   

SalmonScape:

Priorities for Conserving California's Salmon and Steelhead Diversity

The Nature Conservancy of California

August 2011
Version 1.1

The Nature Conservancy
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Acknowledgements

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1.0 Introduction

Salmon, trout, and their relatives, are the iconic fishes of the Pacific. They are characteristic of the region's cold productive oceans, rushing streams and rivers, and deep cold lakes, and are important ecologically, culturally, and economically (Moyle et al. 2008). Despite having been the focus of much restoration and recovery effort of the past 30 years, the southernmost populations of salmon, steelhead and trout remain just a fraction of their historic population numbers. Of the 22 anadromous taxa, 13 (59%) are in danger of extinction (Moyle et al. 2008).

Part of the challenge in conserving salmonids is that they traverse such a diverse array of habitats –from oceans through estuaries, up through mainstem channels to tributaries and back again – and are therefore subjected to numerous stresses and threats including lack of appropriate flows, migration barriers, insufficient spawning and rearing habitat, competition from non-native species, and overfishing. As such, they integrate environmental stresses, and serve as indicators of the condition of the various systems they traverse.

A key strategy to effect salmon conservation at scale is to identify priority populations, issues that compromise viability, and to develop solutions to address those problems. Demonstrated solutions can serve as a model that can be replicated for greater impact. A key to demonstrating solutions is knowing where the best return-on-investment may exist to address different strategies. This analysis is designed to inform that.

We developed a database that can be used to prioritize populations and habitat bottlenecks for California's anadromous salmonids, and an analytical approach that evaluates the potential return on investment of different major conservation strategies. The goal of this initial analysis is to identify where habitat restoration strategies may provide the highest return for salmon in the state. Although a number of salmon population and habitat prioritizations exist, because of the differing priorities and jurisdictions of lead agencies and organizations, few focus across the range of salmonids in the state. This analysis utilizes a database consistent across temporal and spatial scales, making analysis across species ranges possible. Initial steps to achieve this goal were to develop a science foundation and database focused on salmonids that:

- Encompasses the ranges of salmonid populations in the state;
- Provides an understanding of the viability of the 492 populations of Coho, Chinook and Steelhead in the state (Box 1);
- Characterizes habitat conditions across the ranges including habitat stresses; and
- Identifies future threats

The database was then used to identify a priority landscape focused on protecting and restoring existing California salmon and trout populations. The analysis was predicated on the hypothesis that the most efficient and effective strategies to halt the declines of, and increase the abundance of priority populations, is to focus on those places where salmon and habitat are still present in the state.

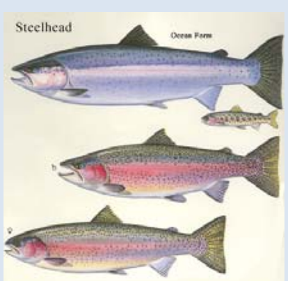
This initial analysis focused on those places in the state where salmon still persist – that is, on existing habitat and runs. This analysis did not focus on those places where salmon and habitat no longer exist – that is, where extirpated runs may be reestablished. However, we note that this database and this approach could be used to help identify priorities for those conditions and goals as well.

Box 1: California's Anadromous Salmon and Trout Diversity

In California, anadromous salmon and trout diversity is among the highest in the nation, containing the southernmost runs of salmon and steelhead (Moyle et al. 2008). This analysis focuses on three species of timing at which the species swim back up the rivers in which they were born to spawn. We included 6 runs of salmon and trout in the study – Fall Coho, Fall, Spring and Winter Chinook and Winter and Summer Steelhead. These runs in turn are made up of 471 populations of anadromous salmon and trout in the state. A population is a group of fish of the same species that spawns in a particular locality at a particular season and does not interbreed substantially with fish from any other group. (McElhany et al. 2000)

Coho Salmon

Spawning Chinook Salmon



Steelhead – all forms

Species (Run)	Populations (#)	ESU (# populations)	Conservation Status
Coho	56 current 31 historic only	Central California Coast (34 current; 25 historic only)	Federally endangered
		Southern Oregon/Northern California (22 current; 6 historic only)	Federally threatened
Chinook (Fall)	75 current 26 historic only	California Coastal Chinook (20 current; 15 historic only)	Federally Threatened
		Central Valley Fall & Late Fall Chinook (35 current; 10 historic only)	Federal Species of Concern
		S. Oregon and N. California Coastal Chinook (12 current; 1 historic)	Listing not warranted
		Upper Klamath-Trinity Rivers Chinook (8 current)	Listing not warranted
Chinook (Spring/Summer)	27 current 15 historic	Central Valley Spring Chinook (15 current; 15 historic only)	Federally Threatened
		California Coastal Chinook (6 – no historic data)	Federally Threatened
		Upper Klamath-Trinity Rivers Chinook (6 – no historic data)	No listing
Chinook (Winter)	3 current 4 historic only	Sacramento Chinook (3 current; 4 historic)	Federally endangered
Steelhead (Winter)	214 current 20 historic only	Central Valley Steelhead (30 current; 6 historic only)	Federally Threatened
		Klamath Mountains Province (18 current)	Listing not warranted
		Northern California Steelhead (57 current)	Federally Threatened
		South-Central California Coast Steelhead (37 current)	Federally Threatened
		Southern California Steelhead (27 current; 11 historic only)	Federally Endangered
		Central California Coast Steelhead (45 current; 3 historic only)	Federally Threatened
Steelhead (Summer)	21	Northern California Steelhead (11 – no historic data)	Federally Threatened
		Klamath Mountains Province (10 – no historic data)	Listing not warranted

