6 South-Central/Southern California Coast Recovery Domain

David A Boughton[15]

Listed Distinct Population Segments

The domain is inhabited by two Distinct Population Segments (DPSs) of steelhead. The South-Central California Coast DPS (listed as Threatened) inhabits coastal stream networks from the Pajaro River system in Monterey Bay south to, but not including, the Santa Maria River system in Santa Barbara County. The Southern California Coast DPS (listed as Endangered) inhabits coastal stream networks from the Santa Maria River system south to the U.S. border with Mexico. For convenience I refer to fish of both DPSs as "southern steelhead."

Freshwater-resident (non-anadromous) *O. mykiss*, commonly known as rainbow trout, also occur in the same geographic region, frequently co-occurring in the same river systems as southern steelhead. Clemento et al. (2009) found that southern rainbow trout above impassable dams and southern steelhead below dams tended to be closely related genetically, suggesting that each steelhead DPS is simply the anadromous component of a corresponding Evolutionarily Significant Unit (ESU; Waples 1991) comprising both anadromous and non-anadromous *O. mykiss*. Anadromous and/or non-anadromous forms of the species also occur in some basins south of the U.S. border, on the Baja California Peninsula (Ruiz-Capos and Pister 1995).

Listing History and Initiation of Recovery Effort

The first comprehensive status review of steelhead was conducted by Busby et al. (1996), who characterized Evolutionarily Significant Units (ESUs) using the conceptual framework of Waples (1991), and then assessed extinction risk of each ESU. The South-Central California Coast and Southern California Coast Steelhead ESUs were subsequently listed as Threatened and Endangered, respectively, by NMFS under the U.S. Endangered Species Act (ESA). The original listing characterized the southern range limit as the southern end of the Santa Monica Mountains just north of Los Angeles, but it was later determined to occur further south, at least as far as the Tijuana River system at the U.S.-Mexico border, and possibly further south in Baja California. The listings were

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[15] This section authored by D. Boughton is dedicated to Pete Adams, retired NMFS biologist who started the Science Center along this path of scientific recovery planning for California anadromous salmonids. A number of important planning efforts have been completed since the last viability assessment, including Federal recovery plans for each DPS (National Marine Fisheries Service 2009b, 2012b), and the design of a comprehensive monitoring plan that will track the extinction risk of each DPS over the long term (Adams et al. 2011). The recovery plans and the monitoring plan formally constitute the initiation of a recovery effort, in which actions affecting the fish either positively or negatively can be placed within the context of criteria for a viable metapopulation of the species. This viability assessment is thus the first to use these plans as a forward-looking frame of reference for updating the risk status of each DPS.

also modified to include only the anadromous component of each ESU, which are composed of both anadromous and non-anadromous forms of *O. mykiss*. Good et al. (2005) updated the status of Pacific coast steelhead populations five years after the listings, and another update was conducted in 2010 (Williams et al. 2011) and is available on-line. None of these updates led to changes in status of either listed DPS.

Consistent with ESA statute, the listings triggered the preparation of recovery plans. The first phase of recovery planning focused on the synthesis of scientific and technical guidance for recovering the two DPSs, and was conducted by NMFS Southwest Fisheries Science Center. This phase of planning was based on available scientific information and a conceptual framework for viable salmonid populations (McElhany et al. 2000). Findings are described in a series of NMFS Technical Memoranda describing ESU structure (Boughton et al. 2006, Boughton and Goslin 2006), viability criteria (Boughton et al. 2007), research needs (Boughton 2010c), a conceptual framework for recovery (Boughton 2010a), and a plan for ongoing monitoring of risk status of each DPS (Adams et al. 2011).

The second phase focused on preparation of recovery plans that describe strategies and goals for recovering the DPSs. Since the last viability assessment, the NMFS West Coast Region and its partners have formally adopted recovery plans for both DPSs (NMFS 2009b, 2012b). The plans are based on the biological needs of the fish and provide a foundation for restoring each DPS and its constituent populations to levels at which they would no longer be considered at risk of extinction.

These "levels" are formally known as viability criteria, and the summary statistics used to assess each DPS are known as viability metrics (e.g., Figure 6.1). With the publication of recovery plans and a monitoring plan, the goal of status review updates now becomes an assessment of whether viability metrics for each DPS are moving toward or away from the viability criteria. Unfortunately, this simple process of reviewing status is hampered at the moment by two problems: 1) scientific uncertainty about the viability criteria themselves, and 2) incomplete data on viability metrics. To address (1), below I review new information relevant to the viability criteria. To address (2), I review the implementation thus far of the monitoring plan, known formally as the California Coastal Monitoring Plan[16], or California CMP.

New Information Relevant to Viability Criteria

Risk status is based on the concept of viability at two levels of organization: the overall DPS, and individual populations composing the ESU of which the DPS is part.

[16] For information on the California Coastal Monitoring Program: http://www.calfish.org/ProgramsData/ConservationandManagement/CaliforniaCoastalMonitoring.aspx

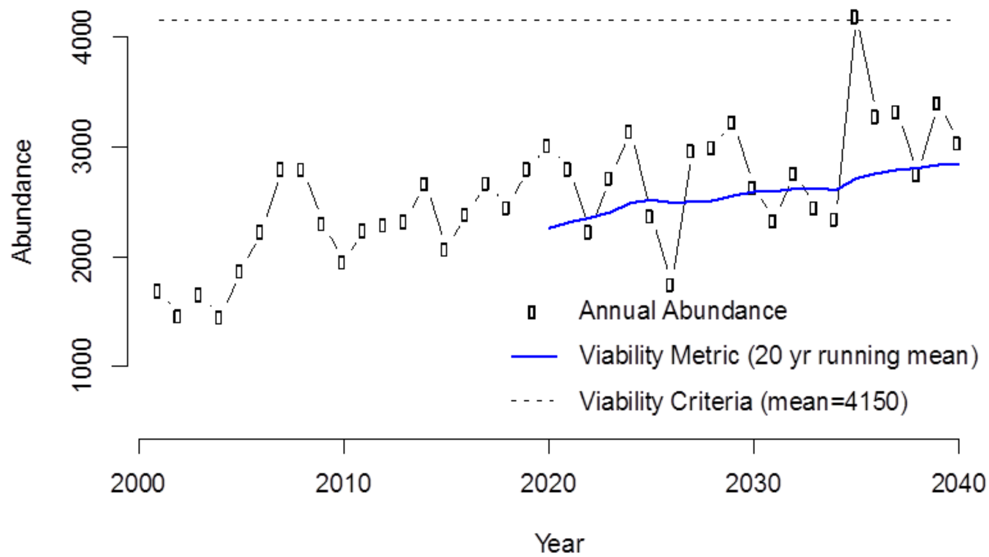

Figure 6.1. Concept of viability metric and a viability criterion applied to a hypothetical population.

