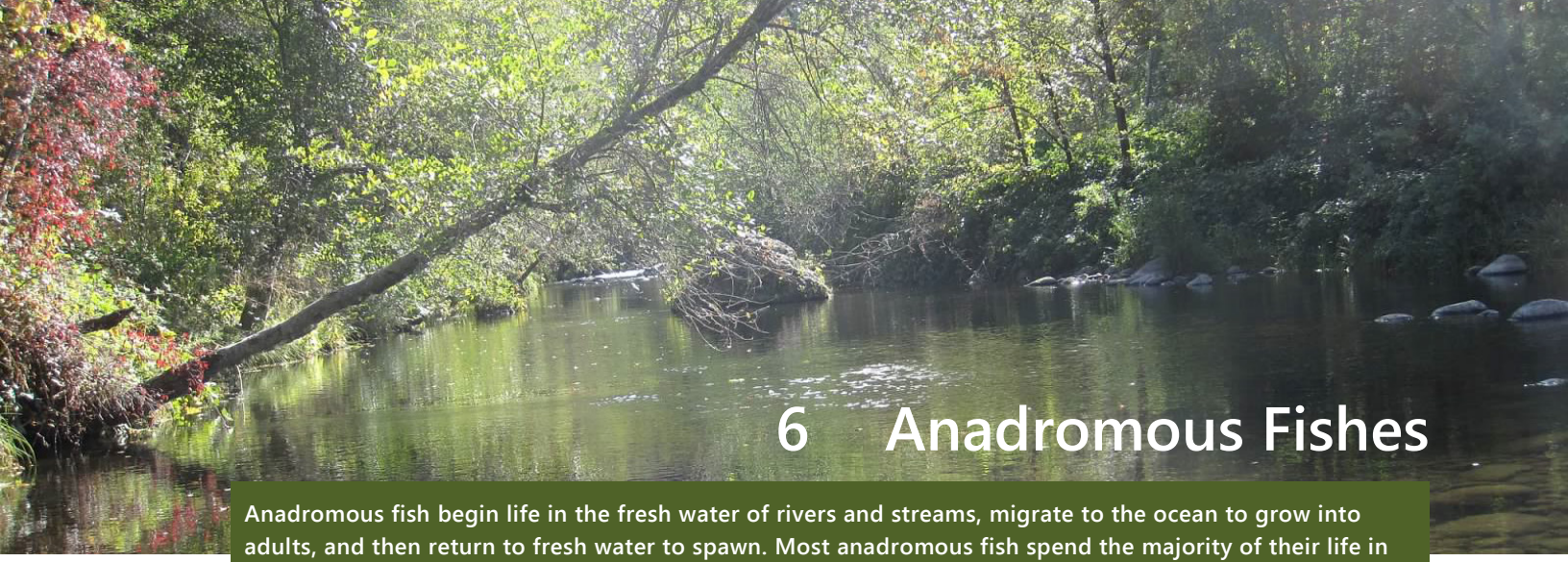


6 Anadromous Fishes

Anadromous fish begin life in the fresh water of rivers and streams, migrate to the ocean to grow into adults, and then return to fresh water to spawn. Most anadromous fish spend the majority of their life in marine environments and travel great distances between their marine habitat and spawning rivers or streams. Because the geographic ranges of anadromous fish span many of the provinces developed for SWAP 2015, the organization of conservation strategies by hydrologic unit or even province does not adequately address their conservation needs. As such, conservation strategies for anadromous fish have been developed separately, as discussed in this chapter, to capture their full life cycle and geography.

Chapter 6 has been prepared by Kevin Shaffer, CDFW Program Manager, Anadromous Management and Conservation, Fisheries Branch

6.1 Vision

CDFW has a fundamental objective for California's native anadromous fish species and fisheries: to manage and conserve these amazing species and the near-shore, estuary, and river habitats they occupy for their ecological significance, recreation, commercial, and tribal values and for enjoyment by current and future residents and visitors.

This chapter describes California anadromous fishes—Chinook and coho salmon, steelhead and cutthroat trout, green and white sturgeon, eulachon, longfin smelt, and Pacific lamprey. It also discusses their estuarine and freshwater distribution; crucial aspects of their ecology; the pressures they face; and fundamental conservation targets and strategies to protect, enhance, and manage their populations, habitat, and ecological processes.

At the center of CDFW's recommendations and future actions are six core principles. For each species and ecoregion and for the anadromous fish guild and state as a whole, these principles will guide CDFW in its actions and collaborations with federal, state, private, and public partners:

- *Water Conservation* - identifying and implementing water management strategies designed to provide sufficient instream flow quality and quantity to meet suitable fish and habitat needs;
- *Habitat Restoration* - restoring and enhancing physical and water habitat, restoring unimpeded flows, securing sustainable ecological processes, addressing future environmental stresses (sea-level rise, increased water temperature, prolonged drought), and eradication or control of invasive species;
- *Species Recovery* - identifying and implementing actions to recover species until protections under state and/or federal endangered species act listing are no longer warranted;

- *Angling Opportunities* - ensuring the public has appropriate recreational, commercial, and tribal anadromous fisheries harvest opportunities in ocean, estuary, and river waters of the state;
- *Hatchery Management* - improving the science of hatchery aquaculture and management, and ensure hatchery practices maximize fish health and diversity, while minimizing adverse effects on native stocks and river habitat; and
- *Promoting Partnerships* - pursuing inter-state, agency, tribal, private, and academic partnerships and cooperative efforts to conserve and manage California anadromous species.

6.2 Goals and Objectives - Targets and Strategies

Conservation targets pertinent to anadromous fish species are a combination of habitat, fish species, and ecological processes. Targets and strategies are proposed at two scales: statewide and salmonid ecoregional. In each case, the priority targets are limited to three per area, and the priority strategies are limited to three per target. It needs to be noted that the targets and strategies are but a subset of vital needs and actions known for anadromous species. They are a result of knowledge obtained from scientific studies and experience garnered over decades. They are based on the principle that geographic and temporal scales are pivotal to anadromous fish population viability, and that sustaining ecological processes is the central means to recovering and supporting fish populations and fisheries.

In Section 6.6, Challenges to Anadromous Species and Watersheds, both the targets and their strategies are briefly discussed. The listed actions represent CDFW's primary proposals for collaboration and implementation with state and federal agencies, private and non-governmental partners, Native American tribes, and the academic community. They constitute activities for immediate implementation and long-term commitment, and can be implemented at different scales and rates in each salmonid ecoregion, depending on available resources, interest, and necessity.

6.3 Anadromy and Species Diversity in California

California is home to several species of fishes characterized by spending the majority of their lives in estuarine or marine waters and returning to fresh water to spawn. This life-history strategy in fishes is known as anadromy. Native anadromous fishes are represented by jawless lamprey (*Petromyzontidae*) and cartilaginous, bony plated sturgeons (*Acipenseridae*) to the highly migratory salmon and steelhead trout (*Salmonidae*), and the small, short-lived smelts (*Osmeridae*). Some of these are widely recognized and managed for their commercial and sport values, while others are more obscure and seldom seen by the public.