2.0 Developing a SalmonScape: a Portfolio of Priority Landscapes

2.1 Framework

Salmon and steelhead populations in western North America have experienced substantial declines over the past 150 years. Remaining populations are greatly reduced in number and persist only in a fraction of their historical range. Their habitats have been degraded by a variety of factors – and with global climate change they are sure to face a future of myriad increasing threats. Spatial planning tools can assist in directing salmon conservation efforts by identifying patterns in habitat and population conditions and threats, and their relative importance to species recovery and persistence. This information, in turn, should support more strategic and cost-effective salmon recovery actions.

Historically anadromous salmon and trout were distributed across ~45,000 streams miles of California rivers, from the Otay River in the southernmost part of the state to the Oregon border. Currently, salmon are found in ~15,000 stream miles of California's rivers – a 65 percent reduction in occupied habitat (Figure 1). This pattern is similar for each run in California (Figure 2). For example, Coho historically occupied ~11,000 stream miles, but have been reduced to ~4,500 stream miles. Fall Chinook are currently found in 70 percent of the 10,000 miles historically occupied. And in those places where salmon are currently persisting, their numbers are in severe decline (Moyle et al 2008). Current available spawning and rearing habitat is not adequately being utilized, therefore the current production capacity is not being achieved in available, accessible habitat.

Because of this, we focused this analysis on those places where population and habitat conditions are best suited to do one of more of the following:

- maintain current viable populations, restore habitat of the most viable populations, and/or
- restore populations located in areas with high habitat integrity

Using habitat and population indicators (developed by Trout Unlimited, called the "Conservation Success Index") for 6 runs of salmon and trout in the state—Coho, fall Chinook, spring/summer Chinook, winter Chinook, winter steelhead, summer steelhead—we conducted an analysis resulting in a priority landscape for conservation action. The Conservation Success Index (CSI) integrates population viability data compiled from regional, state and federal salmon experts by the Wild Salmon Center as part of the North American Salmon Stronghold Partnership (http://www.wildsalmoncenter.org/programs/north_america/strongholds.php), with information about natural and anthropogenic landscape features into a spatial database. The methods of CSI were published in the peer reviewed journal *Fisheries* in 2007 (Williams et al. 2007).

Our spatially-explicit approach to a prioritization analysis provides a portfolio of places where we can be most efficient in conserving and restoring California's native salmonid diversity. By evaluating population and habitat integrity across our California species' ranges, we have developed a dynamic, science-based framework for informing conservation investment decisions across the range of salmon and trout in the state.

This effort provides a portfolio of places where restoration efforts may most efficiently be directed to improve salmon viability at scale now by:

- Working to protect the strongest populations and best remaining habitat
- Restoring habitat to produce the greatest numbers of fish

- Restoring populations in places where habitat integrity is greatest
- Identifying common bottlenecks across runs that may lead to potential multi-site and policy-based strategies
- Identifying where different models and strategies can be applied at scale.

The key objective of the assessment reported on here, was to identify a regional salmon portfolio—a network of conservation areas that best captures current salmonid diversity within existing habitat. The following provides methods, results and application of these efforts.

Figure 1: Map of historical and current distribution of salmon and trout in California