DPS Viability

For each DPS, the recovery plans (NMFS 2009b, 2012b) developed viability criteria for populations (Table 6.1) and followed scientific recommendations by specifying a set of core populations on which to focus the recovery effort ("Core 1" and "Core 2" populations, Table 6.2). Formally, if each of these core populations were restored to viability (Table 6.1, top), and they also meet DPS-level criteria (Table 6.1, bottom), the DPS as a whole would be considered viable from a scientific perspective. However, there appear to be two discrepancies between the scientific recommendations for DPS viability (Table 6.1) and the list of core populations (Table 6.2):

First, scientific recommendations were that three populations in the Mojave Rim biogeographic area be restored to viability, but the recovery plan prioritizes only two (San Gabriel River, Santa Ana River) as either Core 1 or 2 populations. In addition, scientific recommendations were that eight populations in the Santa Catalina Gulf Coast area be restored to viability, but the recovery plan prioritizes only six (San Juan Creek, San Mateo Creek, San Onofre Creek, Santa Margarita River, San Luis Rey River and San Dieguito River) as either Core 1 or 2 populations. In the Recovery Plan four populations (San Diego, Sweetwater, Otay, and Tijuana) were designated as Core 1 or 2 populations, though Core 3 populations are recognized as important in promoting connectivity between populations, and genetic diversity across the DPS, and are therefore an integral part of the overall recovery strategy of the Recovery Plan. This approach is broadly consistent with the recommendations in the viability report, which noted that it is not clear if historically, the anadromous life history was consistently expressed in these populations of the extreme southern range limit.

Significant new genetic information bears on the question of native steelhead populations toward the southern extent of their range in California. Jacobson et al. (2014) analyzed genetic composition of *O. mykiss* sampled from a variety of sites in the Monte Arido, Mojave Rim and Santa Catalina Gulf Coast biogeographic areas (see also Abadia-Cardoso et al. in press). The majority of sites were found to harbor *O. mykiss* lineages

Table 6.1. Viability criteria emphasized in scientific recommendations.

Criteria for population viability

Prescriptive criteria:

Viability metric	Viability criterion	Notes
Mean annual run size	S > 4,150	Precautionary
Ocean conditions	Size criterion met during poor ocean conditions	
Population density	Unknown	Research needed
Anadromous fraction	100% of 4,150	Precautionary

Performance-based criteria:
One or more prescriptive criteria (above) could be replaced by a quantitative risk assessment satisfying the following:

1. Extinction risk of anadromous population less than 5% in the next 100 years.
2. Addresses each risk that is addressed by the prescriptive criteria it replaces.
3. Parameters are either a) estimated from data or b) precautionary.
4. Quantitative methods are accepted practice in risk assessment/population viability analysis.
5. Pass independent scientific review.

Criteria for DPS viability

Viability metric	Viability criterion
Biogeographic diversity	1. Sufficient numbers of viable populations in each biogeographic group (See Table 6 in Boughton et al. 2007).
	2. Viable populations inhabit watersheds with drought refugia.
	3. Viable populations in basins separated by > 68 km if possible.
Life-history diversity	Viable populations exhibit three life-history types (fluvial-anadromous, lagoon-anadromous, resident)

Table 6.2. Core populations designated by recovery plans for recovering to viability.

Population	Adult abundance[a]	Spatial structure[a]	Smolt counts[a]
<u>South-Central California Coast DPS</u>			
Interior Coast			
Pajaro River	N	I	N
Salinas River	Y	I	B
Carmel River			
Carmel River	B	I	N
Big Sur Coast			
San Jose Creek	N	N	N
Little Sur River	N	N	N
Big Sur River	B*	N	N
San Luis Obispo Terrace			
San Simeon Creek	N	N	N
Santa Rosa Creek	N	N	N
San Luis Obispo Creek	B*	N	N
Pismo Creek	N	N	N
Arroyo Grande Creek	N	N	N
<u>Southern California Coast DPS</u>			
Monte Arido Highlands			
Santa Maria River	N	N	N
Santa Ynez River	B	Y	B
Ventura River	B	Y(I)	B
Santa Clara River	B	N	B
Santa Barbara Coast			
Canada de la Gaviota	N	N	N
Goleta Slough complex	N	N	N
Mission Creek	N	N	N
Carpenteria Creek	Y	N	N
Rincon Creek	N	N	N
Santa Monica Mountains			
Arroyo Sequit	B*	Y	Y
Malibu Creek	B*	Y	Y
Topanga Canyon	B*	Y	Y

Table 6.2. continued.

Population	Adult abundance[a]	Spatial structure[a]	Smolt counts[a]
Mojave Rim			
San Gabriel River	N	N	N
Santa Ana River	N	N	N
Santa Catalina Gulf Coast populations			
San Juan Creek	N	N	N
San Mateo Creek	N	N	N
San Onofre Creek	N	N	N
Santa Margarita River	N	N	N
San Luis Rey River	N	N	N
San Dieguito River	N	N	N

a – Y = yes, N = no, B = estimates are likely biased (B* = redd counts, which can be bias-corrected with data from life-cycle monitoring stations), I = index reaches rather than randomly sampled reaches or complete census of anadromous habitat.

derived from hatchery stocks of rainbow trout rather than native coastal steelhead lineages. Native lineages were generally found throughout the Monte Arido sites, but most of the Mojave Rim and Santa Catalina Gulf Coast sites consisted of non-native hatchery lineages, “representing almost complete introgression or replacement of native fish by introduced hatchery rainbow trout” (Jacobson et al. 2014). Three groups of sites contained significant evidence of native steelhead ancestry: 1) the San Luis Rey River population, 2) Coldwater Canyon, tributary to the Santa Ana River, and 3) the San Gabriel River population, except for sites on the Iron Fork and Devil’s Canyon Creek that showed hatchery lineage. These three groups of sites are part of three core populations listed in Table 6.2. A few other sites, especially Bear Creek, tributary to the Santa Ana River, and Devil’s Canyon Creek, tributary to the San Gabriel River, showed detectable signals of native ancestry co-existing with a strong signal of hatchery lineages. The authors of the report concluded that “overall, relatively few populations [sites] in this study appear to be pure native southern California *O. mykiss*” (Jacobson et al. 2014), but they also noted that some of the non-native genetic introgression may increase the potential for evolutionary adaptation to changing conditions and might therefore contribute to viability.

