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Occurrences of Steelhead Trout (*Oncorhynchus mykiss*) in southern California, 1994-2018

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Observations of federally endangered Southern Steelhead Trout (*Oncorhynchus mykiss*) were compiled for the southern California Distinct Population

Segment (DPS) that extends approximately 500 kilometers from the Santa Maria River (Santa Barbara County) south to the Mexican border. Existing monitoring programs and anecdotal observations documented 177 adult Steelhead in the past 25 years. The level of monitoring effort and technology used varied by watershed and year. Thus, the low numbers of adult Steelhead observed during the past 25 years provides relative abundance and distribution documentation of occurrences but likely underestimates the abundance of adult Steelhead throughout the DPS. The patchy distribution observed suggests that fish are opportunistically entering creeks and river mouths based on available hydrologic passage opportunities associated with higher rainfall years. Given the extremely low numbers of anadromous adults, long recovery timeline, future uncertainty with respect to climate change, and a multitude of anthropogenic factors, additional conservation actions including state and federal protection of resident *O. mykiss* are recommended to increase the likelihood of the continued existence of the species within the DPS. Additional focused monitoring, research, and implementation of recovery actions are needed to expand our knowledge of southern California Steelhead distribution and abundance.

Key words: anadromous adults, Rainbow Trout, southern California, Southern Steelhead

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The Southern California Steelhead Trout (*Oncorhynchus mykiss*) Evolutionarily Significant Unit (ESU) populations located from the Santa Maria River in Santa Barbara County south to Malibu Creek in the Santa Monica Bay were listed as endangered in 1997 under the Endangered Species Act (NOAA 1997: 62 FR 43937). After recognizing that additional populations of Steelhead were found further south in Topanga Creek near Malibu, and San Mateo Creek near San Diego, the ESU was extended to the Mexican border in 2002 (NOAA 2002: 7 FR 21586). Subsequently, the National Marine Fisheries Service (NOAA) adopted the Distinct Population Segment (DPS) designation to replace the use of ESU in 2006 (NOAA 2006: 71 FR 5248). Based on these designations, all naturally spawned *O. mykiss* found in freshwater habitat below impassible natural and artificial barriers are protected by this listing. Additionally, any individuals spawned upstream of these barriers that migrate downstream into designated critical habitat are also protected.

When observed in rivers and streams, it is difficult to determine the life history phenotype of an individual *O. mykiss* without genetic (Pearse et al. 2014), morphological (Beeman et al. 1995; Haner et al. 1995), or physiological evaluations (Negus 2003). However, it is possible to identify anadromous adults when they return to rivers and streams from the ocean because they are typically larger (fork length > 400 mm), have greater girth, and are steel-gray in color (Moyle et al. 2017). Using these identifying characteristics to document adult occurrences in the DPS is critical to evaluate population viability and progress towards recovery goals (Boughton et al. 2006; Boughton 2010a, b; Adams et al. 2011; NOAA 2012). Resident *O. mykiss* in upper watershed areas outside the designated critical habitat are not protected by either state or federal endangered species acts, despite their documented link in maintaining maximum numbers of Steelhead (NOAA 2012).

The federal Recovery Plan (NOAA 2012) defines DPS-level and population-level criteria to lower the risk of extinction both for individual populations in a given river/creek system and the DPS as a whole (Boughton et al. 2007). Criteria listed include preventing extinction by protecting existing populations and all life history expressions, expanding distribution to historically occupied areas, restoring suitable habitat, conserving existing genetic diversity, and providing opportunities for genetic mixing between and within populations. Mean annual run size, which was estimated based on Lindley's (2003) "random walk with drift" model using field data from the Central Valley (Boughton et al. 2007; Williams et al. 2016), resulted in a run size estimate of 4,150 spawners per year (100% anadromous) and generated a 95% chance of species persistence over a 100-year time period. In southern California however, the number of spawners observed is far below this estimate.

The objective of this study was to compile and examine the occurrence and geographic distribution of adult Steelhead over the past 25 years throughout the southern California DPS that could serve as a baseline for future conservation efforts. This information will help assess the effectiveness of restoration and recovery actions. Individuals documented upstream of barriers to anadromous migration were considered resident *O. mykiss* and were not included in the enumeration of anadromous adults, although they are important components of Steelhead recovery. Due to uneven monitoring efforts and detection limitations, these observations provide only a limited snapshot, and they do not represent a census within any specific watershed or the DPS as a whole. They do, however, provide insight into relative abundance, distribution, and monitoring efforts over 25 years (1994 – 2018) since Southern Steelhead were federally listed as an endangered species.

