UPDATES TO BIOLOGICAL VIABILITY CRITERIA FOR THREATENED STEELHEAD POPULATIONS IN THE NORTH-CENTRAL CALIFORNIA COAST RECOVERY DOMAIN

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[1] This document was originally printed on 23 March 2012. This revised version corrects minor errors Tables 1 and 6, as well as a few typographic errors in the text. A reference list has also been added.

Introduction

Recovery planning for ESA-listed salmon and steelhead populations in coastal watersheds of California was initiated in 2002, with formation of the several regional technical recovery teams (TRTs) comprised of scientists representing federal and state agencies, tribes, and academic institutions. The TRTs were assigned two major tasks related to recovery planning for salmon and steelhead: (1) to posit the historical population structure of each listed evolutionarily significant unit (ESU) or distinct population segment (DPS) to ensure that recovery strategies focused on appropriate population units, (2) to propose biological viability criteria describing the set of conditions under which each ESU/DPS would be considered at low risk of extinction. Because of regional differences in data availability and ecological processes governing salmonid production and population dynamics, each TRT approached these tasks in somewhat different ways.

In the North-Central California Coast (NCCC) Recovery Domain, the near-complete lack of historical information on the abundance of salmonids hindered both of these activities. In the absence of such data, the TRT turned to models of habitat potential that could serve as proxies for the relative capacities of different watersheds to support populations of salmon and steelhead. Specifically, the TRT adopted models of intrinsic habitat potential for steelhead and coho salmon that were originally developed by the Coastal Landscape Analysis and Modeling Study (CLAMS) in Oregon (Burnett et al. 2003). Intrinsic potential (IP) models predict the likelihood that a stream reach will develop habitat characteristics favorable for a particular species and life stage based on a set of largely persistent geomorphic and hydrologic attributes, typically stream gradient, valley constraint, and estimated mean annual discharge. Attribute values are translated into index score ranging from 0 to 1 based on prescribed functions, and the geometric mean of these index scores provides a metric of intrinsic habitat potential that likewise scales between 0 and 1 (Burnett et al. 2003, 2007).

For application in coastal California watersheds, the National Marine Fisheries Service’s (NMFS) Southwest Fisheries Science Center (SWFSC) used models for steelhead and coho salmon developed by Burnett et al. (2003), making some adjustments to certain suitability curves to reflect data on fish-habitat relationships collected in California (Agrawal et al. 2005). Output from the IP models was subsequently used by the TRT to produce basin-scale proxies for historical capacity in order to develop hypotheses regarding the historical population structure of listed salmon and steelhead ESUs and DPSs in the recovery domain (Bjorkstedt et al. 2005). Model results were further used by the TRT to develop biological viability criteria for populations and ESUs/DPSs throughout the recovery domain (Spence et al. 2008). At the time of publication of Bjorkstedt et al. (2005), the TRT recognized that the coarse relationships between precipitation and mean annual discharge used in the model likely did not capture fully the nature of hydrologic differences between Oregon and California (Bjorkstedt et al. 2005, pp. 33-34). Specifically, in California, higher summer temperatures and a shorter wet season likely lead to a greater difference between estimated mean annual discharge and summer low flows. Lacking any empirical basis for further refining the model, the TRT developed a qualitative index of potential IP bias (i.e., low, moderate, high, and severe) based on watershed averages of mean annual precipitation relative to mean annual temperature (Bjorkstedt et al. 2005). The bias index shows both latitudinal and longitudinal patterns, with the model expected to exhibit higher bias in southern watersheds compared to northern watersheds, and interior watersheds compared to coastal watersheds.

Since publication of Agrawal et al. (2005), Bjorkstedt et al. (2005), and Spence et al. (2008), a combination of reviewer comments and field observations have caused the SWFSC to re-examine the IP model for steelhead in coastal watersheds of the NCCC Recovery Domain. This assessment prompted the SWFSC to revise the curve relating habitat suitability to estimates of mean annual discharge, which influences calculations of of intrinsic potential for steelhead throughout the domain. In this report, we

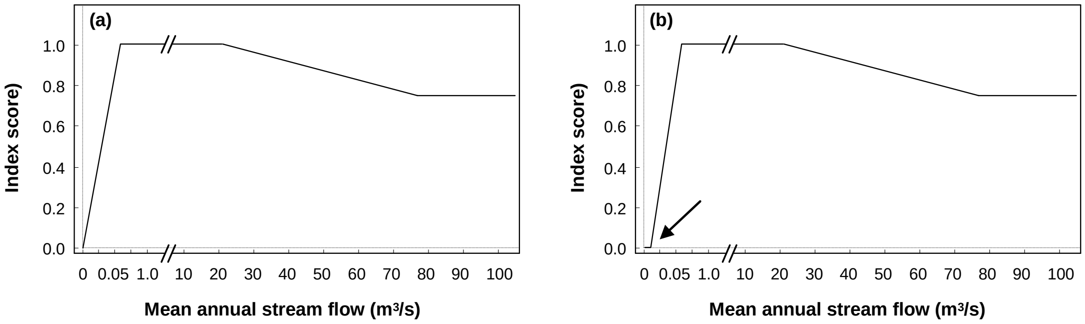

Figure 1. Relationships between mean annual stream flow and suitability index score that were used to calculate intrinsic potential for steelhead in (a) Agrawal et al. (2005) and (b) the revised SWFSC intrinsic potential model.