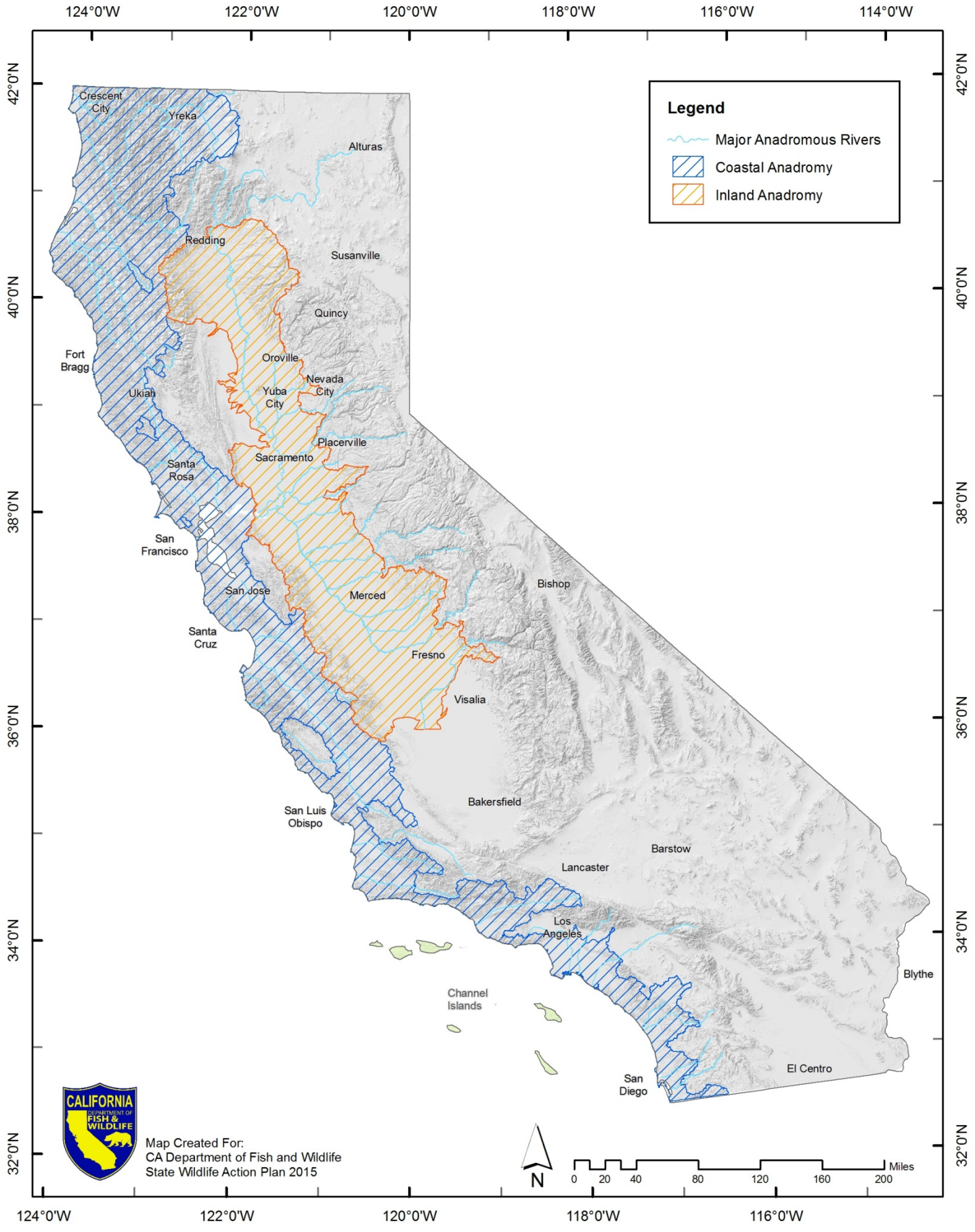
Coho salmon, Matt Elyash, CDFW

Anadromous fishes are widely distributed in California, occurring in coastal watersheds from San Diego to Del Norte counties, the San Francisco Bay system, Sacramento-San Joaquin Delta, and rivers and streams of the Central Valley (Figure 6.3-1). For each of these species, California represents the southern limit of the species range along the west coast of North America. Anadromous species with viable populations occurring in California include two species of salmon (Chinook and coho), two species of trout (steelhead and coastal cutthroat), two species of sturgeon (green and white), two species of smelt (longfin and eulachon), and Pacific lamprey.

Several of the species are separated into unique population assemblages, referred to as Evolutionarily Significant Units (ESU; e.g., salmon and steelhead trout) or Distinct Population Segments (DPS; e.g., sturgeon and eulachon). The status and trend of populations, condition and function of habitat and ecosystem processes, and pressures and limiting factors of these species are determined at the ESU and DPS scale. Such evaluations are used in assessing the need for protection of each species. In California, most ESUs and DPSs are now formally protected by either the California or federal Endangered Species Act (CESA; ESA), or both (Table 6.3-1).

Estuarine and riverine ecosystems across California are utilized differentially by California's anadromous fishes; however, they all rely on these ecosystems as critical habitat to complete their life history strategy. These ecosystems are vital for egg incubation, juvenile rearing, emigration of young to estuaries or the ocean, and then immigration and spawning of adults (Table 6.3-2). For some species, relatively short periods of time are spent in freshwater (e.g., eulachon, Chinook salmon), while for other species (e.g., Pacific lamprey, steelhead trout), in earlier life stages they spend years in fresh water. The same divergence is seen in estuaries, where salmonids spend vital, relatively limited time in estuaries, and sturgeon and longfin smelt spend a majority of their lives in deltas, bays, and estuaries.

Two species of salmon, Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) spawn and rear in watersheds in the northern half of California (Figure 6.3-2). Chinook salmon live three to six years, most of that time in the ocean. Returning adults are in overlapping groups of a similar age, i.e., cohorts. Coho salmon typically live three to four years and return in distinct cohorts, having little overlap between generations of fish from the same watershed.



Data Source: California Ecoregions (Wild Salmon Center, 2009)
Salmonid ESU and DPS(NOAA Fisheries, 2013)

Figure 6.3-1 Limits of Anadromy in California

Table 6.3-1 Anadromous Fish Species in California and Salmonid Ecoregions

Common Name	Scientific Name	Endangered Species Act Protection		California Salmonid Ecoregions					
		State	Federal	North Coast	North Central Coast	Klamath River	Sacramento-San Joaquin Rivers	South Central Coast	Southern California Coast
CHINOOK SALMON	***Oncorhynchus tshawytscha***			**X**	**X**	**X**	**X**		
Central Valley fall-run ESU							X		
Central Valley late fall-run ESU							X		
Central Valley spring-run ESU		X	X				X		
Central Valley winter-run ESU		X	X				X		
California Coastal ESU			X	X					
Upper Klamath-Trinity Rivers Basin ESU					X	X			
Southern Oregon/Northern California Coastal ESU				X					
COHO SALMON	***Oncorhynchus kisutch***			**X**	**X**	**X**		**X**	
Southern Oregon/Northern California Coasts ESU		X	X	X	X	X			
Central California Coast		X	X		X			X	
CHUM SALMON [1]	***Oncorhynchus keta***								
PINK SALMON [1]	***Oncorhynchus gorbuscha***								
STEELHEAD TROUT	***Oncorhynchus mykiss***			**X**	**X**	**X**	**X**	**X**	**X**
California Central Valley			X				X		
Southern California DPS			X						X
South-Central California DPS			X					X	
Central California Coast DPS			X		X			X	
Northern California					X				
Klamath Mountains Province DPS						X			
COASTAL CUTTHROAT TROUT	***Oncorhynchus clarkii clarkii***			**X**	**X**	**X**			
SOUTHERN GREEN STURGEON DPS	***Acipenser medirostris***		**X**	**X**	**X**	**X**	**X**		
WHITE STURGEON	***Acipenser transmontanus***				**X**	**X**	**X**		
PACIFIC LAMPREY	***Entosphenus tridentatus***			**X**	**X**	**X**	**X**	**X**	**X**
LONGFIN SMELT	***Spirinchus thaleichthys***	**X**	**X**[2]		**X**	**X**	**X**		
EULACHON	***Thaleichthys pacificus***		**X**		**X**	**X**			

1 Incidental to California; with no established populations or consistent occurrence.

2 Warrants protection under the federal Endangered Species Act. However, U.S. Fish and Wildlife Service determined that listing is precluded at this time because of the need to address other higher priority listing actions

