect their adaptation to their variable freshwater and marine environments. The more diverse these traits (or the more these traits are not restricted), the more likely the species is to survive a spatially and temporally fluctuating environment (Boughton *et al.* 2006, McElhany *et al*. 2009, 2000). Overall, the greater a species' geographic distribution and the less constrained the diversity of life history traits, the more likely the species' ability to withstand stochastic environmental variation and achieve and maintain a rate of population growth that is viable (*i.e.,* reduces the extinction risk to a negligible level).

Throughout the SCCCS Recovery Planning Area, anthropogenic activities have severely truncated population spatial structure through the construction of structures that have inhibited or blocked completely fish migration, and as a result eliminated certain life history traits, particularly the anadromous life history form which has been classified as threatened in the SCCCS Recovery Planning Area. See for example, California Department of Fish and Game (2011b), Boughton *et al.* (2005).

While the species was historically widespread, artificial migration barriers have resulted in populations that are sparsely distributed over space and significantly reduced in both the size and number of populations. These barriers prevent steelhead from migrating within rivers and to and from the ocean, a critical part of the species' life cycle. Barriers preclude steelhead from accessing upstream spawning habitats and interacting with the freshwater form of *O. mykiss*, which can contribute to the diversity of the O. mykiss complex, and better withstand stochastic environmental fluctuations.

Because the limited and degraded habitat conditions within the SCCCS DPS has reduced the abundance, diversity, spatial structure, and growth rate of the affected steelhead populations, the areas currently occupied by the species are inadequate for recovery of the species (Boughton *et al*. 2007b, 2005, Gustafson *et al*. 2007, Boughton *et al*. 2005, Good *et al.* 2005).

An effective recovery strategy for increasing population growth rate and reducing extinction risk to a level that is considered negligible over a 100-year period is to re-establish access to habitats historically use by steelhead and restoring ecological traits that are necessary for the species to express its variable and complex life cycle.

Habitats within inaccessible areas are capable of supporting essential life history functions.

The available information describing the current abundance and distribution of *O. mykiss* indicates that habitats historically accessible to steelhead possess the capacity to support production of steelhead. Investigators commonly use information on the abundance or distribution of stream fish as a means to infer the existence of suitable habitat for a species (Boughton and Goslin 2006, Thomas R. Payne and Associates 2004, 2001, 2000). Fishery investigations performed in selected coastal watersheds by state and federal resources agencies, as well a variety of academic and private investigators, report on the distribution of *O. mykiss* habitat, including in areas upstream of artificial barriers within Core 1 populations. These investigations indicate that the existing habitats are suitable for spawning and rearing of *O. mykiss*, as evident by the finding of young-of-the-year and older juvenile trout. Inferring the existence of suitable habitat for the anadromous form of *O. mykiss* based on the presence of the resident form is reasonable and ecologically appropriate given that the resident and anadromous forms represent different life history strategies of the same species. See for example, Titus *et al. (*2010), Boughton and Goslin (2006), California Department of Fish and Game (2006), Thomas R. Payne and Associates (2005).

With regard to the amount of suitable steelhead habitat, the findings of fishery investigations and habitat evaluations indicate the existence of hundreds of miles of stream network across the Core 1 populations. Numerous streams within Core 1 watersheds provide an extensive habitat that is capable of supporting spawning and rearing large numbers of steelhead when water and other environmental conditions are suitable. See for example, Casagrande 2011, Smith 2007a, Close 2004, Denise Duffy & Associates 2003, D. W. Alley & Associates 2008, 2007, 2006a, 2006b, 2001, 1997, 1996, Nelson *et al*. 2006a, 2006b, 2005a, 2005b, Thomas R. Payne and Associates 2004, 2001, Hagar 2001, Londquist 2001, Alley Associates 1998, Dettman and Kelley 1986

Restoring steelhead migration to historical habitats upstream of anthropogenic barriers is expected to be feasible and successful.

While implementing the barrier recovery actions will not be without logistical and technical challenges, NMFS' experience as well as the available information regarding fish passage at man-made structures indicate implementation is feasible and would be successful with adequately designed and operated facilities or programs.

Regarding the technical feasibility, physically modifying or partially or completely removing dams, diversions, grade-control structures, and highway crossings for the purpose of restoring upstream migration of steelhead, situations vary significantly and projects must be evaluated on a case-by-case basis, usually with extensive site-specific investigations. However, over the last decade, the removal and modification of dams and other instream structures has accelerated, and the experienced gained in this effort has led to a growing understanding of the technical, logistical and regulatory issues of these types of projects to restore habitat characteristics and conditions for populations of stream fish. See for example, Service (2011), Downs *et al.* (2009), Johnson *et al.* (2008), Keefer *et al.* (2008), Grant (2005), Doyle *et al.* (2003), Graf (2003, 2002, 1999), Kondolf *et al*. (2003, 1997), Williams and Bisson (2003), American Rivers (2002), Aspen Institute (2002), Hart *et al.* (2002), Pizzuto (2002), Bednarek (2001), Dambacher *et al*. (2001), Pejchar and Warner (2001), Stanley and Doyle *(*2003), Smith *et al*. (2000).

Regionally, NMFS has collaborated with project proponents on a variety of fish-passage projects that have involved removal or modification of a highway structure, diversion, or dam for the purpose of either improving or restoring migration of steelhead to historical spawning and rearing habitats. NMFS is currently collaborating with stakeholders on the restoration of river ecosystems including the removal of dams on the Carmel and Ventura Rivers in California, and on the Elwha River in Washington, which require the removal of these dams to allow anadromous salmonids natural access to historical spawning and rearing habitats (Capelli 2007, Wunderlich *et al*. 1994).

With regard to the expected success from restoring steelhead migration to historical habitats, the available information indicates that restoring steelhead access to historical spawning and rearing habitats would increase population growth rate and abundance. Making barriers passable for migratory species effectively increases breeding and living space for the species. Given the extensive amount spawning and rearing habitat upstream of the barriers within Core 1 populations it can be anticipated that steelhead productivity will increase substantially when access to this habitat is restored.

Significantly, historical habitats currently serves as a refuge freshwater habitat that likely contributes to the conservation of the anadromous form of the species (Boughton *et al.* 2006). *O. mykiss* found above artificial barriers exhibit ancestral native steelhead genetics (Clemento *et al.* 2009). These fish possess the ability to transform into smolts and migrate to the ocean (Thrower *et al*. 2004a, 2004b, 2004c). Even today, large adult *O. mykiss* leave the freshwater lakes that have formed behind dams and undertake steelhead-like migrations during the wet season and spawn in upstream tributaries (M. Capelli, personal communication).