briefly describe these changes to the SWFSC IP model for steelhead and the implications of these changes for the TRT's previous assessments of population structure (Bjorkstedt et al. 2005) and proposed biological viability criteria (Spence et al. 2008). Changes were only made to the intrinsic potential model for steelhead; IP models for coho and Chinook salmon are unaffected.

Revisions to the IP model

Revisions to the SWFSC IP model result from refinement of the curve relating suitability to mean annual discharge for stream reaches with predicted mean annual discharges of less than 0.06 m^3/s. The IP model of Agrawal et al. (2005) proposed a suitability value for flow that decreased linearly from a value of 1 at 0.06 m^3/s to a value of 0 at 0.00 m^3/s (Figure 1a). However, field observations by SWFSC staff working in watersheds of Mendocino and Santa Cruz counties have indicated that the upstream extent of *O. mykiss* distributions typically ends in reaches where estimated mean annual discharge approaches approximately 0.01-0.02 m^3/s. To correct for this bias in the original model, we revised the suitability curve so that it declines linearly from a value of 1 at 0.06 m^3/s to a value of 0 at 0.01 m^3/s (Figure 1b).

Intrinsic potential values for steelhead have been recalculated accordingly for the entire recovery domain. Consequently, all reaches with estimated flow of less than 0.01 m^3/s are now assigned an IP value of 0. These revisions make the model consistent with the final CLAMS model for steelhead (Burnett et al. 2007). In the course of this reanalysis, the SWFSC also took opportunity to incorporate new information on natural barriers in five watersheds (Alameda Creek, Coyote Creek, Outlet Creek, Navarro River, and Salmon Creek) that was provided by NMFS' Southwest Region, as well as to correct a few minor errors in IPkm totals presented in Bjorkstedt et al. (2005) and Spence et al. (2008).

Effect of updated IP results on population structure

The revision of the IP model for steelhead in the NCCC Recovery Domain potentially affects the outcome of several analyses conducted by the TRT. For each winter-run steelhead population in the recovery domain, a metric of habitat capacity was calculated as sum of each reach length weighted by its intrinsic potential (Bjorkstedt et al. 2005)[2]. This value, termed IPkm, was used by the TRT as a general guidepost for determining whether, historically, populations were likely independent or dependent (sensu McElhany et al. 2000). Specifically, watersheds with >16 IPkm were deemed most likely to support independent populations of steelhead (i.e., populations with a high likelihood of persisting for 100 years or more absent the influence of immigrants from neighboring populations), whereas those with less than 16 IPkm were deemed to likely have been dependent populations (populations that have a substantial likelihood of going extinct within 100 years absent the influence of migrants from neighboring populations). Note that the 16-IPkm threshold was not a hard-and-fast rule for determining population independence for steelhead. The TRT also factored in the expected IP bias for the watershed. Consequently, some populations that exceeded the minimum IP threshold but were in areas where expected IP bias was high or severe were deemed to be dependent. Additionally, the TRT noted that capacities of watersheds to produce steelhead can be substantially enhanced by the presence of lagoon habitats, resulting in higher population abundances than would be predicted based on IP alone, which does not account for these productive habitats. Thus, it is possible for a stream with less than 16 IPkm to be designated as independent.

Total IPkm values for each population were also used in a model to predict self-recruitment: the estimated proportion of individuals returning to a particular watershed that originated within that watershed (as opposed to being immigrants from neighboring watersheds). This analysis was used to help discriminate between two types of independent populations: functionally independent and potentially independent[3]. Functionally independent populations are those that are likely to have a high likelihood of persisting for 100 or more years and whose population dynamics and extinction risk are not substantially altered by exchanges of individuals with other populations. Potentially independent populations are independent populations that are too strongly influenced by immigration from other populations to exhibit independent dynamics (Bjorkstedt et al. 2005). Populations with self-recruitment values exceeding 0.95 were generally deemed to have a higher likelihood of being functionally independent populations, although again this self-recruitment value was used only as a coarse guidepost, and other factors weighed into the final decisions regarding functionally and potentially independent population designations. In particular, for larger watersheds containing more than one independent population (e.g., the Eel and Russian rivers), the TRT noted that expected rates of straying between populations within a watershed might exceed those for populations a similar distance apart but separated by marine waters. Likewise, the self-recruitment analyses for these internal basins did not factor in potential strays from outside the basin, which would tend to result in lower self-recruitment values than predicted by the model, particularly for tributary watersheds lower in the basin. Consequently, some populations with self-recruitment values of > 0.95 were still designated as “potentially independent” and some with self-recruitment values <0.95 were deemed “functionally independent.” Because self-recruitment estimates depend on the relative size of populations, these values would be expected to change substantially only if proportional reductions in IPkm differed strongly among watersheds within a particular region.