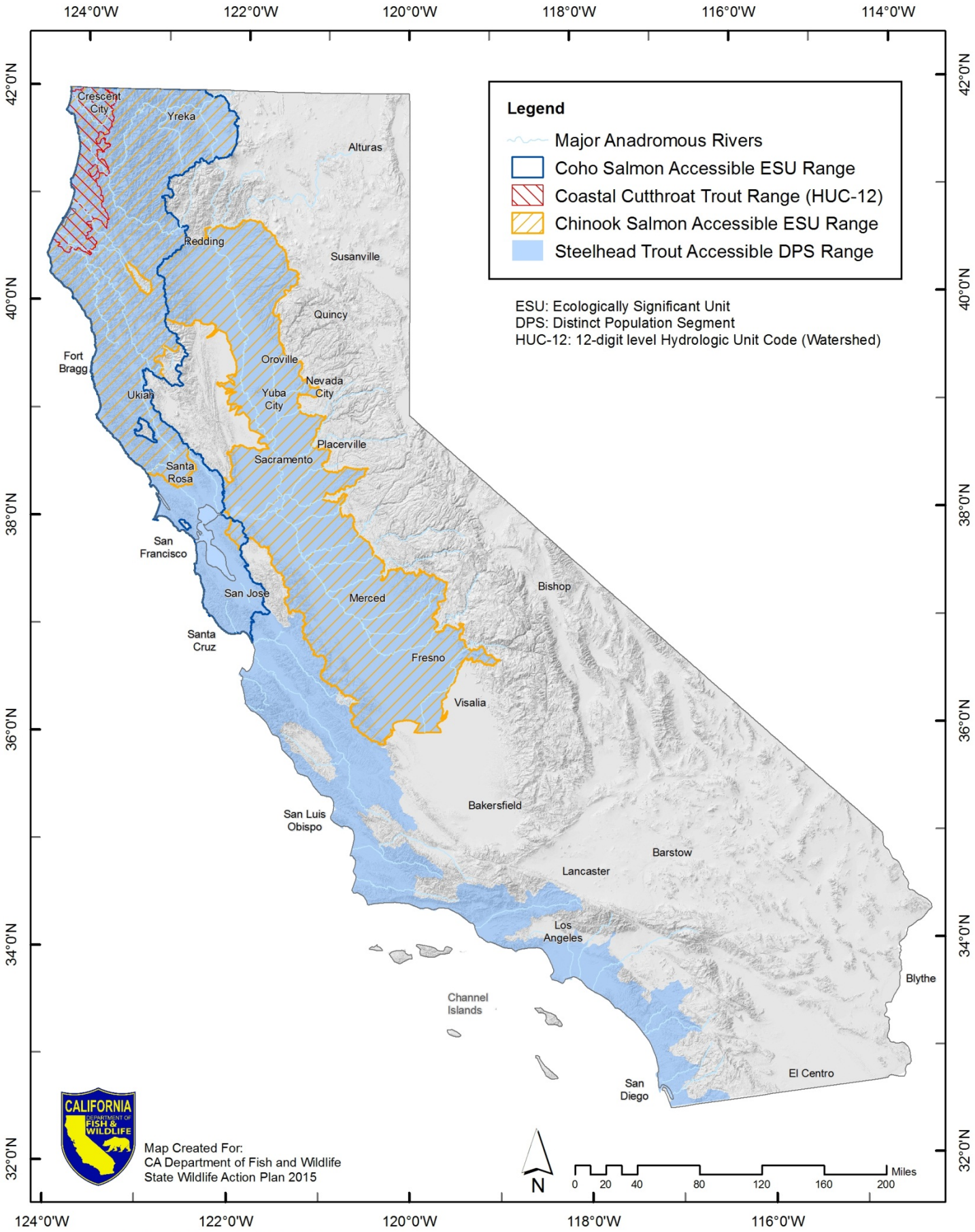
Table 6.3-2 Annual Presence and Use of Freshwater Habitat of Selected Anadromous Fish Species and Runs in Different Major Watershed Drainages in California

Anadromous species, run, and drainage	Life History	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fall-run Chinook salmon, Central Valley	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Late fall-run Chinook salmon, Central Valley	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Winter-run Chinook salmon, Central Valley	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Spring-run Chinook salmon, Central Valley	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Steelhead trout, Central Valley	Adult spawning migration												
	Spawning												
	Adult outmigration												
	Egg incubation												
	Rearing												
	Juvenile outmigration												
Coho salmon [generalized for both Evolutionary Significant Units]	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing												
	Juvenile outmigration												
Fall-run Chinook salmon, Klamath-Trinity Rivers Basin [generalized for lower and middle, upper Klamath, Trinity rivers and tributaries]	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Spring-run Chinook salmon, Klamath-Trinity Rivers Basin [generalized for lower and middle Klamath, Trinity rivers and tributaries]	Adult spawning migration												
	Holding to spawn												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Winter-run steelhead trout, Klamath-Trinity Rivers Basin [generalized for lower and middle Klamath, Trinity rivers and tributaries]	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												

Table 6.3-2 Annual Presence and Use of Freshwater Habitat of Selected Anadromous Fish Species and Runs in Different Major Watershed Drainages in California

Anadromous species, run, and drainage	Life History	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coastal cutthroat trout	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
White sturgeon, Central Valley	Adult river spawning												
	Adult presence (delta and bays)												
	Egg incubation												
	Rearing (river, delta, bay)												
	Juvenile outmigration												
Green sturgeon, Sacramento-San Joaquin Rivers	Adult spawning migration												
	Spawning												
	Egg incubation												
	Delta rearing												
	Juvenile outmigration												
Green sturgeon, coastal rivers	Adult spawning migration												
	Spawning												
	Egg incubation												
	Rearing & juvenile outmigration												
Pacific lamprey, coastal rivers	Adult spawning migration												
	Spawning												
	Adult holding												
	Egg incubation												
	Rearing & juvenile outmigration												
Longfin smelt, Sacramento-San Joaquin Bay Delta	Adult and sub-adult occurrence (bay and nearshore)												
	Spawning (delta)												
	Egg incubation (delta)												
	Rearing (larvae)												
	Rearing (juvenile; bay & delta)												
Eulachon	Adult and sub-adult occurrence (bay and nearshore)												
	Adult spawning migration												
	Spawning												
	Egg incubation (delta)												
	Rearing (nearshore)												

Note: Black denotes greatest magnitude with dark grey and light grey indicating moderate and lesser magnitudes, respectively.



Data Sources: Salmond ESU and DPS (NOAA Fisheries 2013); Coastal Cutthroat Trout Range (Coastal Cutthroat Trout Interagency Workgroup (2014)

Figure 6.3-2 Salmonid Distribution

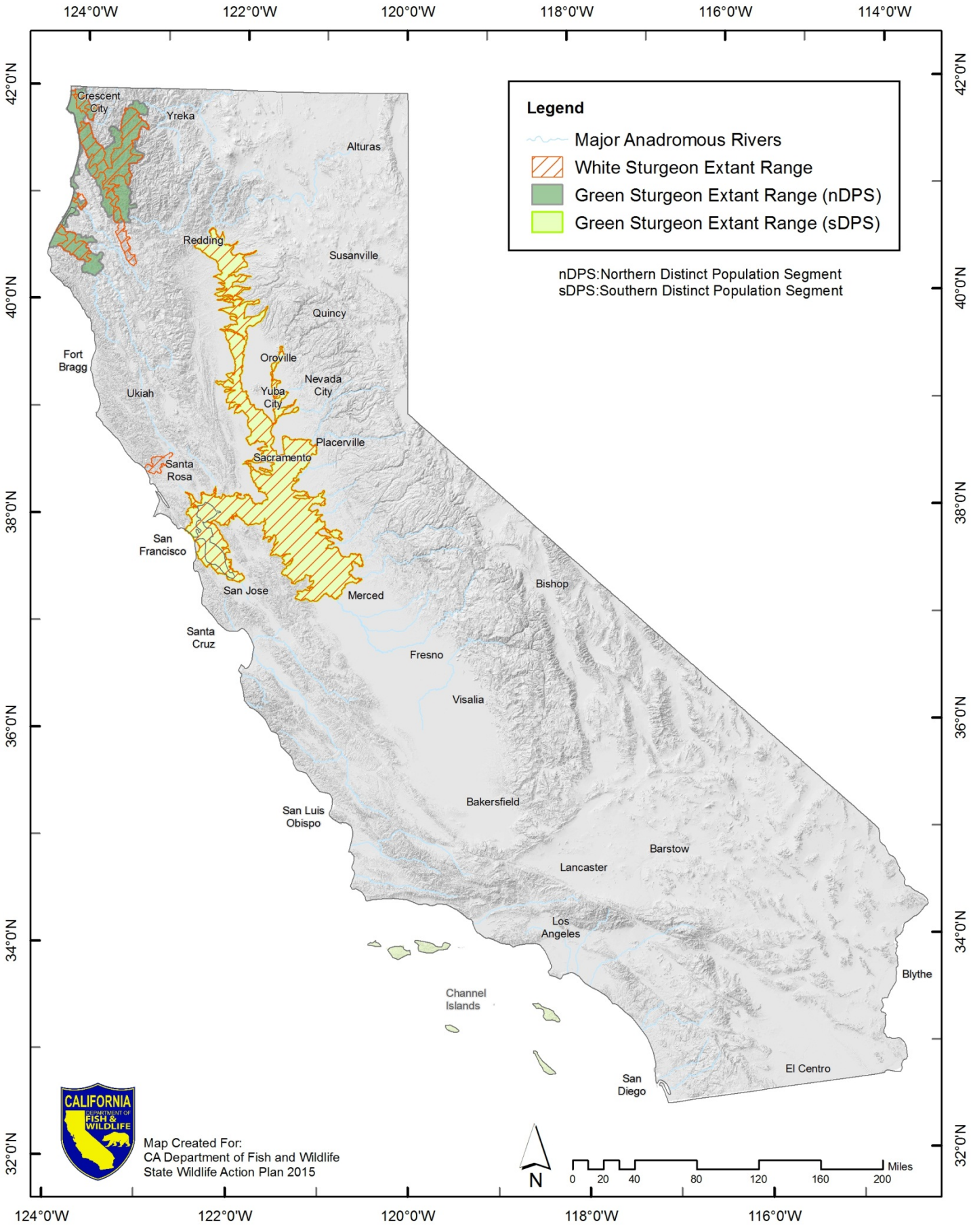
Two ESUs constitute coho salmon and occupy coastal watersheds from San Cruz to Del Norte counties and in the Klamath River, occurring in three salmonid ecoregions (North-Central Coast, North Coast, and Klamath River). Coho salmon in both these ESUs are listed and inland and ocean fisheries for coho salmon are not allowed in California. Chinook salmon are a physically larger and more broadly distributed species, occurring both along the coast and throughout the Central Valley. One ESU along the coast and two in the Central Valley, (i.e., spring and winter-run) are protected. There are ocean, estuary, and inland fisheries for fall-run Chinook salmon in both the Central Valley and Klamath River Ecoregions.