The second discrepancy is that scientific recommendations emphasized that core populations be situated in watersheds with drought refugia (Table 6.1, bottom). There does not appear to be any systematic information on the distribution of drought refugia, even though the current drought provides a valuable opportunity to identify such refugia. Thus it is unclear if the selected set of core populations meets this criterion.

Given the current drought, it might be useful to quote from the viability report: "…tree-ring data described by Cook et al. (2004) go back to the year 800 A.D., and record at least four multi-decade droughts prior to 1300 A.D. These events had far greater magnitudes than anything observed during the historical period. The aboriginal steelhead populations must have either survived in drought-resilient refugia, or have been regionally extirpated prior to 1300 A.D. and recolonized in the subsequent centuries. If the refugium hypothesis is correct, ESU viability is probably contingent on forecasting the location of refugia under future climate regimes. If the recolonization hypothesis is correct, ESU boundaries are currently misspecified. Evaluation of the refugium hypothesis, particularly as it relates to future climate, is an obvious research priority." (Boughton et al. 2007).

Population Viability

Viability criteria at the population level are summarized in the top of Table 6.1. In the scientific recommendations (Boughton et al. 2007), there was broad agreement that the viability metrics of Table 6.1 were sufficient for assessing risk, but also agreement that the specific viability criteria were highly sensitive to scientific uncertainty about key aspects of steelhead ecology. These key knowledge gaps included 1) uncertainty about the magnitude of normal fluctuations in adult abundance, and 2) uncertainty about the underlying biological mechanisms for expression of life-history diversity, especially factors triggering anadromous versus non-anadromous life-histories within populations. Thus the criteria that mean annual spawner abundance 1) be greater than 4150, and 2) be composed of 100% anadromous fish, were recommended as a risk-averse approach. It was expected that further scientific work would either support these criteria or allow one or both to be relaxed, depending on results.

The last five years have seen little progress in developing better scientific information on population fluctuations, but significant progress on maintenance of life-history diversity. However, there has been no work on how the ecological and biological factors that maintain life-history diversity at the population level bear on the viability criterion for anadromous fraction.

Data on population fluctuations will emerge over time with the implementation of the CMP, discussed further in the next section. The CMP emphasizes annual estimates of abundance of anadromous adults in each Core 1 and Core 2 population, which is intended to provide data on abundance and productivity metrics, including abundance fluctuations. Missing from the CMP but just as important with respect to future revision of viability criteria, are ongoing monitoring of abundance and fluctuations of the non-anadromous life-history type in each population over time, and also the lagoon-anadromous form (Boughton et al. 2007).

Maintenance of Life-history Diversity

Previous research led by NMFS and UC Santa Cruz suggested that diversity of life histories (anadromous versus non-anadromous, age of smolting and age of maturation) was largely controlled by diversity in growth rates during the early life history of the fish (Bond et al. 2008, Satterthwaite et al. 2009; Beakes et al. 2010; Satterthwaite et al. 2012), and thus was largely under ecological control. On the other hand, numerous studies have demonstrated the heritability and genetic influence on expression of anadromy (Kendall et al. 2015). In particular, a recent analysis identified an important genetic component on chromosome *Omy5* (Martinez et al. 2011; Pearse et al. 2014; Pearse et al. in preparation). Evidently, a portion of *O. mykiss* chromosome 5 has undergone an inversion, in which a segment of the chromosome has been reversed end to end in some fish but not others. This inversion is passed on to progeny, but for fish in which one chromosome is inverted and the other not (i.e., a parent of each type), no crossing-over can occur during meiosis, and so the set of genes on the inverted section of chromosome are tightly linked (prevented from mixing between the two chromosome types). Such tightly linked sets of genes are sometimes called "supergenes."

Pearse et al. (2014) surveyed the occurrence of these two chromosome types in existing genetic samples from throughout the California coastal mountains, and found several interesting patterns:

1) Both chromosome types were present at most sites,
2) There was strong evidence of selection on the set of linked genes within the inversion,
3) One chromosome type dominated sites in anadromous waters, whereas the other chromosome type dominated sites in formerly anadromous waters that are now upstream of impassable dams.

Pearse et al. (2014) concluded that natural selection favors one chromosome type in anadromous waters, and this chromosome type therefore likely plays a role in maintaining the anadromous life-history, and natural selection favors the other chromosome type in non-anadromous waters, and therefore it likely plays a role in maintaining the non-anadromous life history. However, both chromosome types do occur in both types of waters, and both life-histories are observed in anadromous waters, so the relationship is probably not a simple association between non-anadromous and anadromous genomic elements.

Pearse et al. (In preparation) combined genetic analysis of the Omy5 inversion with a mark-recapture study of juvenile *O. mykiss* in a small population in the Big Sur biogeographic group. For age 0 fish, the probability of emigrating from freshwater to the ocean was associated with chromosome type, sex, and juvenile body size, and also interaction effects for these three traits. However, the associations were probabilistic rather than "complete": emigrants included juveniles of both sexes, a broad range of sizes (100 – 250 mm), and both chromosome types. Pearse et al. (In preparation) conclude that the Omy5 inversion region represents a "supergene with a major effect on a complex behavioral trait (i.e., migration)", but that the individual component genes have not yet been resolved, and also that chromosome Omy12 "also contains regions important for smoltification-related traits… In addition, other genomic regions, heritable epigenetic effects, and subtle population structure or assortative mating may also affect this complex life-history trait." Rundio et al. (2012) also described evidence that females were more likely than males to emigrate in this study population, and Ohms et al. (2014) documented similar female-biased emigration in nine populations distributed broadly across the Pacific Northwest, southern Alaska, and northern California.