Recalculated IPkm values and self-recruitment estimates for the Northern California steelhead DPS are shown in Tables 1 and 2. Overall, changes in IP model results and/or corrections resulting from new information on natural barriers or other issues had minimal impact on the TRT’s hypothesis regarding population independence. Revised IPkm totals resulted in four populations that had previously exceeded the 16-IPkm threshold now falling below this threshold: Hare, Caspar, and Russian Gulch creeks on the Mendocino Coast (Table 1), and Soda Creek in the upper Eel River basin (Table 2). We thus conclude

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[2] Intrinsic potential for summer-run populations was not estimated by the TRT, as it was determined that factors other than juvenile rearing habitat limited production of summer-run populations.

[3] Self-recruitment was also used to discriminate between dependent populations (those expected to receive sufficient immigration to offset risks of extinction due to small size) from ephemeral populations (those expected not to receive sufficient immigration to persist), although the latter were not explicitly detected in our analysis.

that these four populations likely functioned as dependent populations. Additionally, we conclude that three populations that were designated as functionally independent populations by Spence et al. (2008) are more appropriately classified as potentially independent: Albion River (Table 1), and Larabee and Outlet creeks in the Eel River basin (Table 2).

Revised estimates of IPkm and self-recruitment for the Central California Coast steelhead DPS are shown in Tables 3-5. For this DPS, changes in IP model results and/or corrections again result in reconsideration of historical population status for a small number of populations. We conclude that one population, Miller Creek in the San Francisco Bay Area, that was considered a potentially independent population in Spence et al. (2008) should be reclassified as dependent, primarily because of errors in the DEM-generated hydrography, which caused this watershed to be linked to the adjacent Gallinas Creek watershed, which enters directly into the estuary. We recommend that the historical status of San Leandro Creek (also a San Francisco Bay Area tributary) be revised from functionally independent to potentially independent.

Two other coastal populations, Waddell Creek and Laguna Creek, that previously exceeded the 16 IPkm threshold now fall below this benchmark, with 13.7 and 13.1 IPkm, respectively. However, both of these watersheds have sizeable lagoons near their mouths that likely substantially increased the capacity of these watersheds to support steelhead. Additionally, rigorous population abundance estimates from the period 1933 to 1942 indicate that Waddell Creek produced an average of 484 adult spawners (range 428-554) per year (Shapovalov and Taft 1954). As the watershed had already been substantially affected by logging over the previous 50 years, the historical capacity was almost certainly higher than indicated by the Shapovalov and Taft study. Thus, we recommend retaining the potentially independent historical status for this population. Although there are no comparable abundance data for Laguna Creek, the similarity in intrinsic potential, coupled with the sizeable lagoon near its mouth, suggest that this watershed was likely to have supported a population sufficiently large to be treated as potentially independent. Irrespective of the final designations, these watersheds (along with Scott Creek) likely would have contributed disproportionately to connectivity between the two largest watersheds (San Lorenzo River and Pescadero Creek) within this region, which are separated by nearly 60 km.

In addition to above changes, we identify one additional potentially independent population (Saratoga Creek) and one possible dependent population (Permanente Creek). These streams were not classified by Bjorkstedt et al. (2005) or Spence et al. (2008) in part due to the extensive urbanization that has occurred in the lower watersheds, resulting in a highly modified hydrography and, for Saratoga Creek, barriers to anadromous fishes. Nevertheless, there is historical evidence of steelhead occurrence (and extant resident *O. mykiss* populations in the upper watersheds) in the Saratoga watershed, and *O. mykiss* were historically reported in Permanente Creek, suggesting possible use by steelhead (Leidy et al. 2005). Thus, the potential historical roles of these streams should be acknowledged.

Effect of updated IP results on viability criteria

The set of viability criteria developed by the TRT included one criterion that was tied to IPkm totals. This criterion seeks to recognize that populations of different sizes and productive potential played different roles with respect to the persistence of the DPS as a whole (Spence et al. 2008). The IPkm metric was used as a proxy for productive capacity, and low-risk and high-risk abundance criteria for each population were functions of the IPkm total for the watershed.