Chinook salmon are divided into seasonal stocks, based upon the time of year that adults return to rivers to spawn. In the Central Valley, three distinct "runs" (fall, winter, and spring) are identified for their evolutionary significance. Late fall-runs are recognized as being an important life strategy but grouped with the fall run ESU. In the Klamath-Trinity Rivers Basin, fall and spring runs are currently recognized life history strategies in a single ESU. There is a coastal ESU of Chinook salmon which occurs along the coast from the Russian River in Sonoma County to Redwood Creek in Humboldt County.

Pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*) periodically occur in streams or rivers in California but are not documented as having viable populations or regular occurrence. Chum and Pink salmon have been documented returning to Blue Creek, Klamath River by the Yurok tribe. Neither species are addressed in this chapter.

There are two species of trout in the state, steelhead trout (*O. mykiss*) and coastal cutthroat (*O. clarkii clarkii*). Unlike salmon, trout adults can spawn more than once. Coastal cutthroat trout have one of the smallest ranges, occurring only in watersheds of the North Coast and the most northern waters of the North-Central Coast Ecoregions. Steelhead trout, on the other hand, have the largest range in California, occurring in all five salmonid ecoregions. Steelhead trout have a particularly complex life history, with fish in each ESU spending variable time in fresh and marine waters. In addition, the steelhead trout are the anadromous form of O. mykiss, and there is a resident form, commonly known as rainbow trout. Individual offspring from either form can assume the life history strategy of the other. Meaning some steelhead trout offspring mature into resident form fish, and some resident form fish offspring mature into the anadromous form. These factors likely contribute to this species having the broadest distribution and range.

Green sturgeon *(Acipenser medirostris*) and white sturgeon (*A. transmontanus*) both occur in coastal waters and watersheds along the North-Central Coast and Klamath River Ecoregions and the Central Valley (Figure 6.3-3). Both species are large (e.g., white sturgeon reaching more than 13 feet (4 meters), weighing more than 1,100 pounds [500 kilograms]) and long-lived (sometimes not reaching sexual maturity after more than a decade). White sturgeon migrate to bays and estuaries, while green sturgeon enter marine waters and may migrate hundreds of miles. White sturgeon are much more common than green sturgeon in the Central Valley and constitute a recreational fishery. Green sturgeon are more common than whites in North Coast rivers and are federally protected.



Data Sources: Fish Species Extant Ranges
(UC Davis Pisces Project, 2014)

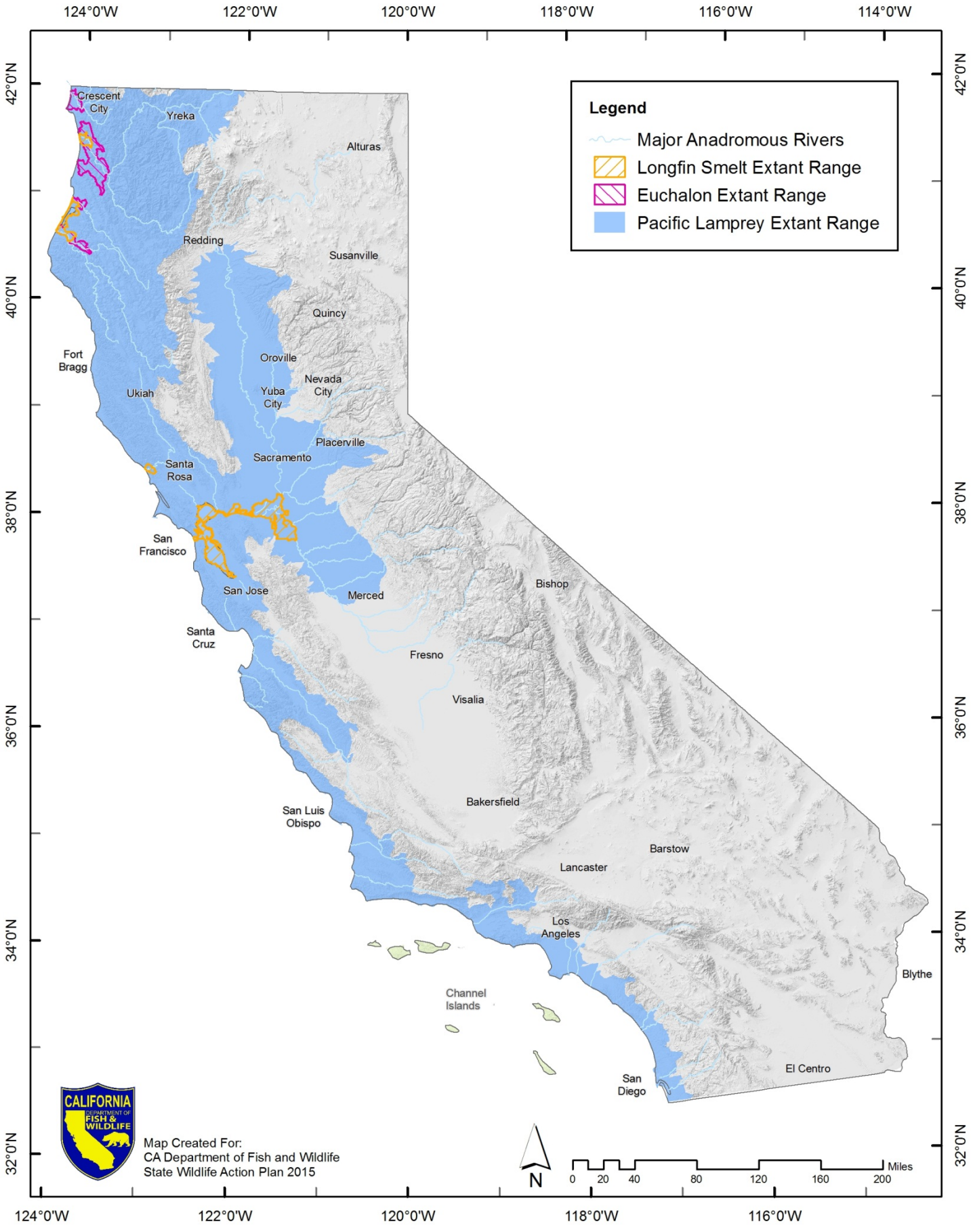
Figure 6.3-3 Sturgeon Distribution

Two species of smelt move from saline water to fresh water and back. Eulachon (*Thaleichthys pacificus*) is truly anadromous, spending one to two years in nearshore, marine waters while spawning in fresh water in the spring. These are the largest smelt in California, averaging 5-10 inches (15-20 cm) and reaching almost 12 inches (30 cm). They occur only along the north coast, known to spawn in the northern most rivers of the North-Central Coast Ecoregion and primarily in the Klamath River (Figure 6.3-4). They were once an important tribal and recreational fishery on the Klamath River. Populations have severely declined since 1990. The species is now federally protected and harvest is not allowed under California sport fishing regulations. Longfin smelt (*Spirinchus thaleichthys*) are smaller, rarely exceeding 5 inches (12 cm). It occurs along a few north coast estuaries and Humboldt Bay, as well as the San Francisco Bay/Sacramento-San Joaquin Delta complex. Longfin rarely enter nearshore, marine waters, although focused sampling for this species is rarely done. Longfin smelt are occasionally caught up and down the coast in the groundfish trawls conducted by National Oceanic and Atmospheric Administration (NOAA) Fisheries. Many one year old longfin smelt leave the San Francisco Bay and go into the ocean during their second summer (Rosenfeld 2007). There is some debate as to whether longfin smelt spawn in fresh water or brackish water, or both.