METHODS

Study area

The study area spans the entire geographic region of the southern California Steelhead DPS identified in the recovery planning area (NMFS 2012; Figure 1). The southern DPS includes 50 creek/river systems and their tributaries covering approximately 500 kilometers of coastline, and it is further divided into five Biogeographical Population Groups (BPG). At the northern end of the DPS, the Monte Arido Highlands BPG includes the Santa Maria, Santa Ynez, Ventura, and Santa Clara rivers, which are large watersheds that extend well inland. Several smaller coastal creeks are also found throughout that region but were not included in the BPG such as the highly urbanized Conejo Creek, which is a tributary of Calleguas Creek. The Conception Coast BPG extends 80 km from Jalama Creek to Rincon Creek and includes: Arroyo Hondo, Mission, and Carpinteria creeks as well as the Goleta Slough complex, which includes Tecolotito, Los Carneros, San Pedro, Las Vegas, Maria Ygnacio, San Jose, and Atascadero creeks. The Santa Monica Mountains BPG extends approximately 52 km from Big Sycamore Creek south to Topanga Creek, including populations in Arroyo Sequit and Malibu Creeks. The Mojave Rim BPG encompasses the large watersheds and upper tributaries of the Los Angeles, San Gabriel, and Santa Ana Rivers, as well as Ballona Creek, which historically was an outlet of the Los Angeles River. The Santa Catalina Gulf Coast BPG extends from San Juan Creek at the north near Dana Point, south to the Mexican Border at the Tijuana River. This BPG includes coastal rivers such as San Mateo, San Onofre, Santa Margarita, San Luis Rey, and San Dieguito Rivers, as well as the larger San Diego Bay estuary, which is the terminus of the Sweetwater and Otay Rivers.

Survey methodology

We compiled and reviewed a variety of gray literature reports and technical memos in addition to published records for Steelhead occurrence data throughout the DPS (M. Gomez (South Coast Habitat Restoration), D. Hyatt (Bureau of Reclamation), K. McLaughlin (CDFW), C. Swift, personal communication; Hovey 2004; Capelli 2000 - 2017, CDFG 2007; CMWD 2009 – 2017; Downie and Kajtaniak 2010; Barabe 2013; COMB 2013, 2015; Allen 2014; Booth 2016; FOLAR 2016; COMB 2018; Dagit et al. 2018a, b). Surveys for adult Steelhead varied widely both in level of effort and timing throughout the DPS, but covered the majority of publicly accessible portions of the designated critical habitat, which extends from the ocean upstream to the limits of anadromy in numerous priority watersheds. Some reaches on private property were not surveyed. Upstream migration barriers were either natural, such as waterfalls, or, more commonly, anthropogenic barriers such as dams, bridges, and culverts. Detailed descriptions of these watersheds and barriers are found in the Southern California Steelhead Recovery Plan (NOAA 2012).

Documenting presence and abundance of adult Steelhead varied from opportunistic observations to more standardized observation methods consistent with protocols developed by the California Department of Fish and Wildlife (CDFW) Coastal Monitoring Program. These methods included snorkel/redd/carcass surveys, fish passage facilities, weir traps, video surveillance systems, Vaki Riverwatchers (VAKI Aquaculture Systems LTD, Iceland), in-stream Passive Integrated Transponder (PIT) antennas, and Dual-Frequency Identification Sonar (DIDSON: Sound Metrics, Washington, USA) cameras. Table 1 summarizes the location of all in-stream monitoring stations and devices. The time of equipment deployment within any year varied, depending on flow.

Table 1. Summary of fish passage/weir traps, video surveillance systems, in-stream antenna, and DIDSON deployments (UWCD = United Water Conservation District, CMWD = Casitas Municipal Water District, COMB = Cachuma Operation and Maintenance Board, RCDSMM = Resource Conservation District of the Santa Monica Mountains, CDFW = California Department of Fish and Wildlife).