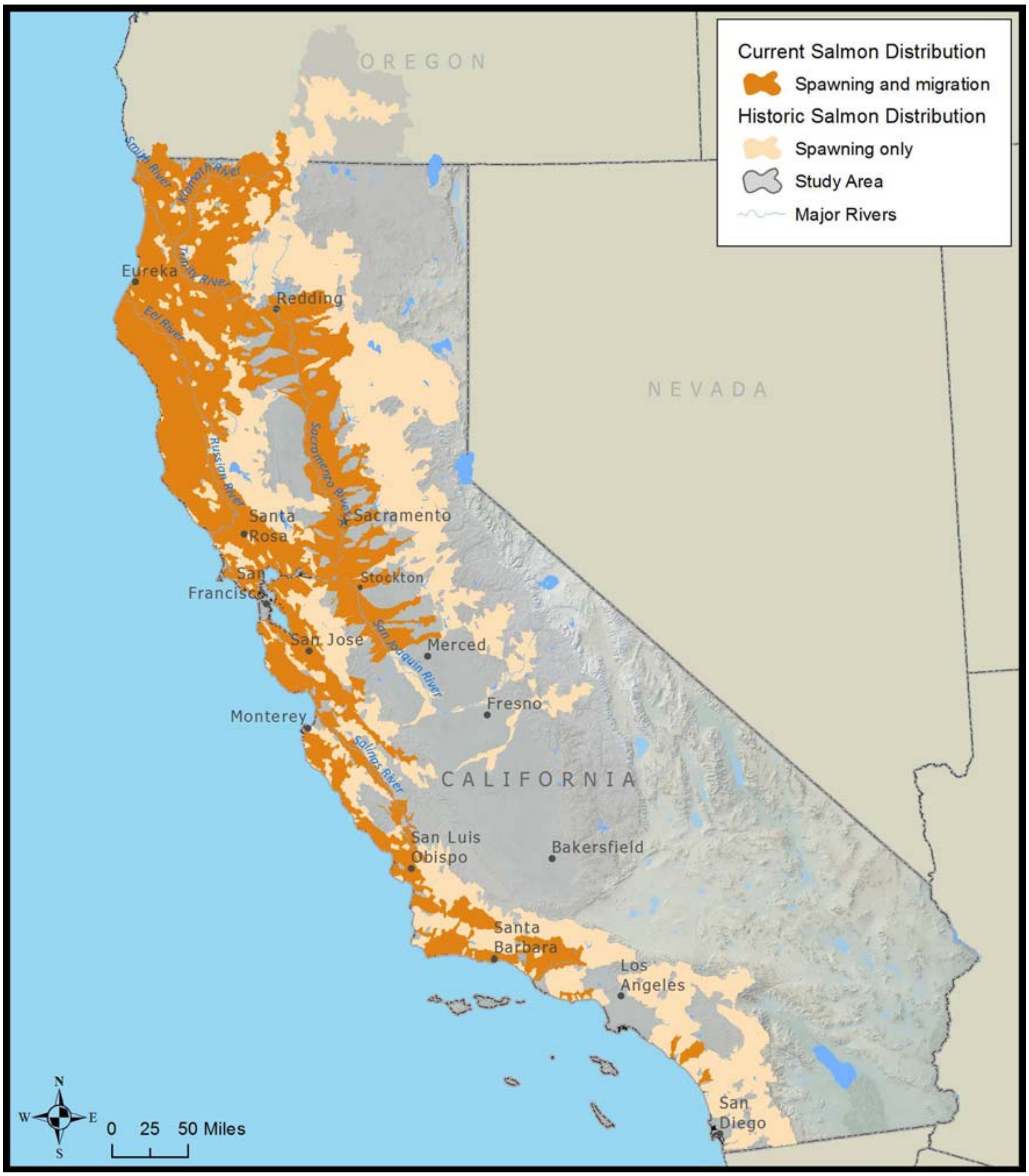
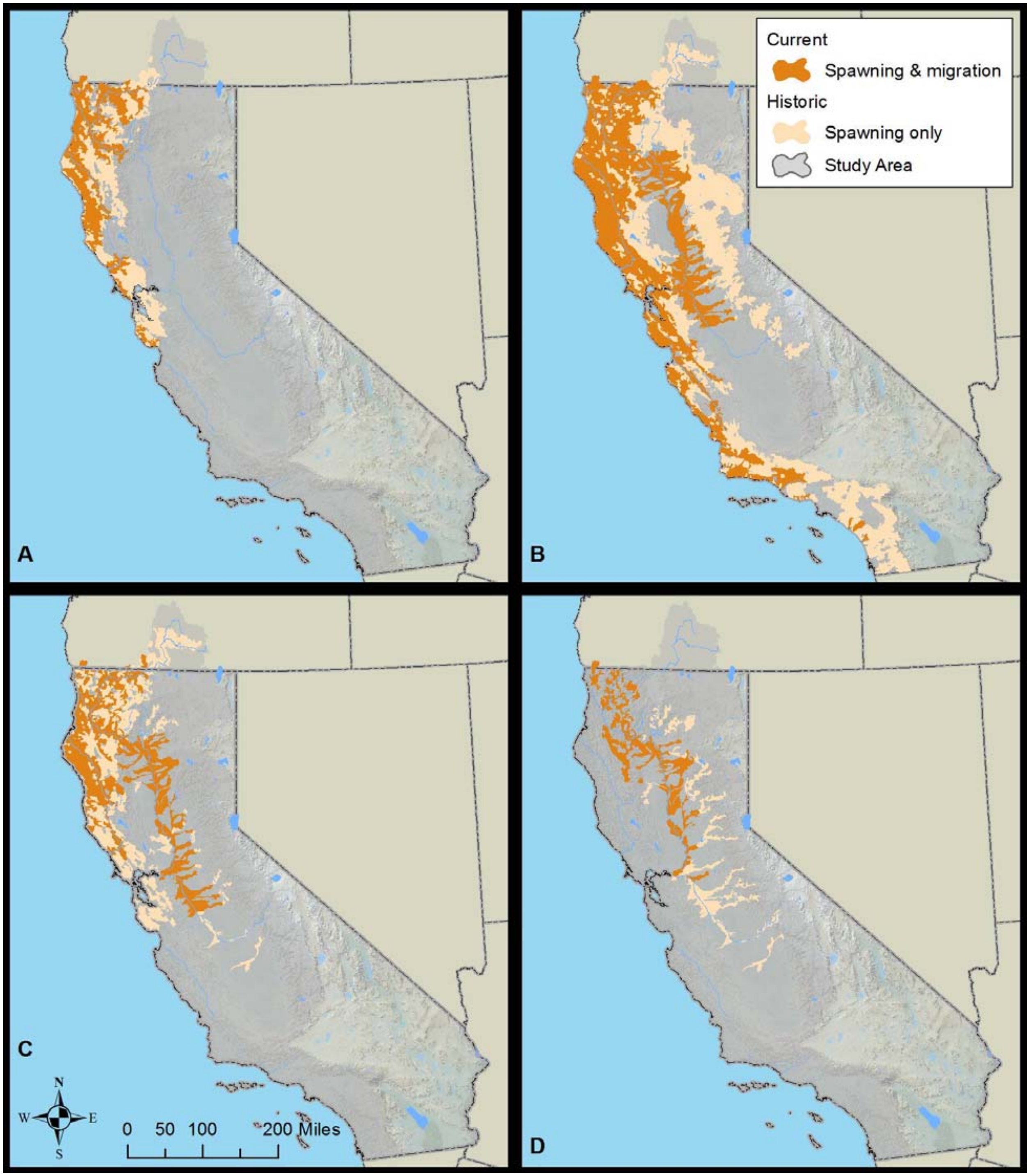