The last member of California's guild of anadromous fishes is Pacific lamprey (*Entosphenus tridentatus*). It is the member of a phylogenetically ancient group of jawless fishes. Pacific lamprey occur in coastal rivers and streams along the California coast and in the Central Valley (Figure 6.3-4). They are occasionally observed in streams south of Point Conception. Populations are also now land locked in Goose Lake and the Pit River due to construction of rim dams in the middle decades of the 20th century. Little is known about populations in the Central Valley Ecoregion. Pacific lamprey was once common and abundant in larger, northern California rivers, including but not limited to the Eel and Klamath rivers. Adults measure more than half a meter and after spending one to three years in the ocean, they return in spring to spawn in gravels similar to salmon. Juveniles (called ammocetes) live in river substrate for five to seven years and during this time must endure pressures related to gravel scour and sedimentation. This species is considered to be an important component of the food web for opportunistic marine predators and was once significant in tribal culture and diet in the Pacific Northwest, including Northern California.

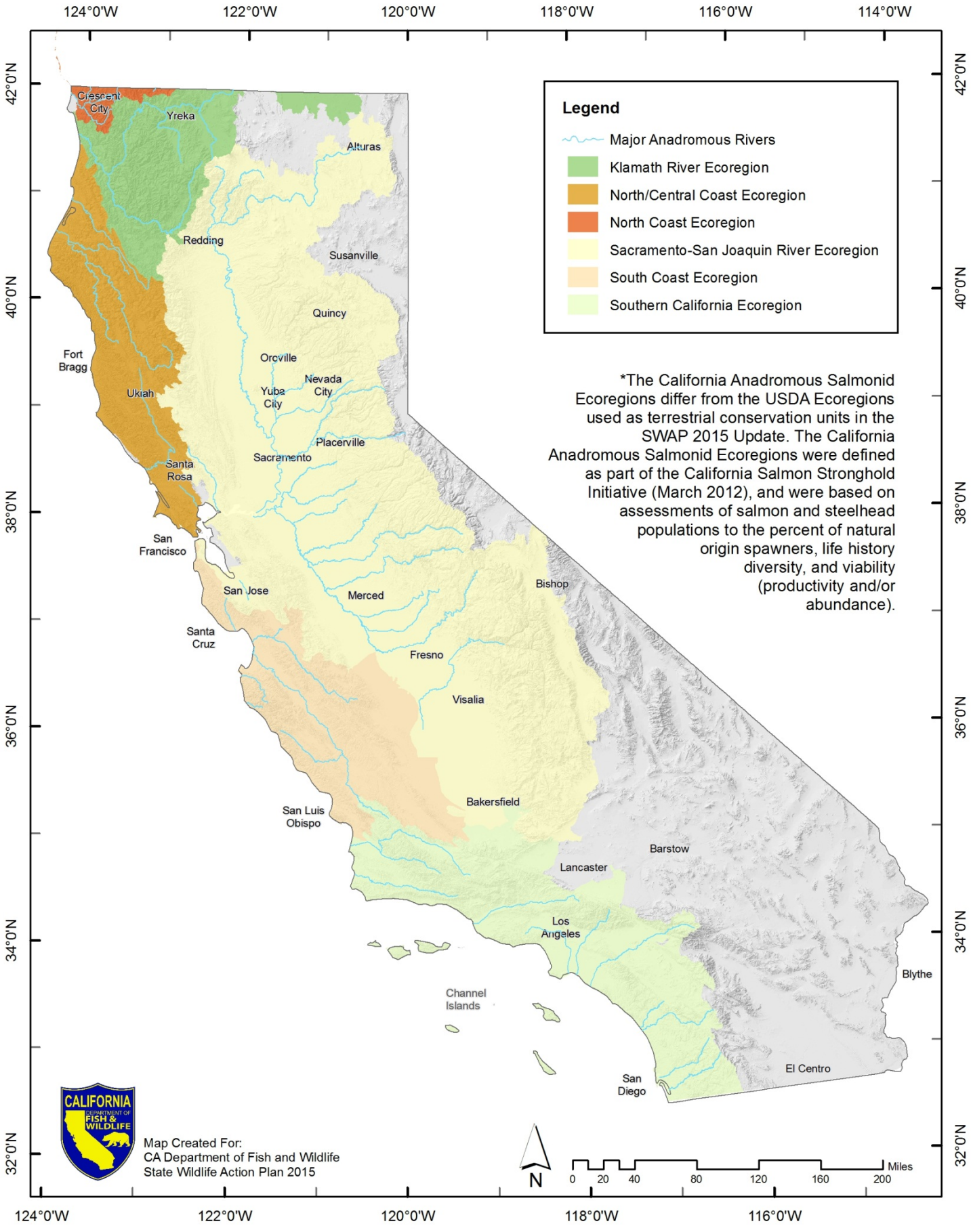
6.4 Salmonid Ecoregions

SWAP 2015 separates California into terrestrial and marine provinces and salmonid ecoregions. For anadromous fish species, the salmonid ecoregion system has been applied. This ecological structure utilizes hydrology, geology, climate, tidal influence, nearshore ocean influence and currents, and limits to anadromy. The analysis was led by the Wild Salmon Center and done in collaboration with federal fisheries agencies, other Pacific state fisheries departments, and conservation groups working to protect anadromous species and watersheds. For anadromous fishes, six salmonid ecoregions exist: South Coast; Southern California, North Central Coast; North Coast, Klamath River; and Sacramento-San Joaquin Rivers Valley (Figure 6.4-1).



Data Sources: Fish Species Extant Ranges
(UC Davis Pisces Project, 2014)

Figure 6.3-4 Smelts and Lamprey Distribution



Data Source: California Ecoregions (Wild Salmon Center, 2009)

Figure 6.4-1 Anadromous Salmonid Ecoregions

Steelhead fry, Teri Moore, CDFW

Vital ecological processes shape and define ecological function, habitat condition and distribution, biodiversity, and the size and distribution of individual species. Some of the more important processes at the ecosystem level affecting anadromous fishes include hydrology, geomorphology, wood debris delivery, and nutrient cycling. Each of the ecoregions include a different guild of anadromous species. The South Coast Ecoregion is represented by a single species, steelhead trout, while the North Central Coast Ecoregion includes every anadromous species occurring in California. The Central Valley Ecoregion has nearly the biodiversity of the northern coast, and both have the greatest diversity of Chinook salmon and the largest populations of both sturgeon species, Chinook salmon, and longfin smelt.

It is important to note that there is a growing body of science and information from habitat restoration disciplines that watersheds may be the minimum scale for which actions need to be taken to recover species, address habitat degradation, re-establish ecological processes, address human interactions, and tackle modifications due to climate change. All of these actions in single watersheds then come together at the ecoregional scale to define ecological health for anadromous species.

6.5 Companion Conservation and Recovery Plans

Because of their dietary, commercial, recreational, tribal, ecologic, and cultural significance, every anadromous species has been the focus of various efforts for conservation, protection, management, and recovery. Some of these efforts, such as Pacific Coast fisheries management, Pacific lamprey conservation, and restoration of salmon and steelhead trout freshwater habitat have and are efforts that span the entire West Coast. Other efforts, such as the Central Valley Improvement Protection Act (CVPIA), California Department of Fish and Game (CDFG) California Coho Salmon Recovery Strategy, and California Water Plan Conservation Strategy are focused plans in California. The National Marine Fisheries Service (NMFS) has developed, or is in the process of developing recovery plans for coastal and Central Valley salmon and steelhead ESUs, and green sturgeon and eulachon DPSs. Since 2013, NMFS has finalized five recovery plans, and three additional plans are in development.

Longfin smelt are protected by CESA, and U.S. Fish and Wildlife Service (USFWS) has released a recovery plan that includes this species. As of 2015, that plan was being updated by USFWS.

The federal CVPIA is a primary mechanism of working to recovery and sustain all anadromous species in the Central Valley. The Anadromous Fish Restoration Program (AFRP), one of the CVPIA's programs, quantified doubling goals for Chinook salmon to guide restoration planning and implementation. In 2014, federal partners commenced work with CDFW and other partners to develop a strategic decision-making plan to better select and implement projects on behalf

of fisheries and water management. CDFW is developing a white sturgeon management plan to both protect the species, and maintain the fishery, in the Central Valley and sits on the federal recovery team developing the recovery plan for green sturgeon in Central Valley rivers and delta, along the north coast, and in the Klamath River Ecoregion.

In 2009, the San Joaquin River Restoration Program commenced. It is a federal-state-private partnership developed to achieve several objectives in the mainstem reach of the San Joaquin River between Friant Dam and the Merced River confluence that benefit salmon and other anadromous fishes. It is meant to recover the mainstem San Joaquin River Chinook salmon river fishery, augment the basin's contribution to the ocean fishery, both re-establish and recover spring-run Chinook salmon [presently extirpated in the basin], maintain and protect river flow, and benefit other anadromous species, such as steelhead trout and sturgeon.