Device	Deployment Location/River	Deployment Time Frame	Operators
Fish Passage	Vern Freeman Diversion Dam, Santa Clara River	1994–2018	UWCD
	Robles Fish Passage Facility, Ventura River	2006–2018	CMWD
Traps	Salsipuedes Creek, Santa Ynez River	1995–2018	COMB
	Hilton Creek, Santa Ynez River	1994–2018	COMB
	Lower Santa Ynez River	2005–2018	COMB
	Topanga Creek	2008–2014	RCDSMM
In-stream PIT antenna	Topanga Creek	2008–2016	RCDSMM
DIDSON camera	Salsipuedes Creek, Santa Ynez River	2013–2018	CDFW
	Carpinteria Creek	2014–2017	CDFW
	Ventura River	2014–2018	CDFW
	Topanga Creek	2012–2018	RCDSMM

Due to a variety of limitations, the level of monitoring effort was not consistent through time and geographic areas. Adult Steelhead were typically observed in traps, weirs, or by in-steam PIT antenna, video surveillance, and DIDSON cameras, or at fish passage facilities following storm events when flows could support migration. During spring and summer visual and snorkel surveys Steelhead were observed when detection in lower flows was possible. Stream flows in this region are flashy and inconsistent, making it difficult to effectively monitor the patchy spatial and temporal distribution of adult Steelhead throughout the DPS, particularly under turbid conditions. High turbidity is a distinctive feature of high flows in this region and depending on the drainage, can last days or weeks after significant rainfall with associated stormflow. Turbid conditions made it difficult to detect adult Steelhead at monitoring stations due to operational challenges and dangerous conditions at high flows when conditions might be favorable for migration. In addition, opportunistic observations were contributed by a variety of sources, including local conservation groups, governmental agency staff, and the general public. Opportunistic observations were verified by state, federal, or other experienced fisheries biologists based on photos, carcasses, or on-site visual confirmation.

Geographic observation details proceeding north to south

Cachuma Maintenance Operations Board (COMB) Fisheries Division staff have conducted migrant trapping from January to June since 1994 using weir traps at several locations within the lower Santa Ynez River (LSYR), Salsipuedes Creek, and Hilton Creek. During the migration season, COMB staff routinely conducted spawner/redd surveys according to National Marine Fisheries Service (NMFS) protocols throughout the LSYR basin in those reaches that historically provided spawning opportunities (AMC 2009). Monitoring was conducted to prepare biological assessments and for compliance measures set forth in the Cachuma Project Biological Opinion (NOAA 2000). In addition, COMB staff conducted snorkel surveys during spring, summer, and fall from 1994 to the present. Most reaches that hold over-summering *O. mykiss* were surveyed annually, and additional estuary monitoring was also conducted opportunistically during the study period in association with migrant trapping to track population abundance and distribution.

Snorkel and spawner/redd surveys were conducted at specific reaches within the Ventura River and upper tributaries. The Casitas Municipal Water District conducted redd and snorkel surveys since 2009 at index sites throughout the Ventura Basin (CMWD 2009 - 2017). Allen (2014) conducted snorkel surveys and electrofishing surveys in a subset of index reaches throughout the upper Ventura River from 2006 to 2012. The Robles Fish Passage Facility (23 km upstream from the ocean) was constructed in 2005 and is operated by Casitas Municipal Water District. Fish passage monitoring through the Robles facility was conducted with a VAKI Riverwatcher.

The Vern Freeman Diversion Dam (16 km upstream from the ocean) on the Santa Clara River is operated by United Water Conservation District and has monitored upstream migration since 1994. Prior to 1997, fish were captured in an upstream migrant trap at the facility's Denil fish ladder. From 1998 to 2003 fish were incidentally encountered through periodic dewatering of the fish ladder facility. In 2003 this facility was retrofitted to include a false weir with a passive, video-based migrant surveillance system and was updated in 2010. This system was thought to potentially undercount adult Steelhead based on collection of several downstream migrating kelts observed in the facility's downstream migrant trap through 2014 that did not match observed upstream migrants. Due to permitting restrictions, the downstream migrant trap was not operated after 2015 and no upstream migrants were observed in the video surveillance system in this period (Booth 2016) although the system continues to be updated as technology improves. Stoecker and Kelley (2005) and Kelley (2008) conducted surveys throughout the Santa Clara River.