Besides increasing population growth rate, restoring steelhead access to historical spawning and rearing habitats within Core 1 populations is expected to produce four additional benefits for buffering the species against extirpation (these benefits further underscore the necessity and value of unoccupied areas for conserving threatened steelhead).

First, there would be an increase in population spatial structure. The spatial structure of a population is important because it can affect evolutionary processes and therefore alter the ability of a population to adapt to spatial or temporal changes in the species' environment. Populations that are thinly distributed over space are susceptible to experiencing poor population growth rate and loss of genetic diversity, and are more likely to be adversely effected by widely fluctuating environmental conditions.

Second, ecological interactions between the resident and anadromous form of *O. mykiss* would be restored, thereby contributing to the viability of the anadromous form. The two life history forms can be sympatric and genetically similar (McPhee *et al*. 2007, Narum *et al*. 2004, Docker and Heath 2003) and the resident form can produce anadromous progeny and vice versa (McPhee *et al*. 2007, Zimmerman and Reeves 2000). These findings underscore the survival advantage of the resident form to the anadromous form of *O. mykiss*, particularly under certain environmental conditions. For example, extended periods of no or low rainfall can limit migratory conditions and preclude steelhead from reaching freshwater spawning areas. Linked poor ocean conditions can inhibit the growth and maturation of the anadromous form while not adversely affecting the freshwater form of O. mykiss (Mantua 2010, 2002, 1997). During such periods, resident *O. mykiss* may be the only life history form of *O. mykiss* spawning and producing progeny - with the innate ability to resume anadromy - that favors future persistence of the anadromous form. Conversely, the anadromous form can re-colonize watersheds following periods of extended drought and temporary extirpation of the resident form of *O. mykiss*.

Third, restoring steelhead access to historical spawning and rearing habitats upstream of artificial migration barriers would promote ecological traits (phenotypic and genotypic) that must be represented and maintained to promote long-term viability of the species (Boughton *et al*. 2007b). Some of these traits involve the capability to migrate long distances and tolerate elevated water temperatures. Many coastal watersheds supporting Core 1 populations extend considerably inland, which requires that steelhead have the physical ability to migrate long distances to access spawning areas in upper reaches of these watersheds. The ability to migrate long distance promotes population diversity. Because these same populations extend into areas that are dry and warm, populations are exposed to environmental conditions that promote formation of specific adaptations such as the ability to tolerate hot and dry climates. The ability to migrate long distances and occupy and use diverse habitats promotes genetic and ecological diversity by subjecting the species to a wide variety of selective pressures.

Fourth, the expected increase in population growth rate has the potential to increase abundance in neighboring Core 2 and Core 3 populations. When restored to an "unimpaired" condition, Core 1 populations are expected contribute steelhead to adjacent watersheds through natural dispersal. Contributing to the maintenance of populations in adjacent watersheds effectively increases the total numbers of individuals in the SCCCS DPS. Given the risk of extinction that small populations face (Pimm *et al*. 1988, Primack 2004, Wilson 1971), a larger number of individuals decrease the risk of extinction.

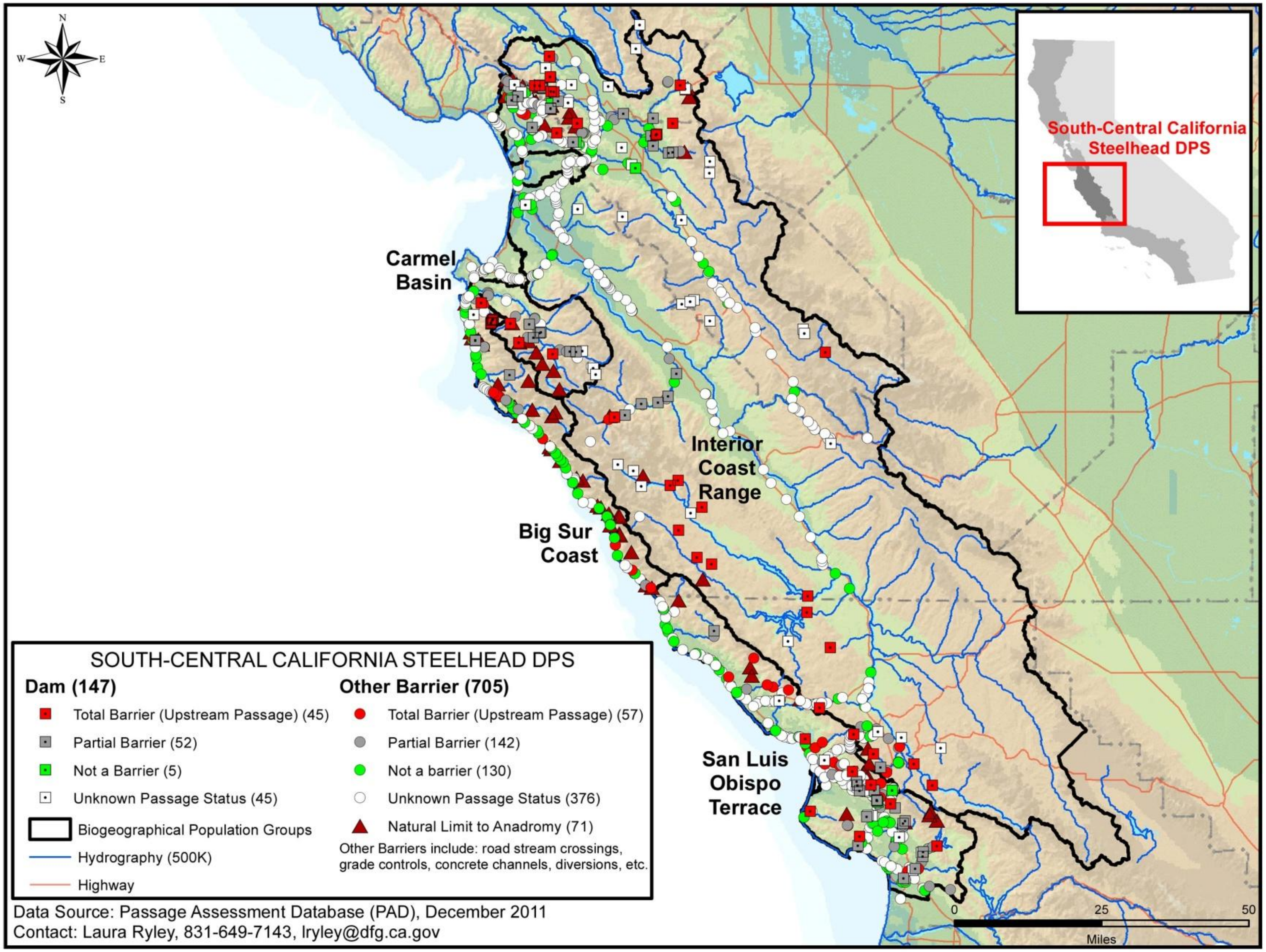


Figure 7-1. South-Central California Coast Steelhead DPS Known and Potential Fish Passage Barriers.