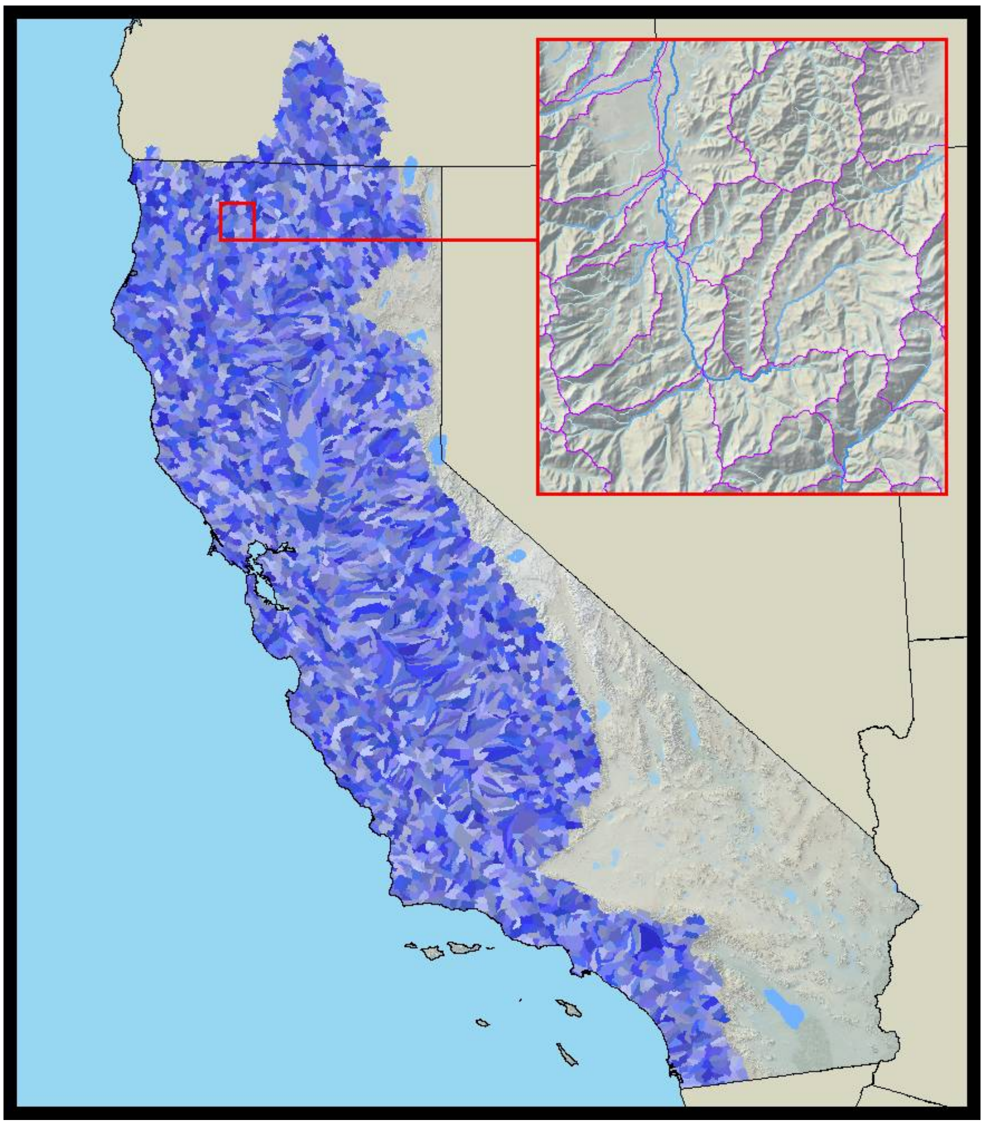
Figure 2: Historical and current distribution of Coho (panel A), winter steelhead (B), fall Chinook (C), and spring/summer Chinook (D). Note: Historical habitat data for spring/summer Chinook is only available for the Central Valley.