Overall, revisions to the IP model resulted in appreciable reductions in IPkm totals throughout the domain; however, the magnitude of these changes varied among regions. In the coastal region of the Northern California steelhead DPS, the reduction in IPkm for independent populations averaged around 17%, whereas in the Eel River basin the average reduction was only 11% owing to the steeper topography (i.e., in high-relief areas, maximum gradient thresholds are more likely to be exceeded before minimum flow thresholds). In the Central California Coast DPS, average reductions in IPkm for independent populations were more substantial, ranging from 23% and 26% in the Santa Cruz Mountain and Russian River regions, respectively, to 39% and 42% in the San Francisco Bay and coastal Marin/Southern Sonoma county areas. The substantial reductions in these latter areas reflect both the more arid climates and the more gentle terrain, which resulted in proliferation of small low-flow tributaries in the DEM-generated hydrography. These reaches were effectively removed from the area considered as potential habitat by the new flow-suitability curve.

The revised low-risk viability criteria for independent populations in the NC and CCC steelhead DPSs declined accordingly (Tables 6 and 7, respectively). For the NC steelhead DPS, revised low-risk viability targets decreased by about 12% from those presented in Spence et al. (2008). For the CCC steelhead DPS, low-risk targets decreased by an average of 27% (range 6% to 50%), with the greatest decreases generally occurring in the San Francisco Bay Area.

Revisions to the IP model substantially alleviate the potential bias in IP model predictions for steelhead acknowledged by Bjorkstedt et al. (2005). Although the new flow-suitability curve was applied to all streams across the recovery domain, the disproportionate influence on IP estimates in more southerly and interior regions closely matches the distribution of the qualitative "IP bias index" developed by the TRT to refine interpretation of the original IP model. The resulting network of streams with positive IP values now more closely corresponds to areas that historically had a high likelihood of contributing to steelhead production. Although some bias may remain in the IP model in certain interior regions (e.g., eastern San Francisco Bay), across the majority of the steelhead's range, we believe any remaining bias likely has minimal influence on estimates of IPkm at the watershed level.

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Table 1. Historical population structure of winter steelhead in the NC-Steelhead DPS. This table supercedes Table A.4 in Spence et al. (2008). Only populations with >1.6 IPkm of habitat are shown.

Population	***IPkm***	**Self-recruitment**	**Historical population status**
Fern Canyon	4.2	0.910	dependent
Squashan Creek	2.2	0.592	dependent
Gold Bluff	2.1	0.390	dependent
Redwood Creek (H)	270.9	0.992	**Functionally Independent**
McDonald Creek	3.6	0.418	dependent
Maple Creek/Big Lagoon	71.7	0.901	***Potentially Independent***
Little River (H)	63.0	0.859	***Potentially Independent***
Strawberry Creek	4.4	0.455	dependent
Widow White Creek	6.0	0.577	dependent
Mad River	453.7*	0.979	**Functionally Independent**
Humboldt Bay	212.1	0.854	**Functionally Independent**
Eel River - Full	3764.3	0.996	See Table 2
Fleener Creek	3.3	0.218	dependent
Guthrie Creek	9.2	0.622	dependent
Oil Creek	10.6	0.560	dependent
Bear River	107.8	0.929	***Potentially Independent***
Singley Creek	11.1	0.569	dependent
Davis Creek	8.0	0.612	dependent
Domingo Creek	2.5	0.523	dependent
McNutt Gulch	11.3	0.747	dependent
Peter Gulch	1.7	0.287	dependent
Mattole River	541.1	0.996	**Functionally Independent**
Fourmile Creek	8.6	0.591	dependent
Cooskie Creek	7.7	0.693	dependent
Randall Creek	1.9	0.461	dependent
Spanish Creek	1.9	0.607	dependent
Oat Creek	1.8	0.503	dependent
Big Creek	3.8	0.648	dependent
Big Flat Creek	5.9	0.788	dependent
Shipman Creek	2.3	0.589	dependent
Gitchell Creek	2.5	0.664	dependent
Horse Mountain Creek	3.2	0.797	dependent
Telegraph Creek	5.3	0.728	dependent
Whale Gulch	5.1	0.701	dependent
Jackass Creek	7.6	0.809	dependent
Usal Creek	17.6	0.898	***Potentially Independent***
Cottaneva Creek	23.2	0.915	***Potentially Independent***
Hardy Creek	9.2	0.910	dependent
Juan Creek	10.8	0.941	dependent
Howard Creek	6.1	0.844	dependent
DeHaven Creek	11.7	0.940	dependent
Wages Creek	17.7	0.949	***Potentially Independent***
Chadbourne Gulch	3.0	0.548	dependent
Abalobadiah Creek	5.4	0.702	dependent

Table 1. (continued)

