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 delisting the SCCCS DPS. Restoring access to a diversity of steelhead habitats and restoring the ecological functions of those habitats to properly functioning conditions are central to the recovery of the SCCCS DPS. This biologically based strategy aims to restore the natural selective regime under which steelhead evolved and which is critical to their long-term survival (Dunlop *et al.* 2009, Propst *et al*. 2008, Lytle and Poff 2004, Bunn and Arthington 2002, Poff *et al*. 1997).

The recovery strategy identifies watersheds where recovery of viable populations is necessary to achieve the recovery DPS 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) necessary to reverse the effects of past and ongoing threats to population abundance, growth rate, diversity, and spatial structure. An integral element in this recovery strategy is development and implementation of a research and monitoring program which will provide 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 the SCCCS DPS will require effective implementation of 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 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 native 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 areas.

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 patterns and associated wildfires will create challenges in maintaining traditional water supply and flood control structures such as dams, levees, and channelized watercourses. Engineered systems which control hydrological systems have often been overvalued and frequently overwhelmed when their design parameters are 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 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, Ligon *et al.* 1995, 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 provides an opportunity to meet a 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 or species of special concern such as Foothill yellow-legged frog (*Rana boylii*) California red-legged frog (*Rana aurora draytonii*), Least Bell's vireo (*Vireo bellii pusillus*), California least tern (*Sterna antillarum browni*), Western snowy plover (*Charadrius alexandrinus nivosus*), Arroyo toad (*Bufo microscaphus californicus*), Tidewater goby (*Eucyclogobius newberryi*), and Pacific lamprey (*Entosphenus tridentata*) that co-occupy the SCCC Recovery Planning Area.

Under present conditions, the viability of individual populations is more likely achievable by focusing recovery efforts on larger watersheds (with some notable exceptions within the San Luis Obispo Terrace BPG) 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) the development of site-specific and project specific information, to ensure that recovery actions are effective and sustainable; 2) 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; 3) 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; 4) close cooperation with other state resource agencies such as the California Department of Fish and Wildlife, California Coastal Commission, CalTrans, California Department of Parks and Recreation, State Water Resources Control Board, and Regional Water Quality Control Boards to ensure consistency of recovery efforts; and 5) 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, National Resource Conservation District, 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 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; establishment and implementation of appropriate flow regimes for individual watersheds; and 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 also addressing new threats that emerge over time. NMFS estimated the costs associated with certain common restoration activities such as those undertaken as part of the CDFW Fisheries Restoration Grants Program. Appendix E, Recovery Actions Cost Estimates For Steelhead Recovery Planning, contains preliminary estimates for these categories of typical watershed and river restoration actions.

7.1.1 Funding Recovery Actions

Many of the recovery actions identified in the recovery action tables in Chapters 9 through 12 are intended to restore basic ecosystem processes and function such as more natural hydrologic conditions, water quality, and riparian and estuarine habitats. These actions will, in many cases, also serve to restore multiple native species and associated human uses of these natural resources. As a result, such activities may be eligible for funding from multiple funding sources at the federal, state, and local levels.

Federal funding sources include:

- *NOAA/NMFS Restoration Center Community-Based Restoration Program*
- *NOAA/NMFS Restoration Center Open Rivers Initiative*
- *NOAA/NMFS Proactive Species of Concern Grant Program*
- **NOAA National Sea Grant College Program**
- *NOAA Coastal and Estuarine Land Conservation Program*
- *NOAA/ACOE/USFWS/EPA/NRCS Estuary Habitat Restoration Program*
- *EPA Wetlands Protection Grants and Near Coastal Waters Programs*
- *US. Department of Transportation Highway Bridge Rehabilitation and Replacement Program*
- *U.S. Fish and Wildlife Service National Coastal Wetlands Conservation Grant Program*
- *U.S. Fish and Wildlife Service Coastal Program*
- *U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program*
- *U.S. Fish and Wildlife Service North American Wetland Conservation Act*
- *National Resource Conservation Service*
- *Federal Highway Administration – Road Aquatic Species Passage Funding*

State funding sources include:

- *California Department of Fish and Wildlife Pacific Coast Salmon Restoration Fund*
- *California Coastal Conservancy Proposition 84 Funds*
- *California Coastal Conservancy Community Wetland Restoration Grants*
- *California Wildlife Conservation Board*
- *California State and Regional Water Quality Control Board Clean Water Grant Program*
- *California Integrated Watershed Management Grant Program Proposition 50 Funds*
- *California Department of Parks and Recreation Habitat Conservation Fund*
- *CalTrans Environmental Enhancement and Mitigation Program*
- *U.C. California/NOAA California Sea Grant College Program*

In addition to federal and state funding sources, there are also numerous private national, regional and local funding sources for South-Central California habitat restoration projects, such as:

- *National Fish and Wildlife Foundation*
- *County Fish and Wildlife Advisory Commissions* (Santa Cruz, Santa Clara, San Benito, Monterey, San Luis Obispo Counties)

Many of these grant programs also offer technical assistance, including project planning, design, permitting, monitoring. Additionally, regional personnel with NOAA, CDFW, and the U.S. Fish and Wildlife Service can provide assistance and current information on the status of individual grant programs.