2.2 Study Area

The study area is comprised of the historic range of anadromous salmon and trout in the state and the areas that contribute flow to those stream reaches (Figure 3). The study area is divided into all 5,922 subwatersheds (average size = ~10,000 acres), each comprised of specific habitat and population characteristics.

Figure 3: Study area of prioritization analysis. The study area is comprised of 5,922 subwatersheds.

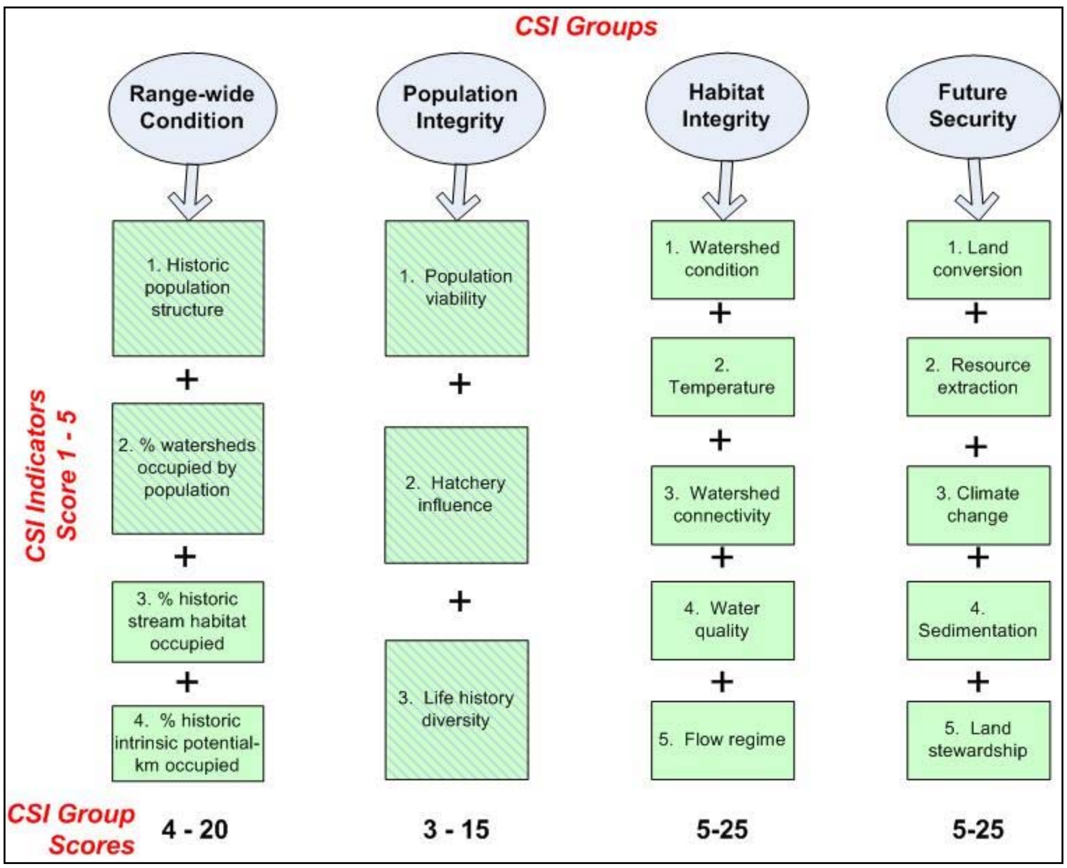


2.3 Methods

To identify the priority salmon landscape, we used habitat and population indicators in the CSI dataset for 6 runs of salmon and trout in the state—Coho, fall Chinook, spring Chinook, winter Chinook, winter steelhead, and summer steelhead.

The CSI includes an analytical framework consisting of 17 indicators (grouped into 4 categories: range-wide condition, population integrity, habitat integrity, and future security) that supports comparisons among runs and across administrative boundaries (Williams et al. 2007) (Figure 4). Each indicator is scored from 1 to 5 based on a ruleset (see Appendix 1 - for details and for datasets) used to develop the CSI. And each subwatershed is then associated with population and habitat indicator index scores for the various runs of salmon and trout that fall within that subwatershed.

Figure 4: Status and trends of each run are examined by this suite of indicators. Each indicator is scored from 1 (poor) to 5 (very good) for every subwatershed.