Population	***IPkm***	**Self-recruitment**	**Historical population status**
Seaside Creek	1.7	0.797	dependent
Ten Mile River	181.3	0.997	**Functionally Independent**
Inglenook Creek	1.9	0.440	dependent
Mill Creek	3.6	0.577	dependent
Virgin Creek	2.2	0.589	dependent
Pudding Creek	24.1	0.934	***Potentially Independent***
Noyo River	157.6	0.990	**Functionally Independent**
Hare Creek	14.4	0.938	dependent**
Digger Creek	1.9	0.612	dependent
Mitchell Creek	4.3	0.733	dependent
Jug Handle Creek	4.2	0.737	dependent
Caspar Creek	12.9	0.928	dependent**
Doyle Creek	2.3	0.589	dependent
Russian Gulch (Me)	6.0	0.699	dependent[†]
Jack Peters Creek	2.8	0.634	dependent
Big River	256.1	0.993	**Functionally Independent**
Little River (Me)	6.6	0.591	dependent
Albion River	48.6	0.932	***Potentially Independent***[††]
Big Salmon Creek	18.3	0.902	***Potentially Independent***
Navarro River	397.9	0.992	**Functionally Independent**
Greenwood Creek	8.0	0.632	dependent
Elk Creek	21.5	0.823	***Potentially Independent***
Mallo Pass Creek	6.5	0.607	dependent
Alder Creek	7.6	0.762	dependent
Brush Creek	23.8	0.908	***Potentially Independent***
Garcia River	137.2	0.983	**Functionally Independent**
Point Arena Creek	3.4	0.506	dependent
Moat Creek	3.1	0.590	dependent
Ross Creek	2.2	0.713	dependent
Galloway Creek	1.9	0.729	dependent
Schooner Gulch	7.7	0.830	dependent
Slick Rock Creek	2.3	0.492	dependent
Signal Port Creek	2.3	0.365	dependent
Gualala River	401.0	0.986	**Functionally Independent**
Miller Creek	2.6	0.145	dependent
Stockhoff Creek	2.2	0.251	dependent

* Mad River value includes habitat upstream of a partial barrier near the confluence of Bug Creek that may not be accessible in all years.

** Population was previously defined as potentially independent in Bjorkstedt et al. (2005) and Spence et al. (2008).

[†] Population was previously defined as potentially independent in Bjorkstedt et al. (2005) and Spence et al. (2008) due to an error in the IPkm estimate.

[††] Population was previously defined as functionally independent in Bjorkstedt et al. (2005) and Spence et al. (2008).

Table 2. Historical population structure of winter steelhead in the Eel River basin. This table supercedes Table A.5 in Spence et al. (2008).

Population	***IPkm***	**Self-recruitment**	**Historical population status**
Lower Mainstem Eel River*			dependent populations
Van Duzen River	317.4	0.997	**Functionally Independent**
Price Creek	18.2	0.913	***Potentially Independent***
Howe Creek	13.9	0.854	dependent
Larabee Creek	88.4	0.921	***Potentially Independent***†
South Fork Eel River	1017.0	0.999	**Functionally Independent**
Lower Middle Mainstem Eel River*			dependent populations
Dobbyn Creek	49.1	0.931	***Potentially Independent***
Jewett Creek	16.8	0.880	***Potentially Independent***
Pipe Creek	17.4	0.844	***Potentially Independent***
Kekawaka Creek	30.7	0.929	***Potentially Independent***
Chamise Creek	36.2	0.882	***Potentially Independent***
North Fork Eel River	318.2	0.987	**Functionally Independent**
Upper Middle Mainstem Eel River*			dependent populations
Bell Springs Creek	18.1	0.737	***Potentially Independent***
Woodman Creek	35.0	0.719	***Potentially Independent***
Middle Fork Eel River	503.5	0.985	**Functionally Independent**
Outlet Creek	192.6	0.934	***Potentially Independent***††
Tomki Creek	90.8	0.973	**Functionally Independent**
Bucknell Creek	19.1	0.682	***Potentially Independent***
Soda Creek	15.7	0.953	dependent**
Upper Mainstem Eel River‡	349.6	1.000	**Functionally Independent**

* Indicates the set of small watersheds tributary to each section of the mainstem Eel River that are not listed by name in this table.

** Population was previously defined as potentially independent in Bjorkstedt et al. (2005) and Spence et al. (2008).

† Population was previously defined as functionally independent in Spence et al. (2008).

†† Population was previously defined as functionally independent in Bjorkstedt et al (2005) and Spence et al. (2008). Change in IPkm total and historical population status partially reflects new information on impassable natural barriers in the watershed.

‡ Includes all the Eel River and all tributaries upstream of the concluence of Soda Creek (exclusive).

Table 3. Historical population structure of winter steelhead in the CCC-Steelhead DPS. This table supercedes Table A.7 in Spence et al. (2008). Only populations with >1.6 IPkm of habitat are shown.