7.5 RECOVERY STRATEGIES TO ADDRESS CLIMATE CHANGE AND MARINE ENVIRONMENT VARIABILITY

Climate change and the conditions in the marine environment are driven by processes on a global scale and are generally not amenable to direct management on a regional scale such as the SCCCS Recovery Planning Area (Riggs, 2004, 2002). However, recognizing the potential challenges posed by climate change and related conditions within the marine environment is useful in designing a recovery strategy which has the greatest likelihood of achieving recovery of the species. Species can respond to climate change in three basic ways: 1) evolve or rely on existing adaptations; 2) colonize new locations with suitable habitat; and 3) go extinct. Given the uncertainties regarding climate change scenarios and localized responses, the most precautionary recovery strategy is to maximize the pathways for adapting and/or colonizing habitats. The two essential components that address the potential adverse effects of climate change on the species freshwater and marine environment are (Boughton 2010a, 2007a):

1. Protect habitat by ameliorating existing and future anthropogenic threats and improve current habitat conditions.

This component encompasses such restoration activities as removing passage barriers to prime upstream spawning and rearing habitats; restoring flow regimes that are essential for both adult and juvenile instream migration; regulating flood control and other instream activities that disrupt river and riparian habitats; and restoring and managing estuarine habitats to ensure that they provide acclimation and rearing opportunities.

2. Establish broadly distributed viable populations within each Biogeographic Population Group by protecting and restoring functional habitat conditions, and controlling and abating existing and future threats.

The over-arching recovery strategy of protecting and restoring multiple populations across the diverse landscape characteristic of the SCCCS Recovery Planning Area is intended to allow the species to continue to evolve adaptations to cope with a dynamic and challenging environment.

Within this basic framework, the Recovery Plan identified specific recovery actions within watersheds of each of the five Biogeographic Population Groups which are intended to address and ameliorate specific adverse effects from projected climate change and related oceanic conditions; most significantly, these include impacts on stream flows, wildfires, riparian habitats, and estuaries. The population and DPS-level biological recovery criteria are intended to establish a threshold for recovery that will ensure the species will persist over an extended period of time, and through long-term (decadal) marine cycles. South-Central California Coast steelhead have evolved a wide variety of life history patterns to exploit the diversity and range of habitat and habitat conditions characteristics of the vegetation, geology, hydrology, and climate characteristics across the SCCCS Recovery Planning Area. The preservation of such life history patterns is essential to the recovery and long-term conservation of the species.

7.6 CRITICAL RESEARCH NEEDS FOR RECOVERY

Successful implementation of the recovery plan and measurement of the species' progress towards recovery requires two critical elements of scientific research and monitoring: 1) population abundance monitoring (including rearing juveniles, smolts, and returning adults) within core watersheds and 2) other research efforts in core watersheds to develop more refined biological recovery criteria. As discussed in Chapter 6, Steelhead Recovery Goals, Objectives & Criteria, and Chapter 13, South-Central California Coast Steelhead Research, Monitoring and Adaptive Management, long-term and consistent population abundance monitoring is necessary to further refine biological recovery criteria such as the mean annual run size. This monitoring can also measure the effectiveness of restoration and recovery efforts within particular watersheds and shed light on the influence of freshwater and marine environmental factors on the long term survival and recovery of steelhead in South-Central California.

Research efforts should be focused on developing a better understanding of the following topics: 1) reliability of migration corridors; 2) productivity of freshwater tributary nursery areas; 3) evaluation of role of seasonal lagoons, particularly for juvenile rearing; 4) productivity of freshwater mainstem habitats; 5) roles of intermittent freshwater habitats for both spawning and rearing; 6) spawner density as an indicator of individual population viability; 7) relationship between anadromous (steelhead) and non-anadromous (resident) forms and population structure and viability; and, 8) rates of dispersal between individual populations.

With respect to topics 2 through 4, the aim is to identify, protect, and, where necessary, restore those habitats which specifically facilitate the anadromous life history form by, among other things, producing a high number of fast-growing and large smolts, and avoid inadvertently promoting only the freshwater life history form of *O. mykiss*. In addition to these biological research topics, research into basic habitat dynamics should be conducted to provide additional direction in habitat protection and restoration. Such research includes the effects of the wildland fire regime and climate change effects on freshwater habitat; environmental factors that affect freshwater temperatures; and factors producing freshwater refugia that sustain *O. mykiss* during seasonal or prolonged droughts. See Chapter 13, South-Central California Coast Steelhead Research and Monitoring and Adaptive Management, for a further discussion.

8. Summary of DPS-Wide Recovery Actions

"The basic recovery strategy . . . mimics the strategy that the species exhibits in its natural distribution among the various watersheds in their unaltered state, and provides the most effective strategy . . . to ensure the long-term viability of individual populations, and the listed species as a whole."

South-Central California Coast Steelhead Recovery Planning Area: Recovery Actions
Hunt & Associates 2008

8.0 INTRODUCTION

The SCCCS Recovery Planning Area is characterized by severe to very severe degradation of habitat conditions along the lower mainstem river channels where development is concentrated, while the upper mainstem and tributaries, often situated within the Los Padres National Forest, retain relatively high habitat values for anadromous *O. mykiss*. Dams, surface water diversions, and groundwater extractions have frequently disconnected the upper and lower portions of watersheds, as well as degraded instream and riparian habitats in both areas. Because the mainstem river channels are the conduits that connect upstream spawning and rearing habitats with the ocean, recovery actions in watersheds impaired in this manner focus on reducing the severity of anthropogenic impacts along the mainstems. Encroachment into riparian areas and flood control activities that degrade instream habitat or restrict fish passage should be avoided or minimized in order to promote connectivity between the ocean and upstream spawning and rearing habitats. Additionally, degraded estuarine conditions stemming from filling, artificial sandbar manipulation, and both point and non-point waste discharges are addressed by specific recovery actions for the SCCCS Recovery Planning Area.