To evaluate population integrity, we used two population integrity indicators, "Population Viability" and "Life History Diversity," and one rangewide condition indicator "Percent of Historic Stream Habitat Currently Occupied." The Population Viability indicator estimates abundance and productivity of a population; the Life History Diversity indicator evaluates the variety of life history traits – age/year classes, sizes, fecundity, run timing – present in a population; and Percent Historic Stream Habitat Occupied provides just that – the percent of the historic stream habitat that is still occupied. The rationale for including "Percent of Historical Stream Habitat Occupied" in the evaluation is that a run occupying a larger percentage of their historic stream habitat is more likely to persist. In addition, by using this indicator, we were able to focus the analysis on currently occupied habitat only.

To calculate the population integrity score (for each subwatershed for each run) we used the following additive model:

> Population Integrity (PI) = (2 * "Population Viability" indicator) + "Life History Diversity" indicator + "Percent Historic Stream Habitat Currently Occupied" indicator

Population viability was doubled to account for the relative importance of this measure for ranking population integrity. This approach was adopted by the Wild Salmon Center when developing their California salmon strongholds at the suggestion of a consensus of regional and statewide salmon experts. Using this approach, the population integrity score ranges from 0 to 20.
Population Integrity scores were then categorized as high (score between 15-20), medium (9-14), or Low (1-8). Extirpated populations (score 0) were not included in this analysis.
To evaluate habitat integrity, we used all five habitat indicators:

> Habitat Integrity (HI) = "Watershed condition" + "Temperature" + "Watershed connectivity" + "Water quality" + "Flow regime"

Using this approach the score for habitat integrity ranges from 5 to 25. Habitat integrity scores were categorized as high (score between 19-25), medium (12-18) or low (5-11).

These habitat and population rankings (high, medium or low) were then used to classify the subwatersheds in the study area, for each run, based the matrix shown in Figure 5.

For example, strong populations in places with high habitat integrity were classified into the maintain stronghold strategy, the top left hand box of the matrix. Subwatersheds that fell into this box were weighted the highest. Strong populations with medium to low habitat integrity were categorized into the restore habitat strategy, left hand side of the matrix, weighted either with a 3 or 2. Subwatersheds with medium or low population scores and high habitat integrity fell into the restore population strategy type, and weighted with either 3 or 1. Note that populations with low population integrity and medium to low habitat integrity, or populations with medium population integrity and habitat integrity were not classified into a strategy type. Note also that we did not include those places with extirpated populations in this analysis – instead this analysis was focused on places with current populations and available habitat.

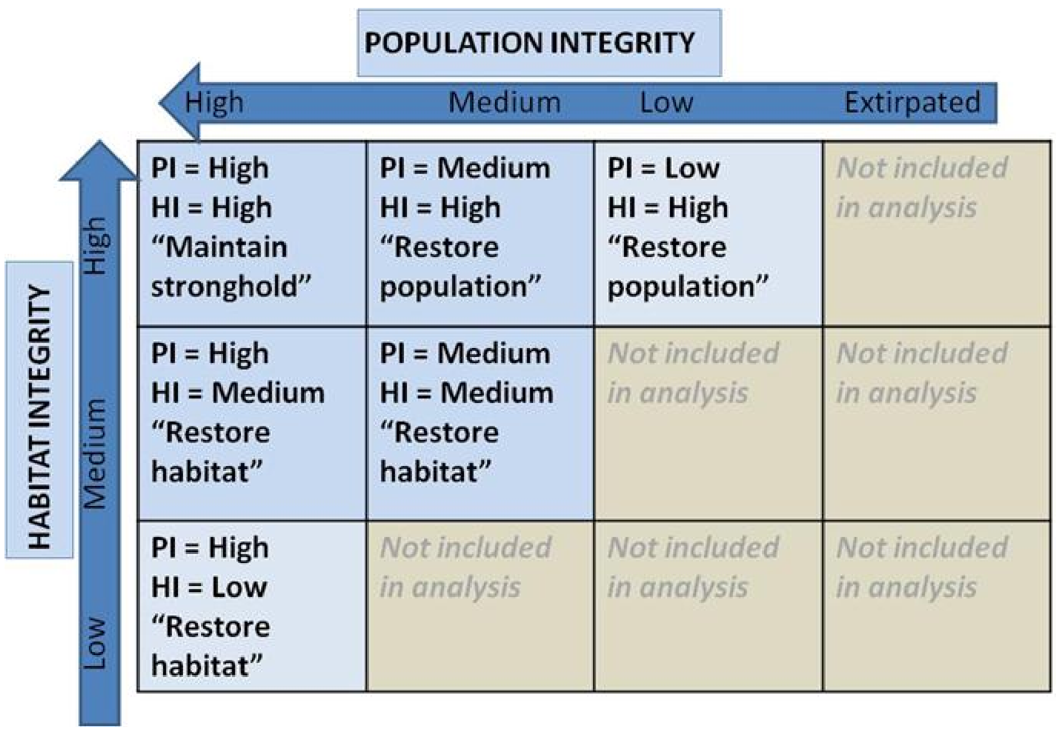
All 5,922 subwatersheds in the CSI dataset in the study area were coded for the 6 runs of salmon and trout included in this analysis per the strategy matrix. Therefore, a subwatershed could conceivably be categorized into 6 different strategy types. These codes were then summarized by the 3,108 larger subwatersheds for use in an optimization analysis.