Population	***IPkm***	**Self-recruitment**	**Historical population status**
Kolmer Creek	3.5	0.396	dependent
Fort Ross Creek	1.9	0.187	dependent
Russian Gulch (S)	16.0	0.507	dependent
Russian River	1736.5	0.999	See Table 4
Scotty Creek	4.6	0.258	dependent
Salmon Creek (S)	36.6	0.782	***Potentially Independent***
Bodega Harbor	8.7	0.500	dependent
Americano Creek	35.4	0.859	***Potentially Independent***
Stemple Creek	45.1	0.911	***Potentially Independent***
Tomales Bay	187.2	0.936	
Walker Creek	77.1		***Potentially Independent***
Lagunitas Creek	110.1		***Potentially Independent***
Drakes Bay	6.7	0.296	dependent
Pine Gulch	9.7	0.317	dependent
Redwood Creek (Ma)	6.7	0.199	dependent
San Francisco Bay	2232.1	0.999	See Table 5
San Pedro Creek	na	na	dependent
Pilarcitos Creek	28.9	0.489	***Potentially Independent***
Canada Verde Creek	2.2	0.184	dependent
Tunitas Creek	10.8	0.653	dependent
San Gregorio Creek	55.2	0.953	**Functionally Independent**
Pomponio Creek	6.2	0.685	dependent
Pescadero Creek	66.4	0.961	**Functionally Independent**
Arroyo de los Frijoles	4.1	0.520	dependent
Gazos Creek	13.2	0.860	dependent
Whitehouse Creek	5.1	0.867	dependent
Cascade Creek	4.2	0.898	dependent
Green Oaks Creek	2.2	0.708	dependent
Ano Nuevo Creek	3.1	0.700	dependent
Waddell Creek	13.7	0.887	***Potentially Independent****
Scott Creek	18.9	0.939	***Potentially Independent***
San Vicente Creek	6.2	0.867	dependent
Liddell Creek	5.0	0.871	dependent
Laguna Creek	13.1	0.926	***Potentially Independent****
Baldwin Creek	3.9	0.742	dependent
Wilder Creek	8.4	0.822	dependent
San Lorenzo River	161.5	0.994	**Functionally Independent**
Rodeo Creek Gulch	4.2	0.714	dependent
Soquel Creek	54.2	0.981	***Potentially Independent***
Aptos Creek	29.7	0.917	***Potentially Independent***

* Although IPkm values are lower than 16 IPkm, historically productive lagoon habitats are assumed to have resulted in steelhead populations large enough to be independent. See text for further elaboration.

Table 4. Historical population structure of winter steelhead in the Russian River basin. This table supercedes Table A.8 in Spence et al. (2008).

Population	***IPkm***	**Self-recruitment**	**Historical population status**
Lower Russian River*			dependent populations
Austin Creek	95.4	0.972	***Potentially Independent***
Dutch Bill Creek	13.3	0.826	dependent
Green Valley Creek	37.1	0.939	***Potentially Independent***
Mark West Creek	286.8	0.993	***Potentially Independent***
Middle Russian River**			dependent populations
Dry Creek	282.9	0.993	***Potentially Independent***
Maacama Creek	77.1	0.976	***Potentially Independent***
Sausal Creek	12.0	0.904	dependent
Upper Russian River †	679.0	0.999	**Functionally Independent**

* Unnamed and smaller tributaries downstream of the confluence of Mark West Creek.

** Unnamed and smaller tributaries between Mark West and Big Sulphur creeks.

† The Upper Russian River population occupies the mainstem and tributary habitats upstream from the confluence of Big Sulphur Creek (inclusive).

Table 5. Historical population structure of winter steelhead in tributaries of San Francisco, San Pablo, and Suisun bays. This table supercedes Table A.9 in Spence et al. (2008).

Population	*IPkm*	Self-recruitment	Historical population status
Northwest Bay			
Arroyo Corte Madera del Presidio	7.0	0.292	dependent
Corte Madera Creek	26.4	0.876	***Potentially Independent***
Miller Creek	11.2	0.741	dependent*
Novato Creek	48.9	0.810	***Potentially Independent***
North Bay			
Petaluma River	148.5	0.918	***Potentially Independent***
Sonoma Creek	198.1	0.928	**Functionally Independent**
Napa River	426.2	0.998	**Functionally Independent**
Suisun Bay			
Green Valley/Suisun Creek	99.3	0.839	***Potentially Independent***
Arroyo del Hambre	11.8	0.409	dependent
Walnut Creek	97.8	0.888	***Potentially Independent***
Mt. Diablo Creek	21.3	0.911	dependent
East Bay			
San Pablo Creek	29.1	0.751	***Potentially Independent***
San Leandro Creek	44.0	0.891	***Potentially Independent*****
San Lorenzo Creek	40.8	0.948	**Functionally Independent**
Southeast Bay			
Alameda Creek	432.0	0.964	**Functionally Independent**
Coyote Creek	286.6	0.926	**Functionally Independent**
Southwest Bay			
Guadalupe River	113.1	0.959	**Functionally Independent**
Saratoga Creek	59.1	0.896	***Potentially Independent***†
Stevens Creek	31.4	0.840	***Potentially Independent***
Permanente Creek	21.9	0.921	dependent†
San Francisquito Creek	43.3	0.828	***Potentially Independent***
San Mateo Creek	33.3	0.886	***Potentially Independent***
unnamed tributaries			dependent populations

* Population was previously defined as potentially independent in Bjorkstedt et al. (2005) and Spence et al. (2008).
** Population was previously defined as functionally independent in Bjorkstedt et al. (2005) and Spence et al. (2008).
† Population inadvertently omitted from Bjorkstedt et al. (2005) and Spence et al. (2008).