7.2 CORE POPULATIONS

The findings of the TRT (Boughton *et al*. 2007b, 2006) and additional review by NMFS indicate certain watersheds and their steelhead populations 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 summer and reliable winter streamflow, stream network extending inland) most likely to sustain independently viable populations, and that are critical for ensuring the viability of the DPS as a whole. Population viability is more likely achievable by focusing recovery efforts on these watersheds in each BPG capable of sustaining viable populations, though the recovery strategy also identifies a role for smaller watersheds which may serve as important sources of fish dispersed between larger watersheds (see Table 7-1 below). DPS viability is more likely achievable by focusing on the most widely-dispersed set of 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 populations identified as the highest priority for recovery 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.

Core 2 populations are generally smaller populations, and may have less diverse and complex threats than Core 1 populations, though the conditions in individual cases vary considerably. Core 1 populations and Core 2 populations are the principal focus of identified recovery actions.

Core 3 populations are generally the smallest populations with lowest intrinsic potential, though within the Big Sur Coast and San Luis Obispo Terrace BPGs, the viability of these populations may rely less on population size than on other factors such as reliability of access to upstream spawning and rearing habitats and more stable hydrologic and thermal conditions. As with Core 2 populations, Core 3 generally have less diverse and complex threats, though the conditions in individual cases varies considerably, and may be important in meeting the DPS viability criteria.

The weight given these factors in designating populations as either Core 1, 2 or 32 may vary with individual watersheds. Generally larger watersheds with the highest intrinsic potential, such as the Salinas and Pajaro, are designated Core 1 populations (see Appendix B for the relative intrinsic potential rankings of watersheds evaluated as part of the recovery planning process). 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 essential to the recovery of the DPS as well as on watersheds with greatest need for recovery actions.

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

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, though several Core 2 populations along the north portion of the San Luis Obispo Terrace Biogeographic Population Group such as San Carpoforo and Arroyo de la Cruz Creeks are important as relatively unimpaired references streams for chaparral dominated watersheds (see 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. These Core 2 populations are ranked differently than Core 1 populations based on the factors noted above; NMFS recognizes timing of recovery actions on these populations may also 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 the same priority as Core 1 and 2 populations, these populations may be important in providing connectivity between populations and genetic diversity across the SCCCS Recovery Planning Area, and therefore are an important 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-basin 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 a critical component of the recovery strategy is securing extant inland populations in the 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. The populations of the Interior Coast Range and Carmel Basin BPGs are particularly important because they 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 populations 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 identified individual populations are not viable, restoration of more closely spaced populations (e.g., Islay or Coon Creek) 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, Coon, or Islay 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, questions remain regarding species ecology (*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 actively pursuing recovery opportunities in Core 3 watersheds as a precaution to reduce extinction risk. 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

Recovery actions are the critical elements for alleviating major threats to steelhead in Core populations. 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 are the highest priority across the SCCCS DPS and within Core populations to achieve recovery objectives and criteria. The highest priority actions have a priority ranking of 1, and generally address threats related to reduced flows and impediments to fish passages that result in the destruction or curtailment of steelhead habitat. 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), 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 significance 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 adverse impact to steelhead and their habitat. However, two types of developments and activities generally pose the most widespread threats to the species in these watersheds (and the DPS as whole): 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, the recovery strategy places a high priority on recovery actions alleviating 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; this will entail, among other things, restoration and protection of upstream spawning and rearing habitats, rearing habitats in coastal estuaries as well as other potential refugia rearing habitats, and controlling or eliminating non-native species such as those in artificial reservoirs above dams. 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 (Tables 9-4 through 9-6, and Tables 12-4 through 12-13).

Regarding the impacts 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 allowing sustainable effective access to historical spawning and rearing habitats. Historical habitats are often situated in protected areas such as the Los Padres National Forest, and provide essential attributes for spawning and rearing such as suitable substrate, sustained base flows, and pool habitats. In addition to allowing access to historical habitats, dam modification provides additional ecological benefits essential to attaining recovery objectives. 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) through restoration of the natural spatial population structure. Mechanistic solutions to fish passage impediments 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), Agostinho *et al.* (2002), Oldani and Baigum (2002), Nemeth and Kiefer (1999), Cada *et al.* (1995, 1993), Clay (1995), 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 steelhead ecosystems. See for example, Wegner *et al.* (2011, 2010), Carlisle *et al.* 2010, Marks *et al.* (2010), Poff and Zimmerman (2010), Poff *et al.* (2010, 1997), Annear *et al*. (2009, 2004), Instream Flow Council (2009, 2004), Olden and Naiman (2009), Lytle and Poff (2004), Bunn and Arthington (2020, 2007, 2006), Gibbons *et al.* (2001), Hatfield and Bruce (2000), Vadas (2000), Kraft (1992), MacDonald *et al*. (1989).