The Resource Conservation District of the Santa Monica Mountains (RCDSMM) in Arroyo Sequit and Malibu Creeks conducted monthly snorkel surveys in the Santa Monica Mountains BPG from 2005 through 2019, and in Topanga Creek from 2001 through 2019. Presence/absence surveys and lagoon monitoring were also conducted in Big Sycamore, Las Flores, Solstice, Trancas, and Zuma Creeks annually 2013 through 2018. DIDSON cameras have been used in several locations (Table 1) to augment storm event monitoring, but limitations due to high turbidity, bedload, fine sediment fouling, and extremely low flows resulted in fewer than 10 confirmed observations. The RCDSMM conducted five seining and angling efforts in the lower Los Angeles River from May 2014 to August 2015.

In 2016, the South Coast Steelhead Coalition initiated post-rain reconnaissance surveys in the four high-priority Steelhead recovery rivers in San Diego and Orange Counties including: San Juan/Arroyo Trabuco Creek, San Mateo Creek, Santa Margarita River, and the San Luis Rey River. These river mouths have seasonally accessible estuaries where adult Steelhead have occasionally been observed. Prior to the more organized surveys, opportunistic monitoring and incidental observations by CDFW, Caltrout, local conservation groups, and Trout Unlimited members documented adult Steelhead on several occasions.

Finally, we attempted to fit regression models to test for relationships between precipitation and associated stormflow with adult Steelhead abundance. However, due to the variable sampling methods, efforts and locations, the models fit the data poorly and had low explanatory ability, so the results were not reported.

RESULTS

In the 25 years from 1994 through 2018, we observed a total of 177 adult Steelhead throughout the southern California DPS. Annual Steelhead observations ranged from 1 fish (1997, 2016, and 2018) to 49 fish (2008), with a mean of 7 fish (SD = 10). Three or fewer fish were observed in 11 years. Most noteworthy were the Santa Ynez River (n = 16) and Mission Creek (n = 13) (Capelli 2008; USBR 2011).

Records of adult Steelhead observed are presented in Table 2 and were compiled from various sources. Observations are grouped based on the BPG location and 34 of the 50 river/creek systems within the DPS were surveyed. Of these, annual monitoring occurred for 25 years at the Freeman Diversion on the Santa Clara River, 24 years on the Santa Ynez River, 18 years in Topanga Creek, and 14 years in both Arroyo Sequit and Malibu Creeks. Monitoring in all other systems was more erratic and limited due to private property access issues, although seven more systems (Ventura River, San Antonio, Big Sycamore, Las Flores, Solstice, Trancas, and Zuma Creeks) were annually monitored from 2013 through 2018.

Table 2. Summary of adult steelhead observations for locations in the southern California Distinct Population Segment Biogeographical Population Groups (BPG) from 1994 through 2018 listed from north to south. Blank spaces indicate that no formal visual or snorkel survey results were available, and opportunistic observations noted in bold. A zero indicates that surveys were conducted but no anadromous *O. mykiss* observed.

BPG	Location	DPS Core Ranking	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Monte Arido Highlands	Santa Maria River	1	1	0	0	0	0	0						3	0	1	0	0	0									5
	Santa Ynez River	1		0	0	2	1	3	0	4	0	1	0	1	1	0	16	1	1	9	0	0	0	0	0	0	0	40
	Robles Diversion	1													4	0	6	0	1	0	0	0	0	0	0	0	0	11
	Ventura River	1														4						0	0	0	0	0	0	4
	San Antonio Creek	1																				0	0	0	0	1	0	1
	Santa Clara Freeman Diversion	1	1	1	2	0	0	1	2	2	0	0	0	0	0	0	2	2	0	0	3	0	0	0	0	0	0	16
Conception Coast	Arroyo Hondo	3																								**2**		2
	Goleta Slough Maria Ygnacio Creek	1							**1**								**1**	**1**								**1**		4
	Goleta Slough Atascadero Creek	1																	**2**			**2**						4
	Goleta Slough San Pedro Creek	1		1													**1**											2
	Mission Creek	1							**2**		**2**		**1**	**2**	**1**	**5**	**13**							**1**				27
	Carpinteria Creek	1															**3**											3
Santa Monica Mountains	Conejo Creek	Not listed																				**1**						1
	Big Sycamore Creek	3																				0	0	0	0	0	0	0
	Arroyo Sequit Creek	2												0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
	Las Flores Creek																					0	0	0	0	0	0	0
	Solstice Creek	3																				0	0	0	0	0	0	0
	Malibu Creek	1												0	1	2	4	1	2	2	3	3	5	1	0	1	0	25
	Topanga Creek	1								2	0	0	0	0	1	2	2	1	1	0	1	0	0	0	0	2	0	12
	Trancas Creek	Not listed																					0	0	0	0	0	0
	Zuma Creek	Not listed																					0	0	0	0	0	0

Table 2 continued.