Table 6. Projected population abundances (N_a) of NC-Steelhead independent populations corresponding to a high-risk (depensation) threshold of 1 spawner/*IPkm* and low-risk (spatial structure/diversity=SSD) thresholds based on application of spawner density criteria (see Figure 5 in Spence et al. 2008). Values listed under "historical" represent criteria applied to the historical landscape in the absence of dams that block access to anadromous fish. Values listed under "current" exclude areas upstream from impassible dams.

				High Risk		Low Risk			
				Historical	Current	Historical SSD		Current SSD	
Population	**Historical *IPkm***	**Current *IPkm***	***IPkm* lost**	**Depens. N_a**	**Depens. N_a**	**Density Spawner/*IPkm***	**N_a**	**Density Spawner/*IPkm***	**N_a**
Redwood Creek (H)	270.9	270.9	0%	271	271	20.0	5400	20.0	5400
Maple Creek/Big Lagoon	71.7	71.7	0%	72	72	32.3	2300	32.3	2300
Little River (H)	63.0	63.0	0%	63	63	33.5	2100	33.5	2100
Mad River	453.7	290.5	36%	454	291	20.0	9100	20.0	5800
Humboldt Bay	212.1	212.1	0%	212	212	20.0	4200	20.0	4200
Eel River - Full									
Price Creek	18.2	18.2	0%	18	18	39.7	700	39.7	700
Van Duzen River	317.4	317.4	0%	317	317	20.0	6300	20.0	6300
Larabee Creek	88.4	88.4	0%	88	88	29.9	2600	29.9	2600
South Fork Eel River	1017.0	1017.0	0%	1017	1017	20.0	20300	20.0	20300
Dobbyn Creek	49.1	49.1	0%	49	49	35.4	1700	35.4	1700
Jewett Creek	16.8	16.8	0%	17	17	39.9	700	39.9	700
Pipe Creek	17.4	17.4	0%	17	17	39.8	700	39.8	700
Kekawaka Creek	30.7	30.7	0%	31	31	38.0	1200	38.0	1200
Chamise Creek	36.2	36.2	0%	36	36	37.2	1300	37.2	1300
North Fork Eel River	318.2	318.2	0%	318	318	20.0	6400	20.0	6400
Bell Springs Creek	18.1	18.1	0%	18	18	39.7	700	39.7	700
Woodman Creek	35.0	35.0	0%	35	35	37.4	1300	37.4	1300
Outlet Creek	192.6*	176.4	8%	193	176	20.0	3900	20.0	3500
Tomki Creek	90.8	90.8	0%	91	91	29.6	2700	29.6	2700
Middle Fork Eel River	503.5	501.7	0%	504	502	20.0	10100	20.0	10000
Bucknell Creek	19.1	19.1	0%	19	19	39.6	800	39.6	800
Upper Mainstem Eel River	349.6	1.8	99%	350	2	20.0	7000	-	-
Bear River	107.8	107.8	0%	108	108	27.2	2900	27.2	2900
Mattole River	541.1	541.1	0%	541	541	20.0	10800	20.0	10800
Usal Creek	17.6	17.6	0%	18	18	39.8	700	39.8	700
Cottaneva Creek	23.2	23.2	0%	23	23	39.0	900	39.0	900
Wages Creek	17.7	17.7	0%	18	18	39.8	700	39.8	700

Table 6. (continued)

				High Risk		Low Risk			
				Historical	Current	Historical SSD		Current SSD	
Population	**Historical *IPkm***	**Current *IPkm***	**IP-lost**	**Depens. N_a**	**Depens. N_a**	**Density Spawner/*IPkm***	**N_a**	**Density Spawner/*IPkm***	**N_a**
Ten Mile River	181.3	181.3	0%	181	181	20.0	3600	20.0	3600
Pudding Creek	24.1	24.1	0%	24	24	38.9	900	38.9	900
Noyo River	157.6	156.7	1%	158	157	20.0	3200	20.0	3200
Big River	256.1	253.0	1%	256	253	20.0	5100	20.0	5100
Albion River	48.6	48.6	0%	49	49	35.5	1700	35.5	1700
Big Salmon Creek	18.3	18.3	0%	18	18	39.7	700	39.7	700
Navarro River	397.9*	397.9	0%	398	398	20.0	8000	20.0	8000
Elk Creek	21.5	21.5	0%	22	22	39.2	800	39.2	800
Brush Creek	23.8	23.8	0%	24	24	38.9	900	38.9	900
Garcia River	137.2	137.2	0%	137	137	23.2	3200	23.2	3200
Gualala River	401.0	400.3	0%	401	400	20.0	8000	20.0	8000

* Total reflects incorporation of updated barrier information.