Recovery of the SCCCS DPS requires restoration of 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. 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 more natural streamflow patterns are restored (*i.e.*, timing, frequency, duration, magnitude, and rate-of-change). There are many sites within Core watersheds where past and present anthropogenic activities alter the pattern and magnitude of streamflow and for which essential recovery actions are identified. In some situations, 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. 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.* 2012, 2008, Casagrande 2012, 2010a, Bond 2006, Smith 1990, Moore 1980). Two other habitats are streams with high summer flow (sometimes augmented by releases from reservoirs or reclaimed water) or in-channel impoundments like Sprig Lake on a seasonal tributary to Uvas Creek that may provide drought resistant refugia habitat for rearing juvenile *O. mykiss* (Smith 1982, 2007a, Casagrande 2011, 2012, 2010a, Moore 1980). The identification, protection, and where necessary, restoration, and/or creation of such habitats should be considered as important recovery actions.

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 conditions in watersheds throughout the entire extent of the DPS, local stakeholders should continue to undertake actions that complement the essential recovery actions in Core 1 watersheds.

To focus recovery efforts and facilitate recovery, the Recovery Plan identifies populations essential to meeting recovery goals and criteria (Core 1, 2, and 2 populations) in each of the four

BPGs within the DPS, and prioritizes recovery actions for each of the watersheds within the BPGs (see Recovery Action Tables in Chapters 9-12).

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) preserving the remaining genotypic and phenotypic characteristics promoting life history variability though captive broodstock, supplementation, and gene-bank programs to reduce short-term risk of extinction; and 3) reintroduction of populations into restored watersheds. However, conservation hatcheries should not serve as surrogates for establishing and preserving essential habitat functions for threatened steelhead, particularly where anthropogenic activities have created threats constraining or eliminate habitat functions and values.

Issues that should be closely 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).

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	Develop and 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 fish passage impediments, (*e.g*. Uvas 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 and restoration of spawning gravel recruitment to the lower mainstem (*e.g.,* Uvas Creek). Manage instream mining to minimize impacts to migration, spawning and rearing habitat in major tributaries, including Uvas, Corralitos, Llagas, and Pacheco Creeks, and the San Benito River. Identify, protect, and where necessary, restore estuarine rearing habitat, including management of artificial sandbar breeching at the river's mouth.
	Salinas River	Develop and implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases from the Salinas 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 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, including management of artificial sandbar breeching at the river's mouth.
	Arroyo Seco	Develop and implement operating criteria to ensure the pattern and magnitude of groundwater extractions from the Arroyo Seco and lower Salinas River provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Physically modify fish passage impediments, including concrete road crossing and diversion structure 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	Develop and 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	Develop and implement operating criteria to ensure the pattern and magnitude of water 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	Develop and implement alternative off channel water supply projects to eliminate or decrease water extractions from the channel (including subsurface extractions), and implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases from San Clemente and Los Padres Dams provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Remove or physically modify San Clemente, Los Padres, and Old Carmel River Dams to provide steelhead natural rates of migration to upstream

		spawning and rearing habitats; passage of smolts and kelts downstream to the estuary and ocean; and restoration of spawning gravel recruitment to the lower mainstem. In the interim ensure provisional fish passage of both adult and juvenile O. *mykiss* around Los Padres, San Clemente and Old Carmel River Dams, and seasonal releases from San Clemente and Los Padres Dams to support all *O. mykiss* life-history phases, including adult and juvenile migration, spawning, and incubation and rearing habitats. Identify, protect, and where necessary, restore estuarine and freshwater rearing habitats (including supplemental water to the estuary, management of artificial sandbar breaching at the river's mouth, and provision of spawning gravel and large woody debris within the lower mainstem).
Big Sur Coast	San Jose Creek	Development and 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 rearing habitat, including management of artificial sandbar breeching at the river's mouth, and upstream freshwater spawning and rearing habitats.
	Little Sur River	Develop and 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 spawning and rearing habitats.
	Big Sur River	Develop and 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 spawning and rearing habitats. Consideration should also be given to establishing fish passage to the upper reaches above the rock cascade within the lower gorge.
San Luis Obispo Terrace	San Simeon Creek	Develop and 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. Manage instream mining to minimize impacts to migration, spawning and rearing habitat. Identify, protect, and where necessary, restore estuarine rearing habitat, including management of artificial sandbar breeching at the river's mouth, and upstream freshwater spawning and rearing habitats.
	Santa Rosa Creek	Develop and 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 rearing habitat,

		including management of artificial sandbar breeching at the river's mouth, and upstream freshwater spawning and rearing habitats.
	San Luis Obispo Creek	Develop and 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, diversions , and culverts, 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 rearing habitat, including management of artificial sandbar breeching at the river's mouth, and upstream freshwater spawning rearing habitats.
	Pismo Creek	Develop and 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 rearing habitat, including management of artificial sandbar breeching at the river's mouth, and upstream freshwater spawning and rearing habitats.
	Arroyo Grande Creek	Develop and 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 rearing habitat, including management of artificial sandbar breeching at the river's mouth, and upstream freshwater spawning and 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, requiring adequate flows and unobstructed migration routes to move between marine and freshwater habitats, including 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 Wildlife 2012a, 2012b; see Figure 7-1). Restoring steelhead access to historical spawning and rearing habitats (*i.e.*, areas upstream of introduced barriers to areas currently unoccupied by anadromous *O. mykiss*) is an essential action for recovering threatened steelhead.