BPG	Location	DPS Core Ranking	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Mohave Rim	Ballona Creek	Not listed														**2**												2
	Los Angeles River	3																						0				0
	San Gabriel River	1																							**1**			1
	Santa Ana River	2																										0
Santa Catalina Gulf Coast	San Juan Creek	1												**2**		**1**	**1**				**1**					0	1	6
	San Mateo Creek	1								**2**		**1**														1	0	4
	Santa Margarita River	1																**3**								0	0	3
	San Luis Rey River	1														**1**										0	0	1
	Los Penasquitos Creek	Not listed																			**1**							1
	TOTAL DPS		2	2	2	2	1	4	5	10	2	2	1	8	8	18	49	9	7	11	9	6	5	2	1	10	1	177

DISCUSSION

Survey results

The level of monitoring effort and efficiency varied throughout the DPS, and as a result, the low numbers of adult Steelhead observed during the past 25 years provides documentation of abundance and distribution. Anadromous Steelhead are difficult to detect, especially when numbers are low, because they typically migrate following peak flows when visibility is usually compromised and accessibility to river sites is dangerous for monitoring. Levels of effort to observe adult Steelhead increased over time using a variety of methods. Absence of documented sightings does not necessarily mean that adult Steelhead were not present, just that they were not observed, or that no surveys were conducted. We recognize that the occurrence numbers reported here likely underestimate the abundance of adult Steelhead across the DPS. As reported by Williams et al. (2016) and confirmed by our observations, at no point since Steelhead were listed as endangered in 1997 was the preliminary provisional viable population goal of 4,150 annual anadromous spawners observed in any individual watershed, nor throughout the DPS as a whole.

No geographic distribution pattern was observed, but larger systems with more hydrologically persistent estuaries and flow regimes (Santa Ynez River watershed) reported more adult Steelhead than smaller, more intermittently connected systems. Adult Steelhead were typically observed in traps, or by in-stream PIT antenna, video surveillance, and DIDSON cameras following storm events when flows could support migration. They were also observed during spring/summer visual and snorkel surveys when detectability was increased in lower flows and fish were trapped in the freshwater system and concentrated in refugia habitats. The large rainfall events in 2005 and 2008 provided good upstream migration, spawning, and rearing opportunities throughout the DPS and the potential for out-migrating smolts, which resulted in a substantial increase in adult anadromous Steelhead returns observed in 2008 and 2011, when there was also enough rainfall and associated flows to support migration. Having a close sequence of wet years provided the opportunity for previous cohorts to return in subsequent years as adults (e.g., the 2005 cohort returned in 2008). However, even though we logically expect these results the overall low abundance, variable sampling methods, inconsistent levels of effort, and differences in monitoring protocols used at each location made it difficult to identify clear correlations between adult abundance and rainfall/flows.

The limited and inconsistent monitoring for all life stages occurring in southern California makes it challenging to answer key questions regarding smolt production and adult returns, although the extreme drought from 2012 to 2016 was known to play a role in the lower Santa Ynez River (COMB 2015) and in Topanga Creek by reducing connectivity and limiting available rearing space (Dagit et al. 2017) and the overall population. Further monitoring and research are needed to determine what combinations of factors are resulting in such low numbers of adults (Boydstun and McDonald 2005; Adams et al. 2011; NOAA 2016). Although more Steelhead of all life stages were observed in locations with more consistent monitoring programs, differences still existed when considering passage limitations and system size. For instance, even though the monitoring effort and detection potential were higher in Topanga Creek than in Malibu Creek, passage restrictions at Topanga lagoon and drought-related low flow conditions resulted in fewer Steelhead accessing that system as compared to Malibu Creek (Dagit et al. 2018a).

Given the limitations of the data available, it was not possible to examine the potential role of other variables on adult Steelhead migration such as lagoon breaching dynamics, timing of wet years needed for sufficient flow for adult migration, basin size, passage barriers, and smolt production, survival and emigration conditions. The fact that adult Steelhead were observed in some locations more frequently than others could reflect migration access, suitable habitat, level and type of monitoring effort and detection efficiency and ocean conditions.