This chapter describes DPS-wide recovery actions. DPS-wide recovery actions are recommendations that are designed to address widespread and often multiple threat sources across the SCCCS Recovery Planning Area such as the inadequate implementation and enforcement of local, state, and federal regulations. Subsequent chapters describe BPG-specific conditions, the results of threats assessments for component watersheds, and the recommended recovery actions for each component watershed.

An array of natural and anthropogenic conditions has reduced the population size and historical distribution of South-Central California Coast steelhead. Many of these causes of decline are systemic and persistent, crossing numerous environmental and political boundaries. The sources and reasons for decline are identified in Federal Register Notices and this Recovery Plan. Effectively addressing these causes of decline involves multiple challenges and opportunities that include: 1) development of new and effective implementation of current laws, policies, and regulations at the local, state, and federal levels; 2) securing adequate funding for implementation of recovery actions; 3) developing strategic partnerships at the local, state, and federal levels; (4) assuring effective prioritization of restoration, threats abatement, and monitoring actions; and (5) conducting education and outreach. (See Appendix E, Recovery Action Cost Estimates for Steelhead Recovery Planning, for a list of federal, state, and local funding sources available to support the implementation of recovery actions.)

8.1 DPS-WIDE RECOVERY ACTIONS

DPS-wide recovery actions addressing widespread threat sources include the following:

- Collaboration between water facility owners and operators, and local, state and federal agencies to ensure releases from water storage and diversion facilities (see Table 8-2 and the BPG recovery action tables) will maintain surface flows necessary to support all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation, and rearing habitat.
- Collaboration between riparian landowners and the State Water Resources Control Board to minimize withdrawals from riparian wells and develop rain/runoff collection facilities to serve out-of-stream water demands, and ensure adequate bypass flows necessary to support all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation, and rearing habitat.
- Physically modify passage barriers (including the dams and diversion facilities listed in Table 8-2 and the BPG recovery action tables) to allow natural rates of migration to upstream spawning and rearing habitats.
- Finalize and implement the California Coastal Salmonid Population Monitoring Plan. Implementation of the California Coastal Monitoring Plan is essential for evaluating the long-term viability of South-Central California Coast steelhead as well as other species of listed salmonids in California.
- Prioritize restoration funds, notably the Pacific Coast Salmon Restoration Fund and California's Fisheries Restoration Grant Program (FRGP), in Core 1 and 2 watersheds.
- Implement restoration projects to provide access to historic steelhead spawning and rearing habitats and increase egg-to-smolt life stage survival.
  - Support agency actions to secure funding for, and engage in, full enforcement of relevant laws, codes, regulations and ordinances protective of steelhead and their habitats.
  - Collaboration between CalTrans, counties, and others with oversight on road practices to reduce or remove transportation related barriers to upstream and downstream passage (including railroad bridges, abutments, and similar structures identified in BPG recovery action tables).
  - Collaboration between U.S. Forest Service and the California Department of Forestry to ensure that fire-suppression and post-fire suppression activities are conducted in a manner which is protective of steelhead and steelhead habitats.
  - Enhance protection of natural in-channel and riparian habitats, including appropriate management of flood-control activities (both routine maintenance and emergency measures), off-road vehicle use, and in-river sand and gravel mining practices commensurate with habitat and life history requirements of steelhead.
  - Reduce water pollutants such as fine sediments, pesticides, herbicides, and other non-point and point source waste discharges (Total Maximum Daily Load) commensurate with habitat and life history requirements of steelhead. This

should be accomplished through public education, watershed–management and management of public and private facilities releasing waste discharges (See Appendix F, Pesticide Best Management Practices).

- Close remaining areas currently open to angling below impassible barriers in all anadromous waters; in non-anadromous waters (*i.e.*, those currently inaccessible to upstream-migrating steelhead because of anthropologic barriers) or complete a Fishery Management and Evaluation Plan for anadromous waters of the SCCCS DPS; assess impacts of angling on native *O. mykiss* above barriers which are currently impassable to upstream-migrating steelhead.
- Eliminate the stocking of hatchery-reared fish in anadromous waters; in waters where stocked fish may reach anadromous waters ensure that such fish are adequately controlled to prevent the introduction of hatchery-reared fish into anadromous waters.
- Convene a committee of agency personnel and scientists (*e.g.*, the DFG, NMFS' Fisheries Science Centers, U.S. Fish and Wildlife Service) for the purpose of establishing a pilot conservation hatchery program for threatened steelhead consistent with the principles and purposes outlined in section 8.3 below.
- Assess the condition of and restore estuarine habitats through the control of fill, waste discharges, and establishment of buffers commensurate with the habitat and life history requirements of steelhead.
- Manage the artificial breaching and/or draining of coastal estuaries consistent with habitat and life history requirements of steelhead (including rearing juveniles and migrating adults).
- Evaluate and mitigate the effects of transportation corridors and facilities on estuarine fluvial processes. When vehicular, railroad, or utility crossings over estuaries are replaced, upgraded, retrofitted, or enlarged, reduce or eliminate existing approach-fill and maximize the clear spanning of upstream active channel(s), floodways, and floodplains to accommodate natural river and estuarine fluvial processes.
- Review California Department of Forestry's rules for timber harvest activities south of San Francisco, and modify, if necessary, to ensure that such activities do not adversely affect steelhead migration, spawning and rearing.
- Conduct research on the relationship between resident and anadromous forms of *O. mykiss*, and related population dynamics (*e.g.*, distribution, abundance, residualization, dispersal, and recolonization rates.
- Provide for the permanent curation of deceased *O. mykiss* specimens for the purpose of making available specimens for examination and study by present and future scientific researchers.
- Survey and monitor the distribution and abundance of non-native species of plants and animals that degrade natural habitats or compete with native species within watersheds identified as core populations. Initiate efforts to eliminate, reduce, or control non-native and/or invasive species.
- Amend Army Corps Section 404 Clean Water Act (CWA) exemptions for farming, logging, and ranching activities; terminate Section 404(f) exemptions for discharges of dredged or fill material into U.S. waters (channelization) associated with agriculture, logging, ranching and farming; incorporate explicit steelhead

habitat requirements into CWA Section 401 water certification permits and 303(d) listings to protect all life-history stages, including adult and juvenile steelhead migration, spawning, incubation and rearing.