CDFW implements two habitat restoration programs, one dedicated to coastal anadromous salmon and steelhead trout (Fisheries Restoration Grants Program [FRGP]) and one that supports ecosystem restoration, including significant projects for salmon, sturgeon, and longfin smelt (Ecosystem Restoration Program [ERP]). FRGP was founded in 1985 and grants $10-20 million annually in federal and state funds for salmon and steelhead trout recovery. ERP was developed under the joint state-federal CALFED Program in the 1990s. ERP is now implemented by DFW and expends funds to restore ecosystem health and biodiversity in the Sacramento and San Joaquin rivers and Delta.

The Klamath-Trinity Rivers Basin has several conservation and management efforts taking place, including CDFW's Klamath River Fishery Program and federal Trinity River Restoration Program. The Klamath River Basin will also be the center of recovery efforts for eulachon, and NMFS leads the team developing the recovery plan.

Several programs collect and assess fish, habitat, and/or water data to guide management and recovery of anadromous species. Those programs and plans that describe them include:

- White Sturgeon Recreational Angling Report Card Program,
- Steelhead Trout Recreational Angling Report Card Program,
- North Coast Salmon Recreational Angling Report Card Program,
- Salmon Coded-Wire Tagging and Recovery Program,
- CDFW Central Valley Chinook Salmon Escapement Survey projects,
- CDFW San Joaquin River Juvenile Salmon Emigration Assessment project,
- Coastal Anadromous Salmon and Steelhead Trout Monitoring Program,
- Central Valley Steelhead Trout Monitoring Pilot Program,
- CVPIA Anadromous Fisheries Restoration Program,
- Klamath-Trinity Fisheries Program,
- Central Valley/Delta acoustic fish tag array consortium,
- CDFW Bay Delta Sturgeon Study, and
- CDFW Bay Delta smelt survey projects.

In addition to these programs, other state agency and local water districts conduct a myriad of monitoring programs and studies, designed to assess fish population abundance, and habitat quantity/quality, to guide management and recovery of anadromous fish species. CDFW has access to this information as needed through its Scientific Collector's Permit (SCP) program.

6.6 Challenges to Anadromous Species and Watersheds

Each anadromous fish species has limits to its freshwater range where spawning and initial rearing occurs. Figure 6.3-1 illustrates the current limits of anadromy for California's salmonid ecoregions. For some species, adults die after spawning (e.g., salmon), while for other species, adults can spawn multiple times as adults (e.g., steelhead trout, sturgeon). Likewise, rearing of juvenile fish can be relatively short, such as a few months (e.g., Chinook salmon), whereas some juvenile fish spend a year or more in fresh water growing and developing before migrating to the ocean (e.g., sturgeon, Pacific lamprey).

All of these species also have essential habitat and life history requirements in estuaries and bays. White sturgeon and longfin smelt spend a considerable portion of their adult life stage in estuarine waters. Eulachon are never far from estuaries, whether as juveniles or adults, and coho salmon and steelhead trout spend important months in estuaries preparing for adulthood in marine waters. For all species, estuaries are the connecting ecosystem between fresh water and marine migrations.

All anadromous fishes are threatened by the decrease, degradation, fragmentation, and diminished functioning of fresh water and estuarine ecosystems due to massive water development, which has occurred in California over the last 150 years. These effects exist in all six salmonid ecoregions of California, and have resulted in insufficient water flow and poor water quality, as well as disjuncture in timing for one or more life stages that impact species in many watersheds and estuaries statewide.

6.6.1 State Growth and Development, Habitat Loss and Fragmentation

A founding reason for historic and current impacts to habitat and functioning ecosystems is the growth of human populations in California. Expanding communities require increased infrastructure needs, such as transportation corridors and road networks, which have degraded riparian, stream, and estuarine habitat and water quality; contributed to increased stream sedimentation; and created barriers to fish migration. Associated land use practices (e.g., agriculture, forestry, and mining) have damaged, reduced, and fragmented habitat. Human influences, fragmented habitat, and changes in climate and regional hydrologic cycles have also allowed invasive plant and animal species to expand, impacting anadromous fishes through competition, predation, and habitat alteration.

These impacts have occurred in coastal, valley, and mountain ranges of anadromous species. Riverine and estuarine ecosystems have both been affected. Estuaries represent both the conduit between marine and fresh water systems and are vital areas for anadromous fish rearing and development. Manipulation of estuaries and creek mouths has impacted anadromous smelt and salmonid species coast-wide. It is unclear to what extent the changes to estuaries have affected sturgeon and lamprey.

6.6.2 Water Management

The complex life cycle of each anadromous species, and differences in life history strategies between species, result in river and estuary use year-round (Table 6.3-2) by these fish species across California. The most important single factor for fish population health is the hydrologic cycle and management of water releases from reservoirs. Amount and timing of water flow, temperature, and quality are all key factors for successful adult spawning, egg incubation and emergence, juvenile rearing, and seaward migrations.

Competing water needs, water quality degradation, altered hydrology and illegal diversions in many streams, rivers, and estuaries affect habitat quality and quantity, fish behavior, access to rearing and spawning areas, and ecological processes vital for sustainable fish populations. Many rivers and creeks have small to moderate dams and thousands of water diversions exist across the state. There are also a series of large dams on major rivers statewide (e.g., Klamath, Eel, Trinity, Sacramento, Feather, Russian, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, and Carmel rivers). These structures have not only altered hydrology, but have interfered with nutrient cycles, as well as altered wood and sediment transport cycles, which are vital to anadromous species. Perhaps their greatest effect has been creating permanent barriers to historic habitat. There are no statewide calculations for the amount of lost habitat for anadromous salmon, trout, smelt, sturgeon, and Pacific lamprey. A conservative estimate is 50 percent loss. NMFS has estimated that over 75 percent of Central Valley anadromous habitat has been lost for Chinook salmon, steelhead trout, and green sturgeon.

6.6.3 Vulnerability to Climate Change

All natural aquatic ecosystems and native California fish species are vulnerable to the ecological stresses resulting from climate change. Anadromous species may be one of the most vulnerable guilds of aquatic species, because they have complex, diverse life histories dependent on many different habitat types and aquatic communities. Some of the more significant stresses for California's anadromous fishes due to climate change include:

- changes in upwelling, coastal currents, and warmer marine waters disrupting food supply for sturgeon, smelt, and juvenile salmonids;

- decreased stream flow, habitat connectivity, and water quality during summer months in rivers and estuaries, impacting migration, juvenile fish over-summer rearing, and adult spawning;
- increased and sporadic winter flooding, impacting over-wintering rearing, degrading instream and riparian habitat, and disturbing spawning grounds and incubation of eggs;
- changes in rain- and snow-fall patterns, impacting reservoir water supplies essential for managing species below dams and decreasing snowpack, affecting spring and summer flows; and
- increased and prolonged droughts, decreasing habitat connectivity, increasing mortality in both juvenile and adult populations where water supply and quality reach critical lows. This poses a high risk for species (e.g., winter-run Chinook salmon, eulachon) or populations (e.g., coho salmon south of San Francisco Bay) with limited distribution and low population size.
- proliferation of non-native and invasive species which out-compete native species for food, cover, and spawning areas.

6.7 Anadromous Fish Conservation Targets and Strategies

Anadromous species have been a focus of conservation and management for decades. Since the late 19th century, California's salmon have been the focus of research, management, and protection because of their economic, cultural, and ecologic value. In the late 1980s and early 1990s, all anadromous salmonids became a focus of management and conservation efforts. Since that time, the scientific and resource management communities have commenced efforts to understand, manage, and protect anadromous smelt species, sturgeons, and Pacific lamprey.

Reports and summaries listed at the end of this chapter summarize significant information, analyses, and recommended actions for California's anadromous species, and represent thousands of targets, strategies, activities, and tasks to conserve, manage, and protect these species. They represent the authoritative and scientific foundation for what is known about these species and what actions are needed in future decades. For example, recovery plans and strategies and habitat and natural community conservation plans have planning and implementation schemes of 30-100 years.

Anadromous conservation targets are key species, species guilds, habitat types, or ecological processes essential to future conservation of anadromous species (Table 6.7-1). Species, habitat, and ecological processes were all considered in developing prioritized conservation targets to adequately encapsulate the evolutionary and ecological significance of the species. For each target, three primary strategies are proposed to advance comprehensive conservation and management of each species, associated habitats, and key ecological processes. Anadromous fish biodiversity differs considerably across California's ecoregions (Table 6.3-1). To ensure maximum benefits to all species can be achieved, where species diversity is greatest, single-species targets were not selected.