Reestablishing access to currently unoccupied areas is essential for conserving threatened steelhead (Boughton *et al.* 2007b, 2006) in the SCCCS DPS. Additionally, the characteristics and condition of historical habitats must remain functional to support their intended conservation role. Implementing these recovery actions will require removing or physically modifying anthropogenic barriers, concurrently with protecting, and where necessary, restoring these habitats.

The following discussion summarizes the ecological rationale for these recovery actions. Central to the rationale is the historical steelhead population structure and distribution, and the necessity of restoring access to historically highly productive steelhead spawning and rearing habitats as a means to increase the population growth rate (*i.e.*, the productivity of a population), and thus reduce the extinction risk to these populations.

Native steelhead historically existed in areas that are currently inaccessible.

A review of the scientific and historical literature on the distribution of steelhead within the SCCCS Recovery Planning Area indicates steelhead were widespread up until the mid-20th century. See for example, Becker *et al*. (2008), Boughton *et al.* (2006), Boughton and Goslin (2006), Boughton *et al.* (2005), Boughton and Fish (2003), Swift *et al.* (1993), Nehlsen, *et al.* (1991), Wells *et al.* (1975), Boydstun (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 the present-day populations are dominated by individuals with ancestry from 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 persist upstream of anthropogenic barriers are largely or entirely descended from relic *O. mykiss* populations. These findings, as well as the intrinsic potential of certain watershed-specific populations for recovering this species, underscore the importance 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 (in combination with associated alteration of flows and habitat complexity) 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 access to historical steelhead habitats is necessary to reduce extinction risk to a level that is considered negligible over a 100-year period.

Population extinction risk is related to the numerical abundance of the population, which itself is related to the species' areal distribution (*i.e.*, population spatial structure) and the degree the diversity of life history traits are unrestricted. Small populations with limited spatial structure are particularly susceptible to extinction, owing to 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. These characteristics reflect their adaptation to variable freshwater and marine environments. Generally, 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 reduces its extinction risk to a negligible level (Boughton *et al.* 2006, McElhany *et al*. 2009, 2000).

Throughout the SCCCS Recovery Planning Area, anthropogenic activities have severely truncated population spatial structure through construction of instream structures that have inhibited or blocked completely fish migration. These artificial barriers have eliminated the expression of certain life history traits in individual watersheds such as the Nacimiento and San Antonio Rivers, 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 Wildlife (2012a), Boughton *et al.* (2005).

While steelhead were historically widespread, artificial migration barriers (including those caused by reduced flows) have resulted in populations that are spatially restricted 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. Additionally, barriers preclude steelhead from accessing upstream spawning habitats and interacting with the freshwater form of *O. mykiss*, which contribute to the diversity of the *O. mykiss* complex. Ensuring this life history attribute is persevered will facilitate species resiliency by helping it withstand stochastic environmental fluctuations.

Because reduced and degraded habitat conditions within the SCCCS DPS has negatively affected the abundance, diversity, spatial structure, and growth rate of 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 within those habitats 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.

Available information describing the current abundance and distribution of *O. mykiss* indicates habitats historically accessible to steelhead still 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, reported on the distribution of *O. mykiss* habitat, including in areas upstream of artificial barriers within Core

1 populations. These investigations indicate existing habitats above artificial barriers are suitable for spawning and rearing of *O. mykiss*, as evident by the finding of young-of-the-year and older juvenile rainbow 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 because 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 Wildlife (2006), Thomas R. Payne and Associates (2005).

With regard to the amount of suitable steelhead habitat above artificial barriers, the findings of fishery investigations and habitat evaluations indicate the existence of hundreds of miles of stream network across the Core 1 populations, though some reaches may be impacted by development or land uses practices, and require restoration Such areas will require evaluation on a case-by-case basis as part of any proposal to re-establish access. Numerous streams within Core 1 watersheds provide an extensive habitat 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, 1998, 1997, 1996, Nelson *et al*. 2006a, 2006b, 2005a, 2005b, Thomas R. Payne and Associates 2004, 2001, Hagar 2001, Londquist 2001, D. W. Kelley & 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. However, each anthropogenic barrier must be assessed on a case-by-case basis. For example, some dams and associated reservoirs within the SCCC DPS such as Uvas Dam on Uvas Creek, San Antonio and Nacimiento Dams within the Salinas River watershed, and the Los Padres Dam on the Carmel River, are important parts of a regional water supply system, and their modification or management must take into account their existing and future functions. Additionally, as noted previously, restoring access to habitats above anthropogenic barriers, will potentially entail controlling or eliminating non-native species established in reservoirs above dams, and in some cases where habitat above dams has been degraded, restoration of habitat conditions (*e.g.*, riparian cover, instream habitat complexity, including adequate spawning substrate).