These new findings demonstrate that non-anadromous and anadromous life-histories in *O. mykiss* in the southern domain and elsewhere are tightly integrated. This suggests that the viability criterion for a 100% anadromous fraction in core populations (Table 6.1) should be revised. However, the studies summarized above do not include any population-viability analyses, which would be necessary for proposing a specific revision of the criterion.

New Information on Methodology for Viability Metrics

The CMP draws on the VSP framework of McElhany et al. (2000) to assess viability in terms of four population metrics: abundance, productivity, spatial structure, and diversity. The CMP also outlines the creation of a system of Life-Cycle Monitoring stations (LCMs) to collect additional data necessary for the interpretation of those four metrics (Adams et al. 2011). The CMP is intended to provide data sufficient to conduct viability assessments and status reviews under the U.S. Endangered Species Act, but at present is only partially implemented. Here I review methodological issues that appear to be impeding implementation; in the next section I review the level of implementation thus far.

According to Adams et al. (2011), the CMP divides the coastal zone of California into northern and southern areas based on differences in species composition, levels of abundance, distribution patterns, an d habitat differences that require distinct monitoring approaches. The South-Central California Coast and Southern California Coast Steelhead DPSs are in the southern area. Implementation of the CMP in the southern area means monitoring the following metrics in the core populations listed in Table 6.2 (Adams et al. 2011):

1) Unbiased estimates of annual anadromous run size, for tracking abundance and productivity.
2) Unbiased estimates of the spatial distribution of juveniles, possibly also in lower priority populations, for tracking spatial structure.
3) Unbiased estimates of annual smolt production in a subset of Table 6.2 populations that are well-distributed biogeographically (life-cycle monitoring stations), for distinguishing between changes in ocean conditions and freshwater conditions.
4) Unbiased estimates of diversity metrics, still to be determined, for tracking diversity.

Here, "unbiased" is used in the statistical sense of estimators whose long-run sampling distribution is equal to the parameter being estimated—for example, methods that do not systematically undercount or overcount fish over repeated surveys. Below I summarize methodological progress on estimating these four metrics.

Abundance and Productivity

In both northern and southern monitoring areas, the assessment of abundance and productivity is based upon unbiased estimates of the annual number of anadromous adults across each ESU, with productivity calculated as the trend in anadromous adults over time. In the northern area (Santa Cruz area north to Oregon), adult abundance is estimated via redd surveys conducted in a spatially balanced, stratified-random sample of stream reaches, and bias-corrected by redds-per-female estimates obtained from LCMs. At the time of CMP development, redd surveys were believed to be infeasible in the southern area due to the extremely episodic flow regime and high bed loads (movement of sand and gravel) during the spawning season, as well as inaccessibility of many upland tributaries during the rainy season. Instead the CMP specified that abundance be estimated by counting upstream migrants at fixed counting stations in the lower mainstems of rivers, but was somewhat agnostic about how it would be done.

To fully support a viability assessment such as this one, such counting would need to occur in the full complement of populations listed in Table 6.2. However, counting would not necessarily need to occur in every population in every year; a rotating-panel sampling plan could probably be used, similar to the sampling of reaches used for redd surveys in the northern area, but with sampling units being whole populations rather than individual stream reaches. That is, some of the populations in Table 6.2 would be counted every year, others would be counted every 3 or 4 or 12 years on a staggered schedule. This is not something envisioned in the original CMP, but would be consistent with its goals and more efficient to implement.

Since the development of the CMP strategy outlined in Adams et al. (2011), there appear to have been two efforts to conduct redd surveys in the southern area, with mixed results. The Monterey Peninsula Water Management District has conducted redd surveys in the lower Carmel River as District resources have permitted, but could not fully implement the protocols used in the northern area (e.g., Gallagher and Gallagher 2005). These protocols specify that sampled reaches be surveyed every two weeks for the duration of the spawning season, which was not possible in the lower Carmel River due to high flows associated with the episodic flow regime, probably leading to an undercount of redds (K. Urquhart, MPWMD, personal communication). Alternately, the NMFS West Coast Region office in Long Beach has had success conducting redd surveys in the Ventura River that adhere closely to the northern area protocol, though these data have not been continued for sufficiently long enough to support a viability assessment (R. Bush, NMFS, personal communication).

These efforts suggest that redd surveys might be able to produce unbiased estimates of adult abundance in some situations but not others. In situations where they appear feasible, such as the Ventura River system, redd surveys would need to be bias-corrected using estimates of redds-per-female estimated at life-cycle monitoring stations (Adams et al. 2011). If redd surveys were to become a strategy for implementing the CMP in the southern area, they would probably not be a universal solution as in the north. The problem with sampling during high flows is also encountered in the northern area (D. McCanne, CDFW, personal communication). The problem with sampling in inaccessible mountain tributaries during the rainy season has not yet been addressed.

At the time of CMP development, one of the most promising methods for counting anadromous adults was the new DIDSON acoustic camera (Pipal et al. 2010a; Pipal et al. 2010b; Pipal et al. 2012). These have started to be deployed in the domain, currently in the Carmel River, Ventura River, Carpenteria Creek, and Salsipuedes Creek (tributary of the Santa Ynez River). There appear to be three problematic methodological issues. The most important is that in some situations, migrating steelhead go back and forth a lot ("milling"), so that the counts of adult steelhead are really the net difference between upstream migrants and downstream migrants. If significant numbers of adult steelhead survive spawning, and migrate downstream to the ocean as kelts, then kelts and "millers" would be confounded, leading to biased estimates. Two other methodological issues are species identification and the sheer number of person-hours required to review DIDSON output in order to produce the counts. The latter issue should be amenable to improvement by using machine-learning techniques to aid in image interpretation. This is a promising avenue for research that might lead to cheaper, more efficient DIDSON monitoring.