Table 6.7-1 Conservation Strategies for Anadromous Fish Conservation Targets and Strategies

Geography	Conservation Target	Conservation Strategy (Implementation by 2025)
Statewide	In-river spawning and rearing habitat	▪ Document range and distribution of spawning and rearing habitat; ▪ Enhance and protect key spawning and rearing habitat for each specific anadromous species; and ▪ Promote restoration actions that focus on ecological processes and climate change resilience (e.g., removing barriers to migration, expanding riparian corridors).
	River flow	▪ Identify annual flow regimes and habitat connectivity necessary for migration, rearing, and spawning of each anadromous species; ▪ Develop water management and conservation plans necessary to conserve anadromous fishes; and ▪ Implement water management and conservation plans.
	Wetland habitat	▪ Identify current condition of riparian and marsh habitat associated with anadromous species; ▪ Restore marsh and riparian habitat to improve carrying capacity of anadromous fishes; and ▪ Protect key areas necessary to maintain viable populations.
North Coast and North Central Coast	California Anadromous Salmonid Stronghold Watershed Conditions	▪ Establish collaborative working groups for each Stronghold (Smith, Mattole, and South Fork Eel rivers); ▪ Assess ecological and human conditions that are allowing for healthy fish populations; and ▪ Establish technical, agency, and financial support to maintain and expand ecological and human conditions supporting strong salmon and steelhead populations.
	Coastal estuaries	▪ Evaluate current condition and estuarine needs for coho salmon, eulachon, Pacific lamprey, and longfin smelt in key estuaries (i.e., Smith, Klamath, and Eel rivers and Humboldt Bay); ▪ Restore and enhance estuary habitat, connectivity, and ecological processes essential for anadromous species; and ▪ Establish estuary function and structure that will allow anadromous migration and be responsive to climate change.
	Russian River Watershed Conditions	▪ Restore and enhance estuary and river habitat necessary to support viable populations of all listed anadromous fishes (i.e., Chinook salmon, coho salmon, steelhead, green sturgeon); ▪ Develop and implement water management plan to ensure Russian River fisheries and land use are compatible; and ▪ Expand Warm Springs Hatchery complex to function as a potential regional conservation facility for coho salmon and other listed species in the North-Central Domain.
Klamath-Trinity Rivers Basin	Pacific lamprey	▪ Establish standing committee of local, tribal, State, and federal partners in the Klamath-Trinity Rivers Basin to implement interstate/intertribal 2012 Pacific lamprey conservation agreement; ▪ Implement basin-wide habitat restoration and monitoring programs; and ▪ Secure funding specific for conserving Pacific lamprey in the Klamath/Trinity Rivers Basin.
	Ecological processes	▪ Evaluate wood debris, gravel, and water cycling and transport mechanisms across the basins; ▪ Establish agreements and practices to ensure adequate ecological processes, habitat quality, and connectivity are maintained to support sustainable anadromous populations across the basins; and ▪ Establish monitoring and evaluation programs to track ecological processes and functioning.

Table 6.7-1 Conservation Strategies for Anadromous Fish Conservation Targets and Strategies

Geography	Conservation Target	Conservation Strategy (Implementation by 2025)
	Listed and at-risk salmonids	▪ Establish standing inter-organizational team to implement federal and state recovery plans, and continue to support the Trinity River Restoration Plan, and Klamath River Settlement; ▪ Integrate recovery actions with strategic hatchery management (e.g., Iron Gate and Trinity River facilities); and ▪ Integrate sustainable river and tribal fisheries with establishing sustainable, natural populations of salmon and steelhead.
South-Central and Southern California Coasts	Steelhead trout populations	▪ Establish a robust monitoring program to evaluate steelhead populations, habitat, and ecological processes; ▪ Secure additional funding necessary to pursue essential habitat recovery; and ▪ Determine role of resident populations to recovery and sustainability of anadromous populations.
	Migration barriers	▪ Remediate most downstream barriers to steelhead entering rivers and streams; ▪ Accelerate planning and remediation of rim dam barriers to key steelhead populations; and ▪ Modify land use practices (e.g., water use, agriculture, recreation, urban and road development) to minimize effects on migration corridors.
	Water management	▪ In addition to the statewide strategy, identify key streams and locations essential for over-summering juvenile and adult steelhead; ▪ Investigate ability and options to creating water banks for steelhead habitat; and ▪ Update CDFW management and conservation plan to integrate modern water management, including drought and climate change parameters.
Central Valley	Pacific lamprey	▪ Establish standing committee to implement interstate/intertribal 2012 Pacific lamprey conservation agreement; ▪ Implement habitat restoration and monitoring programs; and ▪ Secure funding specific for conserving Pacific lamprey in the Central Valley.
	Sturgeon	▪ Establish fisheries management and conservation plans for white and green sturgeon; ▪ Implement habitat restoration and monitoring programs; and ▪ Secure funding specific for conserving sturgeon populations and fisheries in the Central Valley.
	Chinook salmon and steelhead	▪ Establish biological production goals for each species, coupled with SMART ecological objectives, prioritized restoration actions, focused biotic and abiotic monitoring, and adaptive management planning framework that are developed and overseen by an established standing inter-organizational team to integrate activities of NMFS and CDFW recovery programs, Central Valley Program Improvement Act program, Bay Delta Conservation Plan, San Joaquin River Restoration program, and CDFW fisheries programs to establish sustained salmon and steelhead populations and fisheries; ▪ Revise and integrate hatchery practices of the six facilities in the Central Valley to maximize scientific standards, minimize effects of programs on natural spawning populations and river habitat, and promote healthy fisheries populations; and ▪ Conduct rim dam re-introduction pilot projects on Yuba and Sacramento rivers and evaluate efficacy of expanding rearing and spawning habitats for recovery.

Three strategies are proposed for each statewide or ecological target. The strategies, like their targets, are only a subset of needed actions. Proposed strategies were developed to be broad in both ecological relevance and geographic scope to ensure maximum benefit to the selected targets. Another important feature of each strategy is that it is founded in collaborative implementation.

6.7.1 Statewide

The three targets applicable to all of California are freshwater spawning and rearing habitat, river flow, and wetland habitats. The stresses on these habitats and ecological processes include: (1) habitat fragmentation, loss, and degraded functioning; (2) decreased water supply and quality, altered hydrology, and increased competition for water; and (3) lack of information on the distribution, use, and relative value of spawning and rearing habitat across fish species ranges.

The recommended strategies are meant to restore, connect, and expand habitat; synchronize water management with species needs; and gather information about habitat value and use it to prioritize restoration, enhancement, and protection. SWAP 2015, the Bay Delta Conservation Plan, the Department of Water Resource's Water Plan and associated Flood and Conservation Plans, and the State Water Resources Control Board and Regional Water Quality Control boards, Water Quality Control plans will be pivotal to the CDFW's singular and collaborative efforts to integrate water management, and conservation, with anadromous fish restoration.

6.7.2 North Coast and North Central Coast

These ecological regions include every anadromous species occurring in California. This area is also represented by several California Salmonid Strongholds, the most functioning watersheds for particular species (e.g., Smith River for all species, Mattole River for steelhead trout). It also has important estuaries, from the Russian to Smith Rivers, including the Klamath River estuary, a key location for Chinook salmon, Pacific lamprey, and eulachon, and Humboldt Bay, important to salmonids and longfin smelt. The last target is the Russian River, the most southern major river that has Chinook and coho salmon and steelhead trout and is the key watershed for recovery of Central California Coastal coho salmon.

Strategies for these salmonid ecoregions are characterized by understanding how ecological function (i.e., estuaries, entire watersheds) and land use (e.g., in stronghold areas, where fish populations are faring well) are affecting fish populations, and how actions across the area of interest will be implemented to conserve species (e.g., practical support to organizations in stronghold watersheds; restoring estuary function; and maintaining the success of the conservation program at Warm Springs Hatchery).

6.7.3 Klamath-Trinity Rivers Basin

The Klamath-Trinity Rivers Basin represents one of the largest watershed complexes in California, and the Klamath River is one of the longest rivers entering the Pacific Ocean in the lower 48 states. The system is home to populations of salmon important to commercial, recreational, and tribal fisheries, and the largest populations of Pacific lamprey, eulachon, and green sturgeon in California. Lamprey, eulachon, and sturgeon also are important fisheries for tribes in the region.