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 experience gained in this effort has led to a growing understanding of the technical, logistical and regulatory issues necessary to effectively and efficiently remove or modify fish passage habitat and restore habitat characteristics. 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), 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), Babbitt 1998, Williams and Wolman (1984).

Regionally, NMFS has collaborated with project proponents on a variety of fish-passage projects that have involved removal or modification of highway structures, diversions, or dams 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. These dams are being removed to allow anadromous salmonids natural access to historical spawning and rearing habitats (Capelli 2007, Wunderlich *et al*. 1994). Where dams are not removed, existing fish passage facilities may be required to be up-graded, or where no fish passage facilities exist, the dam may be retrofitted to provide effective fish passage, both for upstream and downstream migrating fish.

With regard to the expected success from restoring steelhead migration to historical habitats, making fish passage 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 is anticipated steelhead productivity will increase substantially, and therefore contribute to the resilience of the population.

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 and Joyce 2004, Thrower *et al*. 2008, 2004a, 2004b). Even today, large adult *O. mykiss* leave the freshwater lakes that have formed behind dams (such as Whale Rock Reservoir on Old Creek in San Luis Obispo County), 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, when reduced, it can adversely affect evolutionary processes and impair the ability of a population to adapt to spatial or temporal environmental changes. Populations with low density (*i.e.,* few fish per mile) are susceptible to low growth rates and loss of genetic diversity, and are more likely to be adversely affected by widely fluctuating environmental conditions, including longer term climate change.

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 currently impaired conditions. For example, extended periods of no or low rainfall can limit migratory conditions and preclude steelhead from reaching freshwater spawning areas. 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 *successfully* 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 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 2008, Wilson 1971), a larger number of individuals decrease the risk of extinction.

7.5 RESTORING STREAMFLOW REGIMES IMPACTED BY DAMS, DIVERSIONS, AND GROUNDWATER EXTRACTIONS

Recovery actions for specific watersheds across the SCCCS Recovery Planning Area provide that the "natural" pattern and magnitude of streamflow must be restored (or approximated) if threatened steelhead are to be recovered. Generally, this recommendation is based on the flow-related dependency of many features of aquatic habitat and the inextricable connections among streamflow, riverine habitat, and steelhead life history, habitat requirements, and population metrics (*e.g*., Harvey *et al*. 2006, Spina *et al*. 2005, Kondolf 1987, Poff *et al*. 1997, Ligon *et al*. 1995, Barnhart 1986, Shapovalov and Taft 1954).

Steelhead have evolved strategies such as opportunistic migration and utilization of available spawning habitat throughout a watershed in response to rainfall-induced streamflow events in the SCCCS Recovery Planning Area. Artificial modification of streamflow regimes, particularly reduction of the duration, frequency, and magnitude of streamflows and hydrologic connectivity between the marine and estuarine environment and upstream spawning and rearing tributaries, has adversely impacted the steelhead SCCCS DPS. The significance of this threat is reflected in the CAP Workbooks, which explicitly identify groundwater extraction, water diversions, and water storage facilities as a Very High or High Threat in most watersheds. Only the smaller streams within the Big Sur Coast BPG appear to be generally unaffected by extensive water development (though groundwater extraction is ranked as a Very High threat in two of these watersheds – San Jose Creek and Big Sur River). See threat source rankings tables in Chapters 9 through 12.

Although there is a general understanding of the ecological effects of modified flow regimes on steelhead, a level of uncertainty still remains. In particular, understanding how fish movement and utilization of microhabitats is impaired by temporal and spatial variation in connectivity between different parts of a watershed is limited. In the SCCC Recovery Planning Domain streamflows during the dry season are highly variable and reduced further by water development to meet human demands. As a result, an improved understanding of the relationships between streamflow and the maintenance of steelhead populations is necessary for the recovery of the SCCCS DPS (Booth *et al*. 2013, Grantham 2013, 2010, Kondolf *et al.* 2012, Grantham *et al.* 2012, Nislow and Armstrong 2011, Bond *et al*. 2010, Anderson *et al.* 2006, Acreman and Dunbar 2004, Annear *et al.* 2009, 2004, Bayley 2002, Hatfield and Bruce 2000, Richter *et al.* 1997, Castleberry *et al*. 1996).

The role of streamflow in the life-history of anadromous *O. mykiss* is complex, but can be divided into two basic categories: 1) creation and maintenance of essential freshwater habitat, principally for spawning and rearing, and 2). support migratory behavior and ecology for both adults and juveniles in freshwater habitats. Knowledge of this role contributes to a broader understanding of why restoring the natural streamflow regime is a prerequisite for recovering threatened steelhead. Following the description of this role, we provide considerations for restoring the natural pattern and magnitude of streamflow.

Creation and maintenance of essential freshwater habitat.