- Incorporate appropriate elements of the South-Central California Steelhead Recovery Plan into the state-sponsored and funded Integrated Regional Watershed Management Plans (IRWMP) being developed for major watersheds of South-Central California under the Integrated Regional Watershed Management Planning Act of 2002.
- Coordinate with the California Department of Fish and Game and the State Water Resources Control Board to ensure the effective implementation of California Fish and Game Code Sections 5935-5937 regarding the provision of fishways and fish flows associated with dams and diversions.
- Extend the California Water Code Section 1294.4 dealing with instream flows to protect instream beneficial uses, including native fishes, to South-Central California Coast watersheds.

8.2 RECOVERY ACTION NARRATIVES

Table 8-1 contains a narrative description of the types of recovery actions which are intended to address systemic threats identified throughout the watersheds within the SCCCS Recovery Planning Area, based upon the DPS threats assessments conducted by NMFS technical consultants, and the intrinsic potential analysis conducted by NMFS TRT. These narratives describe the general nature and biological objectives of the recovery actions which must be implemented in order to achieve the goals, objectives, and meet the viability criteria, that are identified in Chapter 6, Steelhead Goals, Objectives and Criteria, and implement the recovery strategy in outlined in Chapter 7, Steelhead Recovery Strategy.

The Recovery Plan applies these recovery actions to individual watersheds (and in some cases individual facilities) to the extent information is available, in the recovery action tables for each watershed within the BPG Chapters 9 through 13. However, the general language of recovery actions does not dictate a specific means of achieving the biological objectives of the recovery actions (*e.g*., assure effective fish passage, provide ecological effective flow regime, control nonpoint sources of pollution or non-native species, or restore estuarine functions).

While SCCCS DPS threats assessments were identified at a watershed scale, and do not necessarily identify all specific threat sources in individual watersheds, many of the recovery actions call for more detailed threats assessment and analysis (*e.g.*, fish passage barrier inventories and assessments in watersheds where complete systematic barrier inventories are not available). Some recovery actions may involve the review and modification of local general plans and local coastal plans (along with other regional plans) to address activities regulated under the plans and programs to restore and protect steelhead habitats, and a means of implementing recovery actions at the local and regional level.

Implementation of the recovery actions will require site-specific investigations to determine on a case-by-case basis the appropriate design details, and where appropriate, operational criteria for individual facilities. For example, the specific means of providing fish passage at a particular site or facility (*e.g*., culvert, diversion, or dam), or the flow regime necessary to provide passage or sustain ecological effective rearing habitats, must be based on site-specific technical investigations such as those undertaken for recovery actions that have already been or are in the process of being implemented. Similarly, the recovery actions dealing with the control or elimination of non-native invasive species will require a watershed-wide, and in some cases, a reach-specific inventory and assessment of the species before the appropriate control measures can be identified and implemented.

Finally, recovery actions that involve development as defined by either the National Environmental Policy Act (NEPA) or the California Environmental Quality (CEQA) will require environmental review that could further refine individual recovery projects alternatives, identify mitigation measures, and/ or require project monitoring, as part of the project permitting process.

Table 8-1. Recovery Actions Glossary.

Threat Source	Recovery Action	Detailed Description
Agricultural Development	Develop, adopt, and implement agricultural land-use planning policies and standards	Develop, adopt, and implement land-use planning policies and development standards that restrict further agricultural encroachment within the active floodplain/riparian corridor to protect *all O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation, and rearing, and their associated habitats.
	Manage livestock grazing to maintain or restore aquatic habitat functions	Develop and implement plan to manage livestock grazing to restore and/or protect riparian functions (*e.g*., control stream bank and floodplain erosion, dissipate stream energy, capture sediment during high flows, *etc*.) to sustain aquatic habitat features (*e.g.*, physical diversity, cover, and water quality) essential for all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing.
	Manage agricultural development and restore riparian zones	Develop and implement plan to manage agricultural development outside of the active floodplain (defined by 2-5 year frequency flood event) to create an effective riparian buffer; restore and re-vegetate a minimum riparian buffer to allow the channel to maintain natural structural diversity to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats. The extent of the floodplain and riparian buffer shall be determined on a case-by-case basis taking into account site specific conditions.
Agricultural Effluents	Develop and implement plan to minimize runoff from agricultural activities	Develop and implement plan to reduce or eliminate nutrient and pesticide/herbicide runoff and sediment inputs into natural watercourses from agricultural activities to provide water quality suitable for all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitat.
Culverts and Road Crossings (Passage Barriers)	Develop and implement plan to remove or modify fish passage barriers within the watershed	Develop and implement plan to prioritize, remove and/or modify anthropogenic fish passage barriers within the watershed to allow natural rates of adult and juvenile *O. mykiss* migration between the estuary and upstream spawning and rearing habitats, passage of smolts and kelts downstream to the estuary and the ocean, and to reduce intrusion into the riparian corridor and restore sediment transport.
	Conduct watershed-wide fish passage barrier assessment	Conduct watershed-wide fish passage barrier assessment between the ocean and all upstream spawning and rearing areas (including above existing barriers). This passage barrier assessment should utilize the protocols identified in the California Department of Fish and Game's California Salmonid Stream Habitat Restoration Manual (Flosi *et al*. 2010, or the most current version).
Dams and Surface Water Diversions	Develop and implement water management plan for diversion operations	Develop and implement a water management plan to identify the appropriate diversion rates for all surface water diversions that will maintain surface flows necessary to support all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, and suitable spawning, incubation, and rearing habitat.
	Develop and implement water management plan for dam operations	Develop and implement operational plan to provide seasonal releases from dams to provide surface flows necessary to support all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation, and rearing habitats.