Targets for this ecoregion include Pacific lamprey, because of its ecological and tribal significance, all anadromous salmonids, because of the multitude of their significance, and ecological processes, because these factors are the basis for the health and biodiversity of the entire ecoregion. For both anadromous salmonids and Pacific lamprey, strategies are targeted on ecoregion-specific groups focused on the conservation of the species. Recovery planning, restoration programs, water settlements, and tribal rights and values demonstrate the worth and strategic value of developing a comprehensive effort to preserve these species. The value of Pacific lamprey is only now being fully appreciated along the entire Pacific Coast of North America, and successful conservation of this species will be founded on success in this ecoregion.

Dams used for water diversion and power generation block salmonid migrations to traditional spawning and juvenile rearing grounds on both the Klamath and Trinity rivers. Mitigation fish hatcheries were built and are operated to compensate for lost salmonid production due to the disruption of fish access to salmonid spawning and rearing habitat above the dams; however, the altered hydrologic regime and dams blocking downstream gravel and wood transport also alter downstream habitat further stressing anadromous fish populations. The significance of improving release flow regimes and wood, gravel, and nutrient cycling is recognized by Klamath and Trinity rivers restoration groups. Actions to improve functional processes related to flow, gravel transport, and riparian function in the affected reaches can benefit all anadromous species in the rivers, tributaries, and Klamath River estuary.

6.7.4 South-Central and Southern California Coasts

The southern, seven coastal counties constitute the southern range of steelhead trout and are represented by two DPSs and the southern extent of Pacific lamprey. Human population size, arid climate, unique geologies, and sporadic rain events currently make these ecoregions a difficult landscape for the species. For these ecoregions, steelhead trout itself is a conservation target. More information is needed to better conserve the species, and the relationship between the anadromous and resident life histories strategies is fundamental to recovering both DPSs. The other two targets represent needs that stem from large urban populations. Water management needs stem from the intense competition for water, alteration of rivers, creeks,

lagoons, and estuaries and the unpredictable nature of hydrology annually and perennially. Targeted water strategies and plans across the region will benefit steelhead trout, especially migration corridors, over-summering pools, estuaries, and lagoons. Restoration of estuarine ecosystems and fish barriers will also be key actions that will benefit Pacific lamprey. Because of human communities and infrastructure corridors, many barriers to migration exist close to the ocean entry of most key rivers and creeks. Addressing key barriers and suites of barriers (e.g., the Santa Inez River watershed) will be needed to conserve Southern California and South-Central ecoregion steelhead trout.

6.7.5 Central Valley

The Central Valley is the single-largest catchment basin in California. It is composed of two large river systems, the Sacramento River flowing south in into the Delta and San Joaquin River flowing north into the Delta. The Central Valley once supported the largest runs of naturally spawning Chinook salmon and white sturgeon in the State. The three targets of this huge ecoregion are all species-based- Pacific lamprey, sturgeon, and salmonids. For lamprey, the key needs are to both better understand the species in the ecoregion and develop specific conservation actions for the species. To-date, the species has not been a focus of investigations or actions. For sturgeon, the success of green sturgeon recovery along the Pacific Coast will hinge on conservation in the Sacramento River. Specific actions for restoration and protection of white sturgeon will need to occur to maintain the current fishery and ensure a viable population persists in the Central Valley and Delta.

Strategies for the Chinook salmon and steelhead trout need to be comprehensive. Steelhead trout occur year-round in the ecoregion's rivers and tributaries and experience various pressures. The Central Valley also has the greatest diversity of life histories for Chinook salmon, and each experience varying pressures. Both species will benefit from improved hatchery management, centered on employing the highest scientific standards and minimizing the influence on naturally spawning populations. For salmonids, water management decisions are a critical and unique conservation concern. In 2014, Shasta Dam operations caused the loss of over 95% of endangered winter-run Chinook salmon, perhaps the entire population of spring-run Chinook salmon below Shasta, and an unknown but likely sizable portion of the commercially-valuable fall-run Chinook salmon below the dam. For this reason, a statewide water management plan should be prepared.

Because major dams exist on most rivers feeding water into the valley floor, this ecoregion needs to be the site of determining the feasibility and efficacy of re-introducing salmon and steelhead trout above rim dams. Presently, the Yuba and Sacramento rivers are intended sites for such, long-term projects. Hatchery and re-introduction efforts will require the collaboration of a large, diverse group of organizations. This same strategy of broad partnerships will be necessary to implement the federal and state recovery and conservation plans completed or in development that will encompass the entire Central Valley within a decade.

6.8 Other Essential Actions

It is clear that conservation of California's anadromous species, their habitats, and their required natural ecological processes will demand a concerted, committed, long-term collaboration; more and better information; and constant educational outreach to the public and leadership in California. CDFW is dedicated to expanding and improving its efforts, to maintaining and enhancing its partnerships, and to exerting its leadership responsibilities to manage and conserve the state's diverse and magnificent anadromous species. This section presents other essential actions to effectively conserve these species.

6.8.1 Unifying Vision

CDFW will develop a comprehensive vision for anadromous fish species that consists of biological goals for each species, and is coupled with the following planning elements:

- ecological objectives that are specific, measurable, achievable, realistic, and time bound (i.e., SMART objectives);
- prioritized restoration actions to guide restoration action priority;
- focused monitoring to update the existing knowledge base; and
- adaptive management framework to ensure progress towards achieving overarching biological goals is being attained, and if not to modify them.

6.8.2 Partnerships, Education, and Outreach

CDFW's partnership and outreach efforts and collaborations will include:

- an improved internet presence, with more information and more frequent updating of species status, conservation efforts, grant fund opportunities, and public involvement opportunities;
- inter-agency outreach and information sharing, such as:
  - Calfish.org, an internet portal for multiple organization data, reports, and contacts on anadromous fishes;
  - PISCES, a new web partnership with the University of California to provide range and distribution information on California's native fishes;
  - partnership with The Nature Conservancy on Salmon Snapshots, an internet site for status and recovery progress of California salmon and steelhead trout;
  - partnership in National Fish Habitat Partnerships, including the Pacific Marine and Estuarine Fish Habitat Partnership, California Fish Passage Forum, and Western Native Trout Initiative, which all address monitoring, assessment, habitat restoration, and public outreach for anadromous species; and

- collaboration with the North American Salmon Stronghold Partnership and Wild Salmon Center to promote watershed partnerships, community support, and habitat enhancement in California's healthiest anadromous watersheds.

6.8.3 Research, Monitoring, and Resource Assessment

Information on fish population status, habitat and water conditions, land use, and outcomes of restoration and resource management actions are essential to conserving anadromous fishes. In addition, continued academic and applied research are vital to understanding less known species (e.g., smelt species along the north coast, Pacific lamprey statewide, and sturgeon statewide), ecological processes (e.g., sea level rise, changes in precipitation patterns, restoration effectiveness), and new conservation priorities (e.g., strategic hatchery management, re-introduction of fish above rim dams).

CDFW and its partners (e.g., University of California and State University research units, NOAA Southwest Fisheries Science Center) will need to expand and improve their collaborations to meet future fish population evaluations and research needs. CDFW has partnered with federal and state agencies, tribes, academic researchers, and private research programs to continue important projects and develop and implement key additional monitoring and assessment programs for population status and trend, restoration efficacy, and ecological functioning. Each existing program will need to be supported and likely expanded in the future, and new programs will need to be developed for some species and some ecoregions.

The following are important existing programs or needed programs central to conserving California's anadromous fishes:

- CDFW Klamath-Trinity River Program and tribal and federal agency monitoring programs- anadromous salmonids, including the Yurok, Karuk, and Hoopa Klamath River Coho Ecology Study, the Lower Klamath River Sub-basin Restoration Plan and the Yurok's Pacific Lamprey monitoring program.
- CDFW-NMFS California Coastal Salmon and Steelhead Monitoring Program;
- Federal Central Valley Anadromous Fisheries Restoration Program- all species (primarily Chinook salmon);
- CDFW San Joaquin River Restoration Program- anadromous salmonids;
- CDFW Delta Investigation and Monitoring Program- smelt and sturgeon species;
- CDFW Ocean Salmon Program;
- Central Valley Steelhead Trout Monitoring Pilot Project- interagency plan to be piloted in 2015 by CDFW;
- Central Valley Chinook Salmon Monitoring Program- interagency plan yet to be implemented;
- Central Valley Sturgeon Monitoring Projects- three integrated pilot projects to be implemented by CDFW, SWFRC, NMFS, and the University of California;

- North Coast Smelt Monitoring- needed for longfin smelt and eulachon in targeted rivers and estuaries on the north-central and north coast ecoregions;
- Pacific Lamprey Monitoring Programs- needed in both the Klamath-Trinity and Central Valley ecoregions;
- CDFW Coded Wire Tagging/Recovery Program – anadromous salmonids; and
- CDFW Hatchery Operation – anadromous salmonids.