The erosive forces of streamflow operating on underling geology and land forms, and in conjunction with vegetative cover, is principally responsible for creating a wide variety of habitats used by steelhead to complete the freshwater phase of their life-cycle. The creation of basic stream channel morphologic features (pools, runs, glides, undercut banks, gravel bars, *etc*.), and lagoon sandbar formation and breaching is an important function of streamflow. Other basic functions of streamflow include the flushing of fine sediments, distribution of nutrients, recruitment and sorting of spawning gravels and large woody debris, and maintenance of riparian vegetation (Meissen *et al.* 2013, Wilcox and Shafroth 2013, Rich and Keller 2013, 2011, Leigh *et al.* 2010, Harrison and Keller 2006, Fausch *et al,* 2001, Montgomery and Buffington 1997, Poff *et al.* 1997, Kondolf and Wilcock 1996, Reeves 1996, Leopold 1994, Calow and Petts 1992, Bjornn and Reiser 1991, Resh *et al.* 1988, Faber *et al*. 1989, Knighton 1984, Keller and Swanson 1979, Reid and Wood 1976, Hynes 1970).

Streamflows control a number of features of aquatic habitats that are of critical importance to the freshwater phase of the steelhead life cycle. For example streamflows in combination with the physical channel geometry and roughness control the velocity, depth and volume of water within various instream habitats, and consequently, the amount, suitability, and connectivity of habitat available to steelhead, including juvenile steelhead rearing instream. Streamflow patterns are closely associated with water quality, including temperature, dissolved oxygen, the concentration of pollutants, and are responsible for the production and delivery of food sources for juvenile steelhead, affecting their growth rates and survival (Grantham *et al.* 2012, Nislow and Armstrong 2012, Wegner *et al.* 2011, Annear *et al.* 2004, Myrick and Cech 2004, Zedonis and Newcomb 1997, Bjornn and Reiser 1991). Overall, streamflow creates and maintains living space and related features for steelhead that are essential for long-term growth and survival of this species.

Understanding the relationships between low flow conditions during the dry season (late spring through late fall) and juvenile steelhead survival is particularly important in California where natural low flows often coincide with peak water extractions for out of stream uses such as agricultural irrigation, either through direct diversion or groundwater withdrawals. Field investigations in central California have shown a strong correlation between summer flows and survival of oversummering juvenile steelhead (Grantham *et al.* 2012, Kondolf *et al*. 1997).

Support for migratory behavior and ecology of adult and juvenile steelhead in freshwater habitats.

Steelhead are a migratory species that require a properly functioning migration corridor for moving to and from the marine and freshwater environment (and between stream reaches within the freshwater environment) to complete their life cycle. In this context, the functional value of hydrology in the migratory behavior and ecology of steelhead in South-Central California watersheds can be best understood by considering the following:

(i) In arid regions, rainfall events can trigger periods of elevated discharge that serve as the primary environmental cue for migration of steelhead into, within, and out of a watershed. As such, the elevated discharge promotes migration opportunities for this species that would otherwise not exist;

(ii) Streams in South-Central California watersheds can experience high runoff of short duration, and peak counts or observation of steelhead migrants coincide with elevated discharge steelhead. This underscores the functional value and importance of periods of elevated discharge for migration of steelhead in this region;

(iii) Steelhead show positive rheotaxis (facing into a current) and therefore more easily navigate streams at higher rather than lower discharge;

(iv) Migration synchronized to the seasonal occurrence of elevated streamflows (timing) is adaptive and increases the chance of species survival (*e.g.,* Lytle and Poff 2004); and,

(v) Steelhead do not enter and subsequently migrate upstream throughout a watershed as a single "run," but rather enter river systems in "waves," with each rainfall-induced discharge event prompting more steelhead to enter a river, and in-river adults to migrate farther upstream, ultimately to the upper spawning reaches. This behavior reflects an evolutionary adaptation to the rainfall and runoff pattern of the South-Central California watersheds, and underscores the ecological importance of frequent rainfall events, of extended duration, and the unimpaired movement of fish throughout the watershed.

Considerations for restoring the natural pattern and magnitude of river discharge to support freshwater steelhead migratory, spawning and rearing habitats.

Steelhead morphology, physiology, and behavioral characteristics have been shaped by biotic and environmental influences over ecological time to exploit and cope with naturally varying seasonal instream flow conditions. However, evidence indicates that artificial changes to the natural streamflow pattern and magnitude can preclude steelhead from completing essential life-history functions. The SCCCS Recovery Plan identifies a series of critical recovery actions for individual Core watersheds. One of the most fundamental actions for the recovery of the species is the regulation of surface and subsurface water diversions and extractions to ensure that the pattern and magnitude of surface flows provide the essential habitat functions to support the life history and habitat requirement of adult and juvenile steelhead; this includes the provision of streamflows necessary to support steelhead migration, spawning and rearing (see Tables 9-3 through 12-3 in Chapters 9-12).

In general, while it is often not possible to re-create original flow conditions, the closer that the managed ("restored") streamflow regime mimics the natural or pre-impact streamflow regime, the more likely the managed streamflow regime will meet the life history requirements of fishes and perpetuate a viable steelhead population indigenous to a particular watershed (Crow *et al.* 2012, Auerbach *et al.* 2012, Poff and Zimmerman 2010, Dunlop *et al*. 2009, Enders *et al*. 2009, Jowett and Biggs 2009, Kendy *et al.* 2009, Propst *et al.* 2008, Lytle 2004, King *et al.* 2003, Bunn and Arthington 2002, Poff *et al* 1997).