Threat Source	Recovery Action	Detailed Description
	Provide fish passage around dams and diversions	Develop and implement plan to physically modify or remove fish passage barriers at dams, debris basins or diversions to allow natural rates of adult and juvenile *O. mykiss* migration between the estuary and upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean.
Flood Control Maintenance	Develop and implement flood control maintenance program	Develop and implement flood control maintenance plan to minimize the frequency and intensity of disturbance of instream habitats and riparian vegetation (*e.g*., modification of natural channel morphology and removal of native vegetation) of the mainstem and tributaries to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing, and their associated habitats.
Groundwater Extraction	Conduct groundwater extraction analysis and assessment	Conduct hydrological analysis to identify groundwater extraction rates, effects on the natural pattern (timing, duration and magnitude) of surface flows in the mainstem, tributaries, and the estuary, and effects on all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation and rearing habitats.
	Develop and implement groundwater monitoring and management program	Develop and implement groundwater monitoring program to guide management of groundwater extractions to ensure surface flows provide essential support for all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, spawning, incubation and rearing habitats.
Levees and Channelization	Develop and implement plan to restore natural channel features	Develop and implement plan to modify channelized or artificially stabilized portions of the mainstem and tributaries, wherever feasible, to restore natural channel features and habitat functions, including natural channel bottom morphology and riparian vegetation, to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Develop and implement plan to vegetate levees and eliminate or minimize herbicide use near levees	Develop and implement plan to vegetate levees with native, naturally occurring vegetation, wherever feasible, and eliminate or minimize the use of herbicides to control native vegetation adjacent to existing levees to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Develop and implement stream bank and riparian corridor restoration plan	Develop and implement stream bank and riparian corridor restoration plan to reduce channel incision, sedimentation from bank erosion, and reduce or eliminate the need for artificial bank stabilization; wherever feasible, remove rip-rap and other artificial bank stabilization features on mainstem and tributaries and replace with bio-engineered bank stabilization, or an additional set-back, to allow the channel to maintain natural structural diversity to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
Mining and Quarrying	Review and modify mining operations	Review aggregate and hard rock mining operations (past, current and future) for conformance with the National Marine Fisheries Services Guidelines for Removal of Sediment from Freshwater Salmonid Habitat (Cluer 2004). Modify current and future mining operations, where necessary to comply with the relevant provisions of the guidelines, and remediate past (including terminated operations to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.

Threat Source	Recovery Action	Detailed Description
	Develop and implement plan to remove quarry and landslide debris from the channel	Develop and implement plan to remove quarry and landside debris from the channel, maintain the channel free from such debris, and establish a riparian buffer with native, locally occurring species to protect all *O. mykiss* life history stages, including adult and juvenile *O. mykiss* migration, and spawning and rearing habitats.
Non-Native Species	Develop and implement watershed-wide plan to assess the impacts of non-native species and develop control measures	Develop and implement watershed-wide plan to identify and determine the type, distribution and density of non-native species; assess their impacts on all *O. mykiss* life history stages; and eliminate or control non-native species of plants and animals (particularly fish and amphibians); restore riparian and upland areas with native, locally occurring plant species to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Develop and implement non-native species monitoring program	Develop and implement on-going monitoring program to track the status and impacts of non-native species of plants and animals on all *O. mykiss* life history stages, particularly rearing juveniles.
	Develop and implement public education program on non-native species impacts	Develop and implement public education program (including signage at public access points) to inform the general public of the adverse effects of introducing non-native species into natural ecosystems.
Recreational Facilities	Manage off-road recreational vehicle activity in riparian floodplain corridors	Develop, adopt, and implement land-use policies and standards to manage off-road vehicular activity within the riparian/floodplain corridor of the mainstem and tributaries to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Review and modify development and management plans for recreational areas and national forests	Review development and management plans for recreational areas and national forest lands and modify to provide specific provisions to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats. Provide specific provisions for the restoration and protection of creeks, rivers, estuaries, wetlands and riparian/floodplain areas, including an effective setback for all development from estuarine and riparian habitats. Regulate the use of day-use areas and other recreational facilities to minimize impacts to aquatic and wetland habitats to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Develop and implement public education program on watershed processes	Develop and implement public education program (including signage at public access points) to promote public understanding of watershed processes (including the natural fire-cycle) and *O. mykiss* ecology to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
Roads	Manage roadways and adjacent riparian corridor and restore abandoned roadways	Develop and implement plan to manage roadways adjacent to riparian/floodplain corridors to reduce sedimentation, or other non-point pollution sources, before it enters natural watercourses to protect all steelhead life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats. Restore and re-vegetate abandoned roadways with native, locally occurring species.

Threat Source	Recovery Action	Detailed Description
	Retrofit storm drains to filter runoff from roadways	Develop and implement plan to retrofit storm drains to filter runoff from roadways to remove sediments and other non-point pollutants before it enters natural watercourses to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Develop and implement plan to remove or reduce approach-fill for railroad lines and roads	Develop and implement plan to remove or reduce approach-fill for railroad lines and roads and maximize the clear spanning of active channels, floodways, and estuaries to accommodate natural river and estuarine fluvial processes to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
Upslope/Upstream Activities	Develop and implement an estuary restoration and management plan	Develop and implement restoration and management plan for the relevant estuary. To the maximum extent feasible, the plan should include restoring the physical configuration, size and diversity of the wetland habitats, eliminating exotic species, controlling artificial breaching of the sand bar, and establishing an effective buffer to restore estuarine functions and promote *O. mykiss* use (including rearing and acclimation) of the estuary.
	Review and modify applicable County and/or City Local Coastal Plans	Review applicable County and/or City Local Coastal Plans and modify to provide specific provisions for the protection of all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Review applicable Integrated Natural Resources Management Plans	Review the relevant Integrated Natural Resources Management Plan (INRMP) and modify to provide specific provisions for the protection and restoration of all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation, and rearing habitats.
Urban Development	Develop, adopt, and implement urban land-use planning policies and standards	Develop, adopt and implement land-use planning policies and development standards that restrict further development in the floodplain/riparian corridor to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing, habitats.
	Retrofit storm drains in developed areas	Develop and implement plan to retrofit storm drains in urban areas to control sediments and other non-point pollutants in runoff from impervious surfaces before it enters natural watercourses to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Develop and implement riparian restoration plan to replace artificial bank stabilization structures	Develop and implement riparian restoration plan throughout the mainstem and tributaries to replace artificial bank stabilization, structures wherever feasible, and provide an effective riparian buffer on either side of mainstem and tributaries, utilizing native, locally occurring species, to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
Urban Effluents	Review California Regional Water Quality Control Boards Watershed Plans and modify Stormwater Permits	Review California Regional Water Quality Control Boards Regional Plans, and Stormwater Permits, and modify to include specific provisions for the protection of all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.