Various other methods have been or are starting to be used to count anadromous adults, such as monthly snorkel surveys in Topanga Creek (Stillwater-Sciences et al. 2010), trapping stations in tributaries of the Santa Ynez River (Robinson et al. 2009), a visual imaging system at a fish passage facility on the Salinas River (Cuthbert et al. 2014a), and a counter on a fish ladder on the Carmel River (MPWMD 2013). In addition, a method has been proposed to use two-stage sampling and PIT-tagging of juveniles combined with monitoring of migrants (Boughton 2010b). I summarize data from these sources and methodological issues later in this section, in the update on the viability of Distinct Population Segments. The most important methodological issues appear to be 1) the need to consistently provide unbiased estimates of adult abundance, for example by estimating observation or capture probabilities and by use of randomly sampled stream reaches rather than subjectively chosen index reaches; and 2) the need for methods suitable for the normal range of environmental conditions expected for the domain, which typically involve extreme flow events, high bedloads, and remote rivers and tributaries that are difficult to access during the wet season.

Spatial Structure

The CMP recommends that spatial structure be monitored using summer and fall snorkel surveys that count juveniles in a stratified-random, spatially balanced sample of reaches (Adams et al. 2011). The sampling is achieved using Generalized Random Tesselation Stratified (GRTS) sampling to achieve spatial balance, and a rotating panel design to achieve a balance between the need to estimate structure at a particular time, and the need to estimate trends in structure over time. This is the same sampling framework used in the northern CMP area for both redd surveys and juvenile surveys.

To my knowledge, no such data have been collected in either DPS in the last five years. Topanga Canyon and Santa Ynez River have received comprehensive snorkel surveys, the former for over a decade (Stillwater-Sciences et al. 2010), but no broad-scale data using reach-sampling have been produced. California Department of Fish and Wildlife is in the process of developing a ground-truthed sampling frame for the Santa Barbara

Coast (D. McCanne, CDFW, personal communication) and for Monterey County (J. Nelson, CDFW, personal communication).

Diversity

At the time of CMP development, diversity traits were not sufficiently understood for their monitoring to be specified. Adams et al. (2011) stated that "local diversity traits will need to be surveyed, eventually leading to local diversity monitoring plans. Specific projects targeting both broad and focused levels and patterns of genetic diversity will be developed. Tissue collections for these projects will be coordinated with other CMP activities." We are now in a better position to propose some diversity traits that need to be monitored to assess viability. The viability criteria (Table 6.1, see also Boughton et al. (2007)) emphasize the critical importance of resident adults. The findings of Pearse et al. (2014) and Jacobson et al. (2014) show the importance of genetic information for assessing viability, both in terms of genetic heritage (e.g., native vs. hatchery introductions) and in terms of occurrence of the supergene variants.

Diversity metrics in the form of unbiased estimates of non-anadromous adults and the distribution and diversity of genetic polymorphisms, could all be integrated in a straightforward manner with the broad-scale juvenile sampling that the CMP specifies for spatial structure. An important methodological change would be required: Collection of genetic samples requires handling the fish, which means that mark-recapture or depletion electrofishing would need to occur at a subsample of the reaches selected for juvenile snorkel counts. Such subsampling would also allow the snorkel counts to be bias-corrected (Boughton et al. 2009). If methods were developed to distinguish juveniles from non-anadromous adults in both snorkel counts and electrofishing samples, an unbiased estimate could then be made of the number of non-anadromous adults in the sampling domain. Additionally, tissues could be taken from electrofishing sites for genetic analysis that would provide unbiased estimates of various gene frequencies. I recommend that updates to the CMP be considered that include such diversity monitoring.

Environmental DNA might provide another avenue for monitoring genetic diversity, but its statistical properties for inferring unbiased gene frequencies in steelhead populations is not clear.

Life-Cycle Monitoring Stations

According to Adams et al. (2011), LCMs are a fundamental component of the CMP that delivers two functions: providing unbiased estimates of ocean survival so that changes in salmonid numbers can be parsed into changes due to freshwater versus marine conditions; and as "magnets for other kinds of recovery-oriented research, particularly studies of fish habitat-productivity relationships and evaluations of habitat restoration effectiveness." For the first function (estimating marine survival), an LCM needs three attributes: 1) annual, unbiased estimates of anadromous adults, 2) annual, unbiased estimates of smolt production, and 3) a sufficiently large number of anadromous adults to provide accurate estimates of marine survival (at least 20 per year, preferably more than 100 anadromous adults each year).

Methodological issues for estimating anadromous adults were described above in the section on abundance and productivity.

Methodological issues for estimating smolt production have seen little progress since the last assessment (Williams et al. 2011) and remain problematic. Originally the DIDSON acoustic camera seemed promising as a tool for estimating smolt production, but the size of smolts is close enough to the resolution of DIDSON imagery that detection probability is probably substantially less than 1 (K. Pipal, UCSC/NMFS SWFSC, personal communication). Fyke nets, traps, and visual imagery at fish passage facilities, developed for counting anadromous adults, are also being used to count smolts, but with qualified success. The main problem is counts that are likely biased low due to failure of counting stations during high flow events. Two other problems are distinguishing smolts from juvenile downstream migrants (typically age-0 or age-1 fish moving down to the estuary near the end of smolting season and in early summer), and the difficulty of estimating smolt body sizes. Although estimates of smolt body sizes were not emphasized in the CMP, we should expect marine survival to involve strong interaction effects between ocean condition and smolt size at ocean entry (Ward 2000, Bond 2006). If this were not accounted for then some unknown component of change in marine survival may instead be due to changes in freshwater condition via its effect on smolt body size.