To incorporate these 6 runs into a multi-species landscape, an optimization analysis using Zonation software (http://www.helsinki.fi/bioscience/consplan/research/consplan4.html) was conducted to identify the places most effective in achieving the most efficient conservation strategies for protecting and restoring salmonid biodiversity across their range. The optimization provided a mechanism to identify streams that benefit multiple runs and that incorporate upstream and downstream connectivity in a spatial prioritization scheme (Moilanen et al. 2008).

Zonation is a reserve selection framework for large-scale conservation planning. It works by assigning a conservation value for each subwatershed in the study area based on the weight derived from our population and habitat matrix data for each run (Figure 5) and the position of the subwatershed upstream or downstream from salmonid populations. The Zonation algorithm then iteratively removes the subwatershed with the least conservation value until all subwatersheds have been removed. The first subwatersheds removed are given the lowest rank, while the last subwatersheds removed are given the highest rank and thus are the most important for conservation.

The primary benefit of this software is to group priority areas based on entire river basins or subbasins, rather than prioritizing fragmented subwatersheds that are not connected to their headwaters and the ocean. Zonation provides a ranking of all priority areas, so the user can identify the top 1%, 2%, 5%, 10%, 30%, etc., of the landscape.

Figure 5: Matrix of population integrity (PI) and habitat integrity (HI) scores and potential strategies (in quotation marks).



2.4 Results

Using the optimization approach described above, we delineated a portfolio of salmon watersheds we are calling our SalmonScape. The SalmonScape represents the top 20% of the study area most effective at conserving and restoring salmon biodiversity using the 6 boxes identified in the matrix (Figures 6-9).

As Figures 6-9 show, the SalmonScape is focused in the North Coast and Central Valley regions of the state, with a few priority locations falling within the Central and South Coast boundaries. Table 1 lists the priority places displayed in Figures 6-9.

Figure 6: SalmonScape: Top 20 percent of study area identified as priority areas to protect and restore native anadromous salmonid diversity in the state.