Table 7. Projected population abundances (N_a) of CCC-Steelhead independent populations corresponding to a high-risk (depensation) threshold of 1 spawner/*IPkm* and low-risk (spatial structure/diversity=SSD) thresholds based on application of spawner density criteria (see Figure 5). Values listed under "historical" represent criteria applied to the historical landscape in the absence of dams that block access to anadromous fish. Values listed under "current" exclude areas upstream from impassible dams.

				High Risk		**Low Risk**			
				Historical	**Current**	**Historical SSD**		**Current SSD**	
Population	**Historical *IPkm***	**Current *IPkm***	***IPkm* lost**	**Depens. N_a**	**Depens. N_a**	**Density Spawner/*IPkm***	**N_a**	**Density Spawner/*IPkm***	**Div/SS N_a**
Russian River	1736.5								
Austin Creek	95.4	95.4	0%	95	95	29.0	2800	29.0	2800
Green Valley Creek	37.1	37.0	0%	37	37	37.1	1400	37.1	1400
Mark West Creek	286.8	271.9	7%	287	272	20.0	5700	20.0	5400
Dry Creek	282.9	116.4	59%	283	116	20.0	5700	20.0	3000
Maacama Creek	77.1	76.1	1%	77	76	31.5	2400	31.6	2400
Upper Russian River	679.0	542.4	20%	679	542	20.0	13600	20.0	10800
Salmon Creek (S)	36.6*	36.6	0%	37	37	37.1	1400	37.1	1400
Americano Creek	35.4	35.4	0%	35	35	37.3	1300	37.3	1300
Stemple Creek	45.1	45.1	0%	45	45	36.0	1600	36.0	1600
Tomales Bay									
Walker Creek	77.1	57.8	25%	77	58	31.5	2400	34.2	2000
Lagunitas Creek	110.1	53.8	51%	110	54	26.9	3000	34.7	1900
Northwest SF Bay									
Corte Madera Creek	26.4	26.4	0%	26	26	38.6	1000	38.6	1000
Novato Creek	48.9	39.1	20%	49	39	35.4	1700	36.8	1400
North SF Bay									
Petaluma River	148.5	147.7	1%	148	148	21,6	3200	21.7	3200
Sonoma Creek	198.1	198.1	0%	198	198	20.0	4000	20.0	4000
Napa River	426.2	357.0	16%	426	357	20.0	8500	20.0	7100
Suisun Bay									
Green Val./Suisun Creek	99.3	82.4	17%	99	82	28.4	2800	30.8	2500
Walnut Creek	97.8	5.6	94%	98	6	28.6	2800	-	-
East SF Bay									
San Pablo Creek	29.1	10.1	65%	29	10	38.2	1100	-	-
San Leandro Creek	44.0	11.9	73%	44	12	36.1	1600	-	-
San Lorenzo Creek	40.8	24.6	40%	41	25	36.5	1500	38.8	1000

Table 7. (continued)

Population	**Historical *IPkm***	**Current *IPkm***	***IPkm* Lost**	**High Risk Historical Depens. Na**	**Current Depens. N_a**	**Low Risk Historical SSD Density Spawner/*IPkm***	**N_a**	**Current SSD Density Spawner/*IPkm***	**Div/SS N_a**
Southeast SF Bay									
Alameda Creek	432.0*	24.8	94%	432	25	20.0	8600	38.8	1000
Coyote Creek	286.6*	140.5	51%	287	141	20.0	5700	22.7	3200
Southwest SF Bay									
Guadalupe River	113.1	87.2	23%	113	87	26.5	3000	30.1	2600
Saratoga Creek	59.1	2.4	96%	59	2	34.0	2000	-	-
Stevens Creek	31.4	14.5	54%	31	14	37.9	1200	-	-
San Francisquito Creek	43.3	28.8	33%	43	29	36.2	1600	38.2	1100
San Mateo Creek	33.3	7.7	77%	33	8	37.6	1300	-	-
Pilarcitos Creek	28.9	20.7	29%	29	21	38.2	1100	39.4	800
San Gregorio Creek	55.2	55.2	0%	55	55	34.6	1900	34.6	1900
Pescadero Creek	66.4	66.4	0%	66	66	33.0	2200	33.0	2200
Waddell Creek	13.7	13.7	0%	14	14	40.0	500	40.0	500
Scott Creek	18.9	18.9	0%	19	19	39.6	700	39.6	700
Laguna Creek	13.1	13.1	0%	13	13	40.0	500	40.0	500
San Lorenzo River	161.5	153.0	5%	162	153	20.0	3200	21.0	3200
Soquel Creek	54.2	54.2	0%	54	54	34.7	1900	34.7	1900
Aptos Creek	29.7	29.7	0%	30	30	38.1	1100	38.1	1100

* Total reflects incorporation of updated barrier information.