Threat Source	Recovery Action	Detailed Description
	Review, assess and modify NPDES wastewater discharge permits	Review and assess National Pollution Elimination Discharge System (NPDES) wastewater discharge permits to determine effects of discharge on adult and juvenile *O. mykiss* life stages, including migration, spawning, and rearing habits. Modify discharge requirements, where necessary, to ensure discharge is adequate to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
	Review, assess and modify residential and commercial wastewater septic treatment facilities	Review and assess residential and commercial wastewater septic treatment facilities to determine effects of discharge on all *O. mykiss* life stages, including migration, spawning, and rearing habits. Modify septic systems, where necessary, to ensure discharge is adequate to protect all *O. mykiss* life history stages, including adult and juvenile migration, spawning, incubation and rearing habitats.
Wildfires	Develop and implement an integrated wildland fire and hazardous fuels management plan	Develop and implement an integrated wildland fire and hazardous fuels management plan, including monitoring, remediation and adaptive management, to reduce potentially catastrophic wildland fire effects to steelhead and their habitat and preserve natural ecosystem processes (including sediment transport and deposition).

8.3 CONSERVATION HATCHERIES

One potential recovery strategy involves the use of conservation hatcheries to preserve imminently threatened populations, or to accelerate restoration of steelhead runs by temporarily supplementing natural production (California Department of Fish and Game and U.S. Fish and Wildlife Service 2010, California Department of Fish and Game 2004, California Department of Fish and Game and National Marine Fisheries Service 2001). While a conservation hatchery program[1] can complement the overall recovery effort, the role of such a program cannot be reasonably expected to substitute for the extensive restoration of habitat function, value, and connectivity that is required to abate threats to South-Central California Coast steelhead.

Conservation hatcheries can be used for a number of recovery related purposes, including: 1) providing a means to preserve local populations faced with immediate extirpation as a result of catastrophic events such as wildfires, toxic spills, dewatering of watercourses, *etc.*; 2) preserving the remaining genotypic and phenotypic characteristics that promote life history variability through captive broodstock, supplementation, and gene-bank programs to reduce short-term risk of extinction; 3) reintroduction of populations in restored watersheds; and 4) conducting research on South-Central California Coast stocks relevant to the conservation of the species. (See the discussion of research issues in Chapter 13, South-Central California Steelhead Research, Monitoring and Adaptive Management.)

Issues that should be considered prior to implementing a conservation hatchery program include: 1) conditions under which rescue, reestablishment or supplementation could be used in wild steelhead recovery; 2) methods for rescue, re-establishment or supplementation, and; 3) protocols for evaluating the effectiveness of such conservation hatchery functions over time. Conservation programs must be guided by scientific research and management strategies to meet program objectives recovering threatened or endangered populations (Flagg and Nash 1999).

Genetic resources that represent the ecological and genetic diversity of the species can reside in hatchery fish as well as in wild fish (Waples 2010). As a consequence, NMFS has extended protection under the Endangered Species Act (ESA) to certain hatchery fish programs which preserve the genetic legacy of the listed species and are managed as refugia populations (70 FR 37204, June 28, 2005).

8.3.1 Recovery Role of Conservation Hatcheries

The principal strategy of salmonid conservation and recovery is the protection and restoration of healthy ecosystems upon which they naturally rely, consistent with the ESA's stated purpose to conserve "the ecosystems upon which endangered and threatened species depend" (ESA section 2(b)). However, a natural recovery of local extinctions depends on one or more recolonization events, a process that operates on an indefinite timescale. Likewise, the viability of a depressed population, characterized by small size, fragmented structure, and impacted genetics (*e.g.,* bottlenecks, inbreeding, outbreeding depression, *etc.*), may be so compromised that its response to restored or increased availability of habitat is not sufficient to prevent imminent extinction (Araki *et al. 2009, 2008,* 2007a 2007b, Berejikian *et al*. 2011, 2009, 2008, 2005, Kuligowski *et al*. 2005, Hayes *et al.* 2004). Either case may require management intervention to attain self-sufficiency and sustainability in the wild.

There is considerable uncertainty regarding the ability of artificial propagation to increase

[1] A conservation hatchery is a program that conserves and propagates steelhead taken from the wild for conservation purposes, and returns the progeny to their native habitats to mature and reproduce naturally.

population abundance over the long-term, and it cannot be assumed that artificial augmentation will reduce extinction risk. The artificial advantage given to hatchery fish during early life stages can result in a higher rate of return over that of natural fish escapement, and result in increasing hatchery fish representation in the natural population over time. There is a risk to natural recovery from increasing dependency on fish augmentation. Conservation hatcheries must therefore monitor the effects of the program on the natural population using criteria which would trigger modification to or cessation of the conservation program (Chilcote 2011, Paquet *et al*. 2011, Tatara *et al*. 2011a, 2011b, Fraser 2008, Myers *et al.* 2004, Ford 2002).

Conservation hatchery programs employing best management practices can reduce the likelihood of extinction by contributing to one or more of the viable salmonid population (VSP) parameters at the population and evolutionarily significant unit (ESU) or distinct population segment (DPS) levels (McElhany *et al*. 2000):

Abundance. Conservation hatchery fish may reduce extinction risk by increasing the total abundance of fish in a population in the short term, providing sufficient numbers to dampen deterministic density effects, environmental variation, genetic processes, demographic stochasticity, ecological feedback, and catastrophes.

Growth Rate. Conservation hatchery fish potentially increase the total abundance of successful natural spawners, thereby increasing productivity in the collective contribution of natural-origin and hatchery-origin spawners to productivity in the natural environment.

Spatial Structure. Small populations are at risk of local and regional extinctions because of ongoing habitat loss and fragmentation, as well as dysfunctional expression of species behavior undermining its sustainability. The introduction of conservation hatchery fish into suitable unoccupied habitat or for supplementing sparsely populated habitat concomitant with restoration projects that increase interconnected natural habitat may reestablish natural spatial population structure.

Diversity. To conserve the adaptive diversity of salmonid populations, the environment in which they co-evolved and the natural processes which select for population fitness should be allowed to continue without human impact or influence. Conservation hatcheries can conserve valuable genes and genotypes, and are managed to minimize ecological and domestication effects on natural populations, conserve and maximize genetic variability and life history diversity within and among stocks.

A conservation hatchery would provide an appropriate platform for undertaking appropriate research of the topics outlined above and could provide effective guidance in the use of a conservation hatchery program to protect the currently depressed steelhead stocks and recover the threatened steelhead populations of the SCCCS Recovery Planning Area.