Lack of a discernible distribution pattern of adult Steelhead is inconclusive given the monitoring limitations, overall low population densities, limited passage opportunities, and persistent drought conditions. All these systems were highly impacted by drought, especially from 2012 through 2016, resulting in little if any connection to the ocean, both intermittent and interrupted stream flow, and fragmented habitat upstream (COMB 2015; Dagit et al. 2017). Genetic data from southern California indicates that although many adults return to their natal stream to spawn, others stray (Clemento et al. 2009; Pearse et al. 2014). Due to the limited genetic information available it was not possible to assess the percentage of strays from the monitoring data evaluated during this study.

Influences of anadromy and residency

Factors influencing residency versus anadromy have been explored by Kendall et al. (2015), and their findings suggest that environmental conditions such as those occurring in southern California play an important role in determining propensity for anadromy, in addition to an individual's genotype (Hendry et al. 2004). The genetic potential for anadromy appears to persist in upper watershed locations throughout the southern California DPS below and in some instance above barriers (Thrower et al. 2004; Pearse et al. 2009; COMB 2013; Abadia-Cardoso et al. 2016; RCDSMM, unpublished data) and when opportunity arises, resident fish can smolt and emigrate to the ocean (McPhee et al. 2007; Holecek at al. 2012; Corter et al. 2013; Kendall et al. 2015). However, given the limited opportunity for passage due to low flows, there may not be sufficient numbers of smolts making it to the ocean, resulting in low numbers of adults returning. The snorkel/redd survey data, various fish passage/traps, and DIDSON camera data available from a few systems (Arroyo Sequit, Malibu, and Topanga Creeks (Dagit et al. 2018a, b); lower Santa Ynez River (COMB 2013; COMB 2018); Santa Clara River (Booth 2016); and Ventura River (CDFW, unpublished data), have documented low numbers of smolts throughout the DPS. Additionally, the effects of ocean conditions on smolts is another important factor. Michel (2018) found that flow levels during outmigration explained survival patterns for Chinook salmon more than marine conditions, and Kendall et al. (2015) suggest that there is a wide range of environmental and individual fitness variables that might influence marine survival. Analysis of the smolt-to-adult survival ratio in Southern Steelhead needs further study.

If the number of anadromous *O. mykiss* continues to decline, there will be increased dependence on resident Rainbow Trout for smolt production to maintain or re-establish the Steelhead life history. Resident *O. mykiss* currently play a key role in smolt production. Ultimately reproduction by both resident and anadromous life histories contributes to the overall abundance of *O. mykiss* (NOAA 2012). However, these resident populations are at risk from negative anthropogenic impacts, environmental effects, and other population-level threats. Decreased expression of and/or retention of genetic markers associated with anadromy, coupled with low population numbers and barriers to migration, could exacerbate the issue of inbreeding in small isolated populations (Pearse et al. 2009). Sharp declines in local population numbers can cause inbreeding depression and lower fitness (Pearse et al. 2014; Abadia-Cardoso et al. 2016; Leitwein et al. 2016). Recent genetic studies of Southern California Steelhead populations indicate that these populations have low allelic diversity (Clemento et al. 2009; Pearse et al. 2009; Jacobson et al. 2014; Abadia-Cardosa et al. 2016; Apgar et al. 2017). Strays may be important for re-establishing populations once extirpated (Bell et al. 2011) and provide additional genetic diversity (Garza et al. 2014). Many of these populations retain alleles associated with anadromy (Pearse et al. 2009; Abadia-Cardosa et al. 2016), suggesting that despite their primarily freshwater resident life history pattern, the genetic potential for anadromy is still present. Importantly, the potential for resident *O. mykiss* to establish anadromous populations (Nielsen 1999; Courter et al. 2013; Phillis et al. 2016; Apgar et al. 2017) further supports their importance in promoting Steelhead recovery. Given recent occurrence of multiple large-scale catastrophic events in this region (e.g., wildfires and drought), genetically informed conservation actions must happen expediently to avoid further loss of genetic diversity potentially present in these isolated populations while other Steelhead recovery efforts continue.