Providing a restored streamflow regime that closely resembles the pre-modified streamflow regime in a watershed requires that certain features of the pre-modified streamflow regime be known and understood in sufficient detail (including long-term natural variations in the flow regime). While a number of streamflow-assessment and development methods exist, only those methods that are capable of guiding derivation of a pattern and magnitude of streamflow that reflects or approximates the natural or pre-impact pattern and magnitude of streamflow are expected to promote recovery of threatened steelhead. In contrast, methods that promote the establishment of "minimum streamflows" are not expected to favor recovery of this species because these approaches generally fail to produce the kinds of hydrologic features and conditions that are necessary for unrestricted expression of life history traits and fulfillment of habitat requirements. Many of the existing methods have not been specifically developed for anadromous steelhead (Milner *et al.* 2012, Moyle *et al.* 2011, Palau *et al.* 2010, Deitch *et al.* 2012, 2009, Poff *et al.* 2009, Orth and, Arthington *et al.* 2007, Huckstorf *et al.* 2008, Murchie *et al.* 2008, Orth 2006 1987, Acreman and Dunbar 2004, Rosenfeld 2003, Tharme 2003, Marmulla 2001, Reiser *et al*. 1989, Estes and Osborn 1986, Orth and Maughan 1982, Wesche and Rechard 1980).

One of the most widely used is the Instream Incremental Flow Method (often referred to as "IFIM") and its microhabitat component model, the Physical Habitat Simulation Model. The IFIM method provides a structured process for identifying habitat information needs, target species, study sites, conducting hydraulic and habitat modeling, determining limiting factors, and evaluating management alternatives (Bovee *et al*. 1998, Stalnaker *et al.* 1995, Milhous *et al*. 1984, Bovee 1992, 1986). The method, however, is generally applied to selected river or stream reaches, and not to entire watersheds, and was not specifically designed for anadromous fishes, or habitat forming and sustaining fluvial processes which operate on watershed-wide and extended time-scales (such as spawning gravel recruitment and pool formation), which may vary substantially with geographic location and individual watershed characteristics. The literature reviewing the limitations of this method is extensive, though there is no consensus currently on how its methods may apply to anadromous salmonids, and steelhead in particular (Moyle *et al.* 2011, Souchon and Capra 2004, Parasiewicz 2007, 2003, 2001, Payne 2003, Hatfield and Bruce 2000, Armour and Taylor 1991, Gore and Nestler 1988, Orth 1987, Scott and Shirvell 1987, Shirvell 1986, Mathur, *et al*. 1985, Orth and Maughan 1982).

The approach that NMFS applies when developing streamflow recommendations for steelhead in south-central and southern California generally involves quantitatively estimating the unimpaired pattern (*i.e.,* timing, frequency, duration, and rate-of-change) and magnitude of streamflow in the subject waterway. Specific numerical metrics are gleaned from the hydrologic estimates and subsequently used in collaboration with stakeholders as a basis to guide development of the streamflow recommendation. The principal benefit of this approach involves using a knowledge of the natural or pre-impact pattern and magnitude of streamflow, and therefore the very characteristics and conditions that are responsible for evolution of the species' essential life-history traits and pre-impact population abundances and population growth rates, to guide development of the streamflow recommendation. Thus, while the specific relationship between steelhead population viability in the planning area and streamflow magnitude continues to emerge, estimates of the unimpaired pattern and magnitude of streamflow can be used as meaningful ecological surrogates for promoting viability.

It is widely recognized that water is a limited resource. As a result, the approach NMFS has adopted in its efforts to restore the natural streamflow regime accounts for the arid climate and related limited availability of water. To ensure that naturally limited water resources are allocated wisely and efficiently, NMFS' streamflow recommendations, including water releases from water projects, reflect criteria that promote synchrony of water releases with natural hydrologic conditions and the instream timing of specific steelhead life stages. Based on NMFS' experience collaborating with stakeholders within the SCCCS Recovery Planning Area and throughout California, objectives guiding water-management needs and recovery of the species are compatible when stakeholders are willing to engage in effective collaboration and innovation.

NMFS recognizes that restoration of the "natural" streamflow regime may not be possible or practical in certain waterways owing to the complexity of modifying water-management operations that local communities and agricultural activities rely upon. However, this expectation should not preclude stakeholders from collaborating with NMFS, and other resource managers such as the CDFW, in efforts to define streamflow recommendations that represent an approximation of the natural or unimpaired streamflow regime.

Stakeholders should be aware that while reaching agreement on an ecologically meaningful streamflow recommendation represents an important initial step for promoting recovery of steelhead, much uncertainty regarding the response of individual populations to a new streamflow regime typically exists at the onset. For example, numerical increases in abundance of steelhead smolts or unimpaired migration rates of immigrants and emigrants, will largely be unknown. To address these and other uncertainties, an adaptive management approach based on the collection of empirical data will be essential.