8.3.2 Basic Elements of a Conservation Hatchery Program

A conservation hatchery program must be:

1) Guided by a Hatchery and Genetic Management Plan, based on the best available scientific knowledge, and/or testable assumptions where information is lacking;

2) Consistent with the overall strategy, goals, objectives, and specific provisions of the Recovery Plan;

3) Based on an adaptive management, iterative process aimed at reducing uncertainty through monitoring and re-evaluation;

4) Supported by a monitoring component to:

a) Evaluate the short- and long-term goals and objectives of the program
b) Determine if and when management protocols need to be revised
c) Determine when the program should adapt to evolving recovery needs
d) Determine when the conservation hatchery program is no longer needed.
e)

5) Supported by a research program to investigate issues such as:
:

f) Fish culture problems that arise within the program
g) Fish response to habitat, environmental challenges, pathogens, *etc*.
h) Factors which contribute to reduced fitness and reproductive success of hatchery fish in the natural environment
i) Behavioral changes of conservation hatchery reared fish released into their natal waters that may lead to changes in the expression of different life history strategies (*e.g.*, anadromous or freshwater resident forms).

6) Contains criteria and a strategy for terminating the conservation hatchery program and re-directing resources to the rehabilitation of watershed processes and sustainable management of fish habitat.

8.3.3 Considerations for Establishing a Conservation Hatchery Program

An important consideration within the overall planning for recovery of threatened steelhead involves knowing when to start a conservation hatchery program (Flagg and Nash 1999).

The appropriate use for a conservation hatchery should be guided by several considerations: 1) the biological significance of the population; 2) genetic diversity; 3) population viability; and 4) the potential loss of populations exhibiting any of the first three characteristics. Each of these is described below.

Biological Significance of the South-Central Coast Steelhead populations. The biological significance of a population is expressed in the innate genetic and phenotypic characteristics, and other novel biological and ecological attributes, particularly those attributes that are not observed in other conspecific populations. With regard to the threatened SCCCS DPS, the characterization of the historical steelhead population developed by the TRT provides evidence that certain watershed-specific populations possess a high likelihood of producing steelhead with genetic and phenotypic characteristics that favor survival in a spatially and temporally highly-variable environment. Because many of the inland populations (*e.g.*, Salinas, Arroyo Seco, Upper Salinas, Pajaro, Carmel, Arroyo Grande) extend over a broad and geographically diverse area, these populations are able to withstand environmental stochasticity and possess ecologically significant attributes likely not found in most other populations.

Genetic Diversity. The amount of genetic diversity among individuals provides the foundation for a population to adapt to fluctuating environmental conditions, and contributes to its continued evolvability in response to longer-term changes such as projected climate changes. Generally, high genetic diversity favors growth and survival of individual populations. Genetic diversity of a population can be estimated quantitatively based on parameters, such as effective population size (N_e). The abundance of a population that falls below a specified N_e may be at risk of losing the necessary amount of genetic diversity that should be maintained over time, which does not favor survival in a stochastic environment. General guidelines or numerical values for N_e are specified in the literature for maintaining minimum N_e for individual populations, but may require further research specifically for populations of South-Central California Coast steelhead.

Population Viability. Whether a population is likely to be viable is another key considering in determining the proper timing of a conservation hatchery. In particular, information about population size, population growth rate, spatial structure, and diversity provide an indication of the sort of extinction risk a species faces. Generally, small populations have a higher risk of extinction than larger populations. With regard to the threatened SCCCS DPS, evidence indicates the populations are at high risk of extinction and are not currently viable.

Potential Population Loss. Finally, a population exhibiting any of the characteristics noted above that is threatened with imminent extirpation as a result of anthropogenic activities, natural catastrophic events such as wildfire or massive sedimentation, or a combination of the two, may be preserved by the temporary placement of representatives of such a population in a conservation hatchery, or other secure location.

8.4 ESTIMATED TIME TO RECOVERY AND DELISTING

NMFS's interim recovery planning guidance (2010a) provides that Recovery Plans "indicate the anticipated year that recovery would be achieved. Estimates should be carried through to the date of full recovery, *i.e.*, when recovery criteria could be met. There may be extreme cases in which estimating a date and cost to recovery is not possible due to uncertainty in what actions will need to be taken to recover the species." In those circumstances "an order of magnitude for cost and some indication of time in terms of decades, should be provided if at all possible."

Estimates of the time to recovery entails three basic elements: time to complete all major recovery actions + time for habitat to respond + time for the listed species to respond to recovery actions:

Regarding the time to complete all major recovery actions, this component should reflect:

The longest time any recovery action would take to complete, assuming that all recovery actions began more or less immediately (or within 10 years) of completion of the Recovery Plan.

Sufficient funding to complete recovery actions.

Regarding the time for habitat to respond to recovery actions, this component should reflect:

The longest time the habitat recovery would take.

The variation in the extent of needed habitat restoration (extremely degraded habitat could have longer restoration estimates).

Regarding the time for the species to respond to recovery actions, this component should reflect:

The number of generations for which demographic targets must be met in order to delist.

Or for South-Central California Coast steelhead. the length of a complete ocean multi-decadal cycle, or 60 years).

The precision of any estimate of time to recover and delist a species is necessarily governed by the specificity with which any of these components can be estimated.

Completion of a majority of the recovery actions is estimated to vary from 5 to 10 years, though some of the larger, more complicated recovery actions such as the physical or operational modification of larger dams may take several decades. The recovery of habitat could vary depending on the type of habitat (e.g., migration, freshwater spawning and rearing, or estuarine habitat), with some migration and estuarine habitats taking less time, and some spawning and rearing habitats taking more time to respond to recovery actions. As with the completion of recovery actions, it is estimated that these time frames would vary in a majority of cases to from 5 to 10 years, though the response of some habitats may taking longer, depending of rainfall and runoff patterns. The time for the species to respond to recovery actions is the most challenging time component to estimate for a variety of reasons: these include the dependency of anadromous runs and spawning and rearing success upon rainfall and runoff patterns, which can be cyclic, and may also be significantly influenced by projected climate changes, and uncertainties regarding aspects of the demographics of South-Central California Coast steelhead (*e.g*., rate of dispersal between populations, rate of switching between resident and anadromous life cycle strategies).

Given the above estimates, and the need to meet the DPS recovery run size criterion during poor ocean conditions (measured over a multi-decadal cycle of 60 years), the time to recovery can be provisionally estimated to vary from 80 to 100 years. A modification of the provisional population or SCCCS DPS viability criteria resulting in smaller run-sizes, or the number or distribution of recovered populations could shorten the time to recovery. Delays in the completion of recovery actions, time for habitats to respond to recovery actions, or the species' to respond to recovery actions would extend the time to recovery.