Boughton (2010b) described a framework for using PIT tags to estimate both smolt production and adult abundance. PIT tags would be implanted in juveniles collected from reaches sampled from a stream network, and thus would be straightforward to integrate with the reach-sampling methods used for spatial structure (described earlier). Smolt production is estimated from the proportion of tagged fish that are detected at a downstream tag-reading station near the mouth of the river. An application of this approach in the southern domain has not yet been described, but some advantages and disadvantages are already clear. Advantages are that the method could be integrated with spatial-structure sampling; could provide information on smolt size (via pre-smolt size at the time of sampling); and since the originating reaches of tagged smolts would be known, it could provide a powerful tool for evaluating habitat-productivity relationships, including testing of various habitat-restoration actions, regulatory actions, or flow-management actions relative to “control” reaches. Disadvantages are that progress is still needed for designing reader stations (particularly antennae) that are robust to high-flow events, and that over time this approach is likely to lead to an accumulation of tags in the river bed (from dead juveniles) (D. Rundio, NMFS SWFSC, personal communication). These “ghost or rogue tags” get moved by high flow events and cannot be readily distinguished from live smolts, thus generating overestimates of smolt production. The bias would tend to increase over time as tags accumulate, such that the ghost tags would generate a “ghost recovery” of smolt production.

Monitoring of Viability Metrics

Below I summarize viability metrics that are currently being collected in the domain. In general the metrics are not formally assessed because the period of record is too short for such assessment to be meaningful.

Interior Coast Range

No adult counts or smolt counts have been made in the Pajaro River. The organization Coastal Habitat Education and Environmental Restoration has rescued a mean of 12 adult steelhead per year (sd = 20) from 2006 through 2013 (J. Casagrande, NMFS West Coast Region, personal communication), suggesting consistent occurrence of at least modest numbers of anadromous fish. Some limited assessments of spatial structure have been made in Uvas Creek, Llagas Creek, and Corralitos Creek since 2005, using backpack electrofishing at index reaches (Casagrande 2014), but there do not appear to be unbiased estimates of spatial structure based on stratified-random sampling.

The Salinas River has an established counting station in operation since 2011 (Cuthbert et al. 2014a), with a mean of 22 (sd = 22) total upstream migrants per year. Also reported are net upstream migrants (total upstream migrants minus total downstream migrants) with a mean of 18 (sd = 18) migrants per year. Smolt production has also been monitored with rotary screw traps since 2010, but the counts are likely biased low due to incomplete coverage of the migration season and low (unquantified) trap efficiency during some flow conditions (Cuthbert et al. 2014b). Juvenile abundance has been estimated via backpack electrofishing at eight index reaches since 2010 (Monterey County Water Resources Agency 2014). There do not appear to be unbiased estimates of spatial structure based on stratified-random sampling.

Carmel River

The Carmel River is the only population within the domain for which there is a time-series of adult abundance longer than 20 years. Unfortunately the counts probably have a bias that has changed over time, because the counting has occurred at San Clemente Dam and misses adults that spawn in the river downstream of the dam. This downstream area has been an area of extensive habitat restoration in the past 15 years, so the number of fish spawning here has likely increased and thus the negative bias in the counts has probably also increased over time (K. Urquhart, MPWMD, personal communication).

A plot of the counts (Figure 6.2) shows interesting variation over time. A period of zero counts from 1988 to 1991 were due to a drought, during which local water users drew down the water table and the lower river remained continuously dry and offered no opportunities for migration. During this period the Carmel River Steelhead Association used a nearby seawater facility to operate a broodstock program, releasing many mature anadromous adults as well as hundreds of thousands of juveniles to the river system (Thomas 1996). Numbers quickly climbed after the end of the drought (and the broodstock program) in 1991.

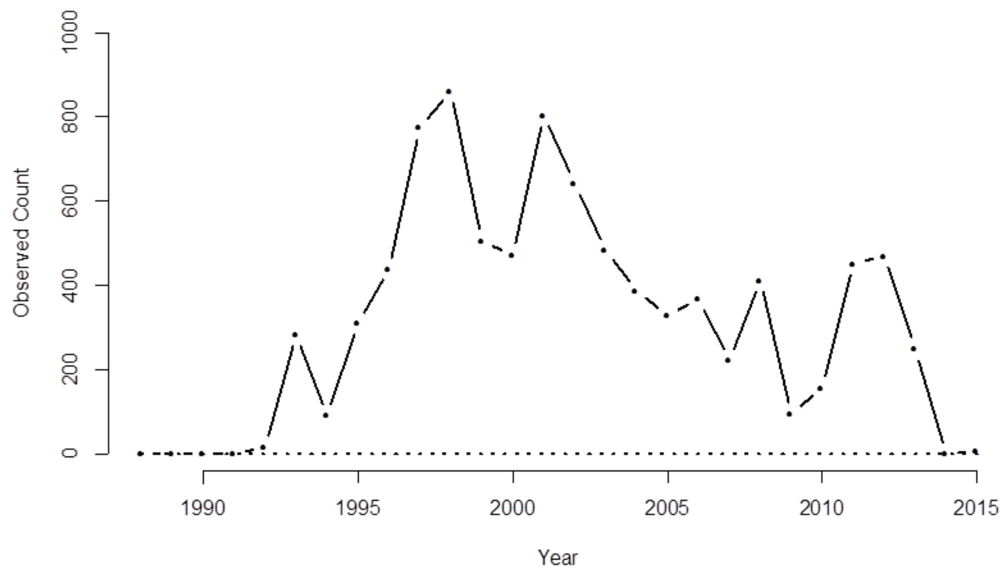

Figure 6.2. Adult steelhead counted at San Clemente Dam on the Carmel River since 1988.

The past 20 years (1996–2015) has seen a consistent though irregular decline in numbers (Figure 6.2), with an average decline of 16.5% per year (or about 50% per generation, assuming a 4-year generation time). Low counts in 2014–2015 are almost certainly due to drought, but the decline was clearly underway prior to 2014.

The 20-year decline coincides with a period of intense management aimed at recovering steelhead, including a restoration of estuary habitat, restoration of riparian vegetation, partial restoration of water tables, and a captive-rearing program for juveniles that get stranded in drying sections of river during the summer. One possible explanation for the decline is that improved conditions in the lower river motivate many adults to stop and spawn prior to reaching the dam and getting counted. However, the local water district (Monterey Peninsula Water Management District, MPWMD) has conducted occasional redd surveys, and found that the number of redds downstream of the dam do not fully account for the decline (see previous viability assessment, Williams et al. 2011), supporting that there has been a decline in abundance.