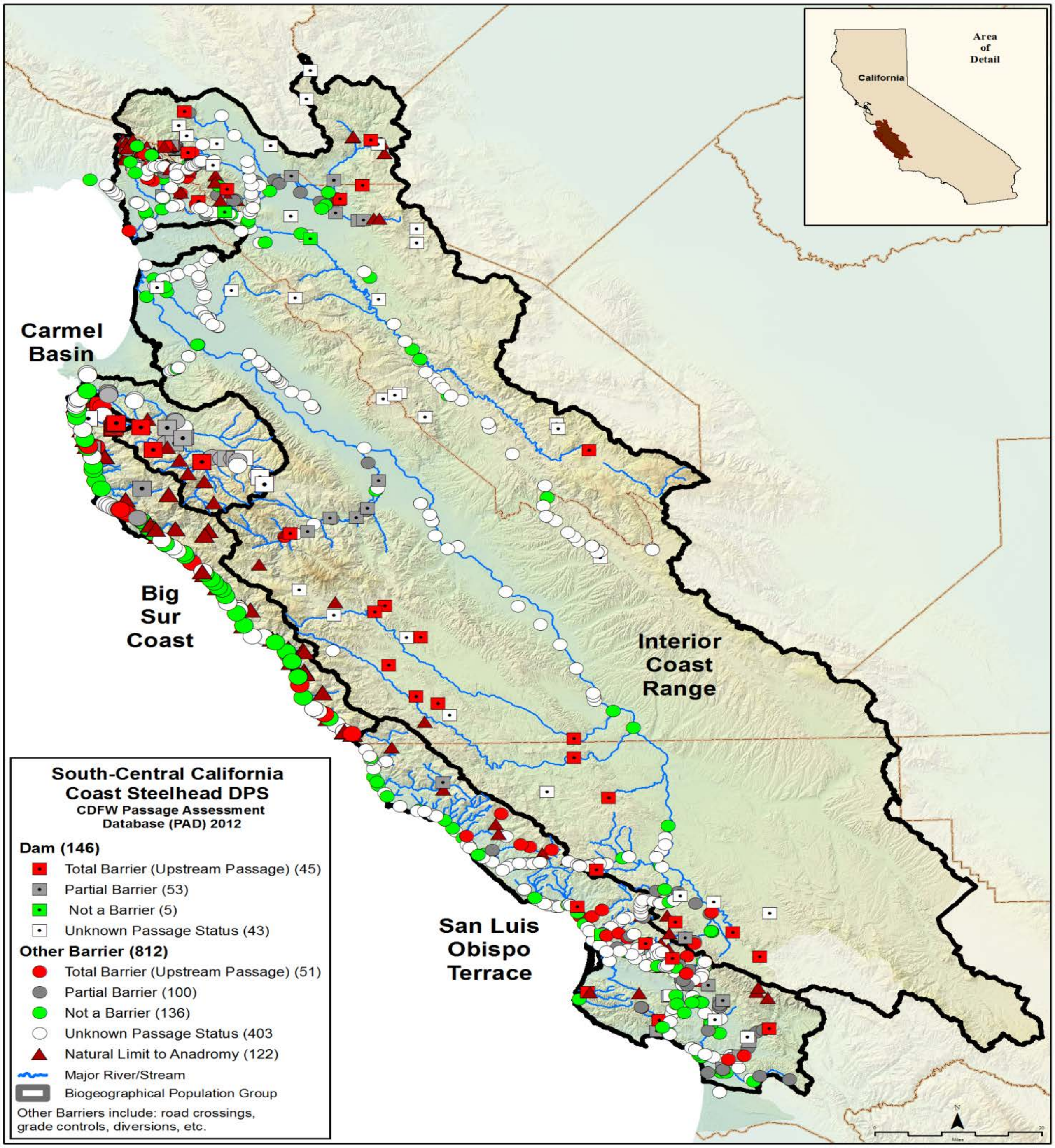

Figure 7-1. South-Central California Coast Steelhead DPS Known and Potential Fish Passage Impediments. Note: the status of fish passage barriers is in flux, with existing ones being removed or modified, while new ones may be installed, or discovered through updated inventories; a current list of priority fish passage impediments can be found on the California Department of Fish and Wildlife website: http//www.cafishpassageforum.org/

7.6 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; or 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; see also Bower *et al.* 2004):

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 historical 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, specific recovery actions within watersheds of each of the five BPGs which are intended to address and ameliorate specific adverse effects from projected climate change and related oceanic conditions were identified. Identified actions 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 to ensure the species will persist over an extended period of time, including long-term (decadal) marine cycles. SCCCS 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 (see Chapter 5, South-Central California Coast Steelhead and Climate Change).

7.7 CRITICAL RESEARCH NEEDS FOR RECOVERY

Successful implementation of the recovery plan and measurement of the species' progress towards recovery requires two additional critical elements: 1) population abundance monitoring (including rearing juveniles, smolts, and returning adults) within core watersheds and, 2) a variety of 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 improve 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 smolts which will exhibit an increased survival rate in the marine environment, 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 affecting 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 further discussion.