Recovery planning and future needs

How should monitoring approaches be adjusted to accommodate challenges in assessing DPS status and trends? There are numerous identified factors contributing to the decline of this species within the southern California DPS both in its freshwater and ocean environments. The federal Recovery Plan (NOAA 2012) provides a thorough assessment of the threats to southern California DPS Steelhead and prioritizes recovery actions specific to each watershed that could help mitigate these threats. Increased and consistent monitoring efforts are needed, especially in the smaller systems and tributaries, to further understand distribution and abundance patterns and assess the effectiveness of restoration and recovery actions to increase populations over time. Further monitoring and research are needed to assess what combinations of factors are resulting in such low numbers of adults, although the extreme drought from 2012 to 2016 played a large role in population reduction in Topanga Creek (Dagit et al. 2017) and the lower Santa Ynez River (COMB 2015). Additional threats such as barriers to fish passage and migration, impacts to freshwater habitat quality, degradation of estuarine habitat, water quality and quantity, increased development, prolonged and intensive drought, loss of habitat due to wildfires, and increased number of both aquatic and terrestrial invasive species are well documented within the southern California DPS and have cumulatively taken a toll (NOAA 2012).

Numerous barrier removal and habitat restoration projects have been implemented in the past 25 years to address some of these threats throughout the DPS (NOAA 2016), but recent wildfires, floods, and persistent drought have seriously reduced the effectiveness of those efforts (Smith et al. 2018). These events, especially wildfires, have further reduced the number of small, isolated remnant populations found mostly in upper tributaries (Smith et al. 2018; CDFW, unpublished data). Restoring dependable flow through a natural flow regime despite drought and anthropogenic impacts are long-term efforts key to promoting Steelhead recovery. Advancements in surface and groundwater management to address the competing needs of providing potable water supply as well as maintain stream baseflow during the dry season may provide opportunities to ensure more reliable stream flows. The Thomas Fire (2017) impacted many drainages throughout Santa Barbara and Ventura Counties; the Whittier Fire (2017) impacted the Santa Ynez watershed in Santa Barbara County, and the Woolsey Fire (2018) impacted all creeks in the Santa Monica Mountains except Topanga Creek. Subsequent fire related floods and debris flows continue to impact these areas and caused local extirpation (CDFW, unpublished data). Evidence from previous wildfires suggests that when local populations are extirpated, intervention may be needed for re-establishment (Rinne 1996; Cooper et al. 2015).

To identify the proximate causes limiting the DPS from meeting population level recovery criteria proposed for viable populations in core watersheds (NOAA 2012), continued and consistent monitoring efforts are needed. Building quantitative models that consider both anadromous and resident fish in the production of smolts, in addition to watershed-specific carrying capacities would be a valuable effort towards refining population goals. Removal of fish passage barriers, habitat improvement, invasive species removal, and adequate river flow are essential components, but may not be sufficient to restore populations.

Novel approaches are needed to protect and increase the resiliency of resident and anadromous *O. mykiss.* Such approaches may include one or more of the following as part of a carefully considered regional conservation strategy for the DPS: 1) removal of invasive aquatic species (in particular predatory species such as bass and sunfish) to create additional suitable habitat; 2) translocation and assisted migration of *O. mykiss* into vacant refugia habitat both above and below dams to increase geographic distribution; 3) conservation hatcheries to increase abundance and genetic diversity; and, 4) cryopreservation to preserve genetic material of high-risk populations (Labbe et al. 2001). Policies that afford further protection to resident Rainbow Trout should also be considered, such as the Similarity of Appearance clause in the ESA (Fejtek 2017). Additional genetic work is needed to better understand factors that regulate anadromy.

Projected impacts of climate changes (Sun et al. 2015) suggest that protecting the more resilient, and warm water tolerant (Matthews and Berg 1997; Myrick and Check 2005; Spina 2007; Sloat and Osterback 2013) Steelhead populations found in southern California would be prudent. Southern Steelhead Trout are incredibly resilient (Boughton et al. 2010; NOAA 2012; Moyle et al. 2017), but despite 25 years of protection under the federal Endangered Species Act, have not been able to overcome the many threats to their survival. The future of this species at the southern extent of its range will depend on a suite of carefully planned and expeditiously implemented recovery actions but most importantly, recognition that protecting both resident and anadromous *O. mykiss* together is beneficial for the recovery of the species as a whole.

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Author Contributions

Conceived and designed the study - RD, ML, DMCC, THR
Collected the data - all
Performed the analysis of the data - RD, MTB, SH, SDL, SJ, THR
Authored the manuscript - RD, MTB, SH, SDL, SJ, THR
Provided critical revision of the manuscript - RD, MTB, TH, SH, SDL,ML, SJ, THE

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