(Arriaza in review) describes the application of a life-cycle model to steelhead data in the Carmel River. The analysis suggests the decline is due to a long-term decline in the growth rates of age-0 juveniles in the river, which reduces the smolting rate and the survival of smolts once they enter the ocean. The decline in growth rates has apparently led to a switch from most anadromous adults being the result of in-river wild production, to most anadromous adults being fish released from the Sleepy Hollow Steelhead Rearing Facility. From 2005 onward, the vast majority of production of anadromous adults appears to have come from the rearing facility (Arriaza in review, see Figure 2.19).

A notable restoration event in the Carmel River during the past five years has been the removal of San Clemente Dam, and the rerouting of the river channel around the large stockpile of sediment that had accumulated upstream of the dam during the prior 90 years. Dam removal and the completion of the re-route channel have been completed as of December 2015, in time for the 2016 water year which commences 1 Oct 2015. The ecological effects of the dam removal on downstream habitats and on steelhead population viability will provide valuable information for future restoration efforts.

Big Sur Coast

National Marine Fisheries Service Southwest Fisheries Science Center has conducted a tagging study of steelhead in Big Creek (Core 3) since 2004, but has not used it to estimate abundance of anadromous adults, spatial structure of juveniles, or smolt production.

California Department of Fish and Wildlife has conducted redd surveys in the Big Sur River in 2012 (first field test) and in the 2014 and 2015 spawning seasons (J. Nelson, CDFW, personal communication). Each year they surveyed the entire anadromous portion of the stream network, using the field protocols established by Gallagher and Gallagher (2005) (T. Anderson, CDFW, personal communication). Snorkel surveys of juveniles were conducted in 2011 to provide a snapshot of spatial distribution, but have not been continued. Investigation is underway for installation of a DIDSON monitoring site, data from which would provide a basis for estimating redds per female, one of the functions of a LCM station.

There is no apparent monitoring of viability metrics in San Jose Creek and Little Sur River, the other Core 1/Core 2 populations in this biogeographic group.

San Luis Obispo Terrace

The city of San Luis Obispo initiated redd surveys in 2015, and plans to continue the effort using field protocols developed in the Ventura River by NMFS West Coast Region - Long Beach Office (F. Otte, NMFS, personal communication). There is no apparent monitoring of viability metrics in the four other Core 1/Core 2 populations in this biogeographic group.

Monte Arido Highlands

The Santa Maria River population does not appear to be monitored for any of the viability metrics. In the Santa Ynez River, adult and smolt counts have been collected since 2001 via migrant trapping (Cachuma Operation and Maintenance Board 2013), but the counts are likely biased low due to inability to trap during high flows and focus of trapping effort on two key tributaries rather than the whole river system (Robinson et al. 2009). From 2001 to 2011 (the latest date for which counts are published), the mean number of anadromous adults trapped per year was 3.4 (sd=5.2) and the mean number of smolts trapped per year was 146 (sd=116). California Department of Fish and Wildlife initiated DIDSON counts in a tributary (Salsipuedes Creek) in 2013 but has not yet released a report. Comprehensive snorkel surveys have been conducted since 2001 by Cachuma Operation and Maintenance Board, and may be suitable for estimating spatial structure if evaluated at the reach level.

In the Ventura River, the Casitas Municipal Water District (CMWD) issues annual reports on movement of *O. mykiss* through the Robles Fish Passage Facility. The most recent report was 2013 (CMWD 2013). Currently, counts do not distinguish adult steelhead or smolts from other age classes of the fish. Allen (2014) surveyed spatial structure from 2006 to 2012 using a combination of snorkel surveys and electrofishing of juveniles. Rather than using GRTS sampling, Allen (2014) used a three-stage hierarchical sampling scheme in which the first stage was subbasin, the second stage used index reaches, and the third stage used random selection of sites within index reaches.

For the Santa Clara River, the United Water Conservation District issues annual reports describing counts of adult steelhead and smolts passing through the Freeman Diversion Facility in the lower river. The most recent report was 2013 (Howard and Booth 2013), when zero (0) anadromous *O. mykiss* and zero (0) non-anadromous *O. mykiss* were observed. In general these counts represent lower bounds on abundance, as they do not enumerate fish that pass over the low diversion dam itself.

Santa Barbara Coast

California Department of Fish and Wildlife initiated DIDSON counts in Carpenteria Creek in 2014; data are not yet available (D. McCanne, CDFW, personal communication). California Department of Fish and Wildlife is developing a sampling frame and plans to initiate spatial-structure sampling in other populations of the biogeographic group. They have conducted pilot surveys in Gaviota Creek, Refugia Creek, and Arroyo Hondo.

Santa Monica Mountains

The core 1 and 2 populations in the Santa Monica Mountains are Arroyo Sequit, Malibu Creek, and Topanga Creek, and population data for each are being collected by the Resource Conservation District of the Santa Monica Mountains (Dagit et al. 2015). Snorkel surveys have been conducted monthly in reaches of each creek “where the majority of *O. mykiss* were confined due to either low water levels…or in Malibu below Rindge Dam” (Dagit et al. 2015). A random sample of reaches had multi-pass dives to calibrate detection probabilities. Life stages were visually classified using a rating protocol. “Smolt” counts (scare quotes as in the original report) were generated from the snorkel data using the visual classification. Redd counts were also made during the snorkel surveys (i.e., once per month), and twice per month since 2011 in Topanga Creek during the January – May spawning season.

Mojave Rim

No apparent monitoring of viability metrics.

Santa Catalina Gulf Coast

No apparent monitoring of viability metrics.

Harvest Impacts[17]

South Central California Coast Steelhead − Ocean harvest of steelhead is extremely rare, and is in particular an insignificant source of mortality for South Central California Coast (SCCC) steelhead. While insufficient data exists to estimate SCCC steelhead freshwater exploitation rates, these rates are likely relatively low given California's prohibition of natural-origin steelhead retention. Fishing effort estimates based on angler self-report cards are available for 2000–2014 which suggest very low levels of effort for this DPS over this period (Figure 6.3). Beginning in 2013, fishing regulations for many streams changed from allowing no steelhead retention to allowing a daily bag limit of two hatchery-origin steelhead per day. In summary, while no direct information is available on the level of SCCC steelhead fishery impacts, it is reasonable to conclude that the level of impact has either not appreciably changed since the 2010 salmon and steelhead assessment (Williams et al. 2011), or potentially increased due to increased bag limits for hatchery-origin fish.

Southern California Coast Steelhead − Ocean harvest of steelhead is extremely rare, and is in particular an insignificant source of mortality for Southern California Coast (SCC) steelhead. While insufficient data exists to estimate SCC steelhead freshwater exploitation rates, these rates are likely relatively low given California's prohibition of natural-origin steelhead retention. Fishing effort estimates based on angler self-report cards are available for 2000–2014 which suggest extremely low levels of effort in this DPS over this period (Figure 6.3). While no direct information is available on the level of SCC steelhead fishery impacts, it is reasonable to conclude that the level of impact has not appreciably changed since the 2010 salmon and steelhead assessments (Williams et al. 2011).

Summary of Findings

• The prevalence of extensive non-native ancestry in Mojave Rim and Santa Catalina Gulf Coast shows that risk status of the Southern California Coast Steelhead DPS is greater than previously thought. Native lineages have been nearly extirpated from this far

[17] Harvest impacts section prepared by Michael O'Farrell

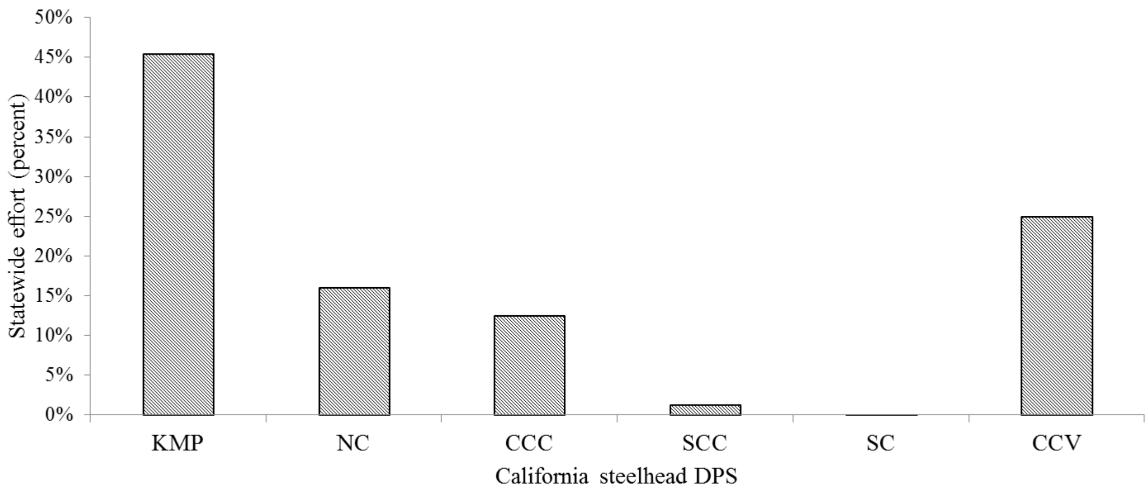

Figure 6.3. Distribution of California statewide steelhead fishing effort by DPS for years 2000−2014 (Jackson 2007; Farhat in preparation).

southern region of the native range of *O. mykiss*. Introduced lineages, primarily from the California Central Valley Steelhead DPS, are extant, introgressing with, and in some cases replacing native lineages. Presumably these introduced lineages have begun to evolutionarily adapt to the local habitats, but do not have the long history of adaptation that the native lineages had. Their potential role in the recovery of the species is not clear.

• There has been a fairly steady 15-year decline in abundance of anadromous adults in the Carmel River, the one population in the southern domain with a reasonably long history of monitoring. This decline is somewhat surprising since it coincides with a concerted effort to restore habitat in the river system and to improve numbers through a rescue/captive-rearing operation. The decline indicates an increase in extinction risk in the South Central California Coast Steelhead DPS, though it is likely that abundance in other populations show different patterns, and possible that such patterns would show that risk is holding steady or even improving (i.e., lower extinction risk).

• Currently, viability cannot be adequately assessed due to lack of implementation of the California Coastal Monitoring Plan (CMP). We recommend:

- Full implementation of CMP abundance monitoring and spatial-structure monitoring,
- Adding to the CMP the monitoring of non-anadromous adults and genetic diversity,
- Greater emphasis on monitoring methods that are unbiased or can be bias-corrected,
- Site-selection and initiation of additional Life-Cycle Monitoring stations. These could serve as study sites to clarify the role of the chromosome inversion in the

maintenance of life-history diversity, and to clarify the potential smolt production of the medium and large alluvial rivers, such as Carmel, Ventura, and Santa Ynez rivers.

• Recent work shows that the tendency to outmigrate (versus mature in freshwater) is associated with particular juvenile body sizes, female sex, the presence of a particular "supergene" on chromosome Omy5, and interactions of these effects. Both variants of the supergene occur in most populations, but one variant tends to predominate in sites with connectivity to the ocean, and the other in populations without connectivity. Overall, these results show that the non-anadromous and anadromous forms are tightly integrated at the population level, suggesting a revision of the viability criterion for 100% anadromous fraction. However, such revision would require additional quantitative analysis of population viability.

• Identification of drought refugia is a pressing need according to the recovery plans, and the current drought provides a valuable opportunity to identify and characterize drought refugia. Knowledge about the distribution of drought refugia might suggest a revision of the Core 1/2/3 assignments of populations.

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VIABILITY ASSESSMENT FOR PACIFIC SALMON AND STEELHEAD LISTED UNDER THE ENDANGERED SPECIES ACT: SOUTHWEST

Thomas H. Williams, Brian C. Spence, David A. Boughton, Rachel C. Johnson,
Lisa G. Crozier*, Nathan J. Mantua, Michael R. O'Farrell, and Steven T. Lindley

NOAA National Marine Fisheries Service
SWFSC Fisheries Ecology Division
110 Shaffer Road
Santa Cruz, CA 95060

* NOAA National Marine Fisheries Service
Northwest Fisheries Science Center
2725 Montlake Boulevard E
Seattle, WA 98112

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