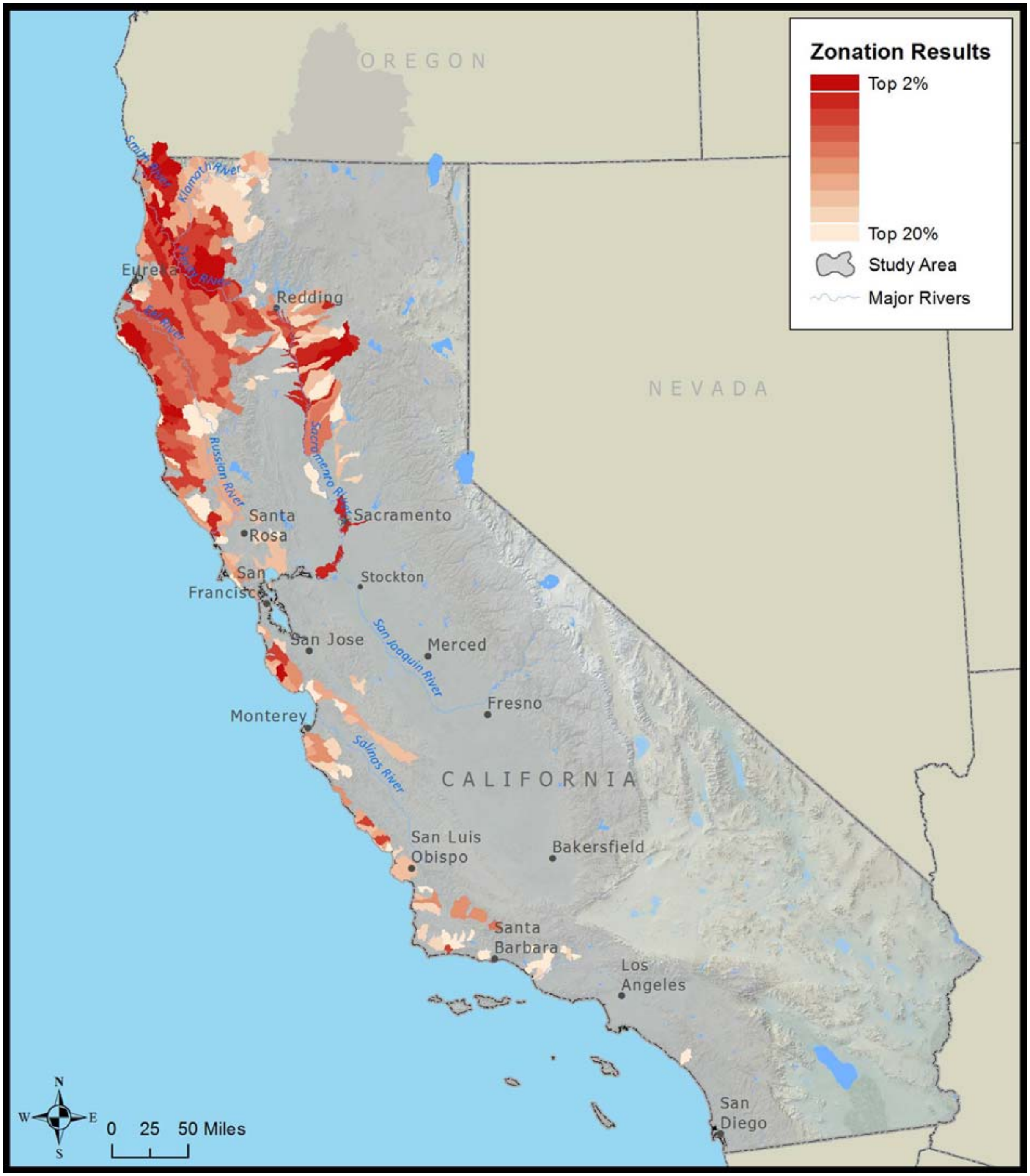


Figure 7: Top 20 percent of northern region of state identified as priority areas to protect and restore native salmonid diversity.

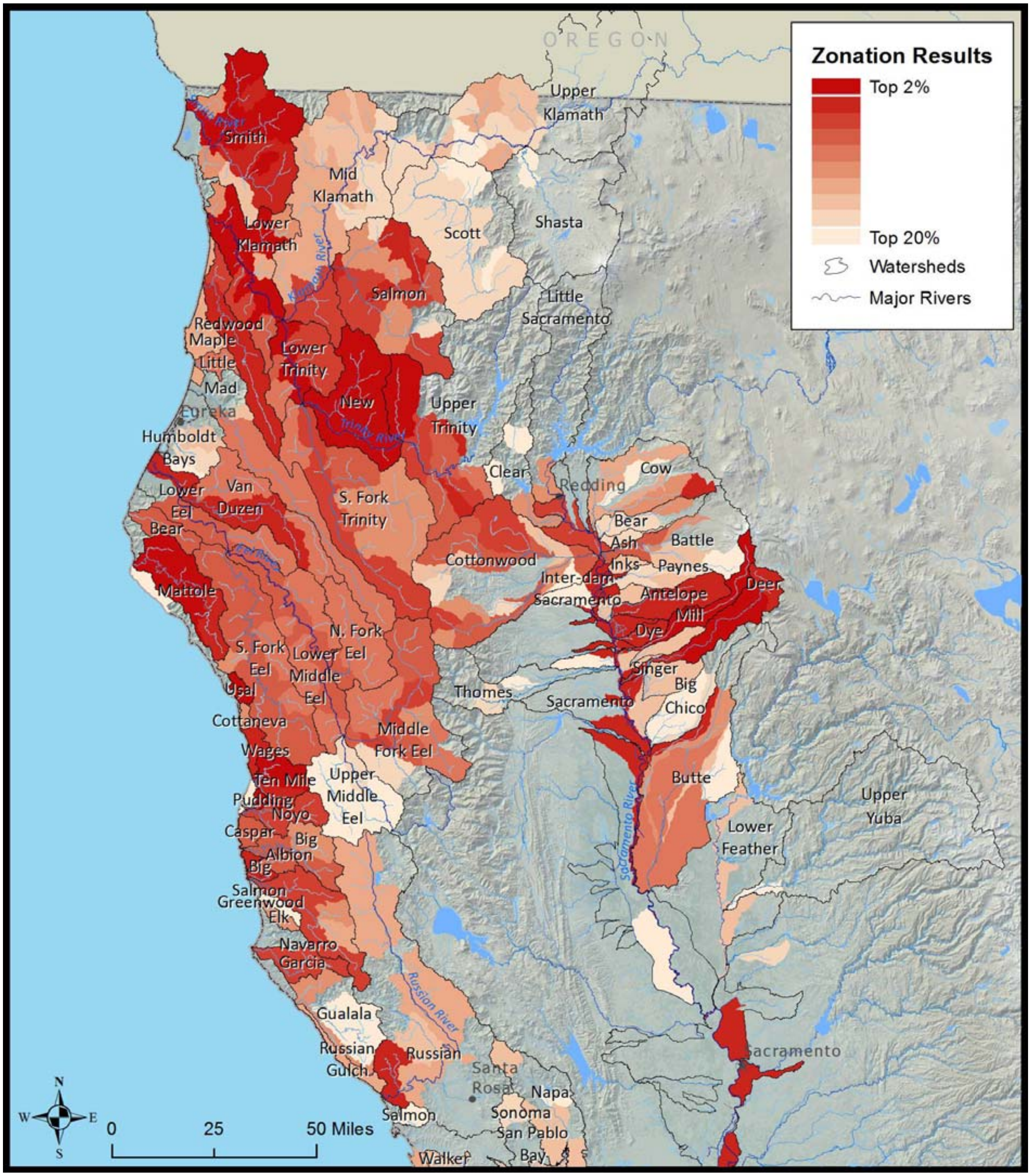


Figure 8: Top 20 percent of central region of state identified as priority areas to protect and restore native salmonid diversity.

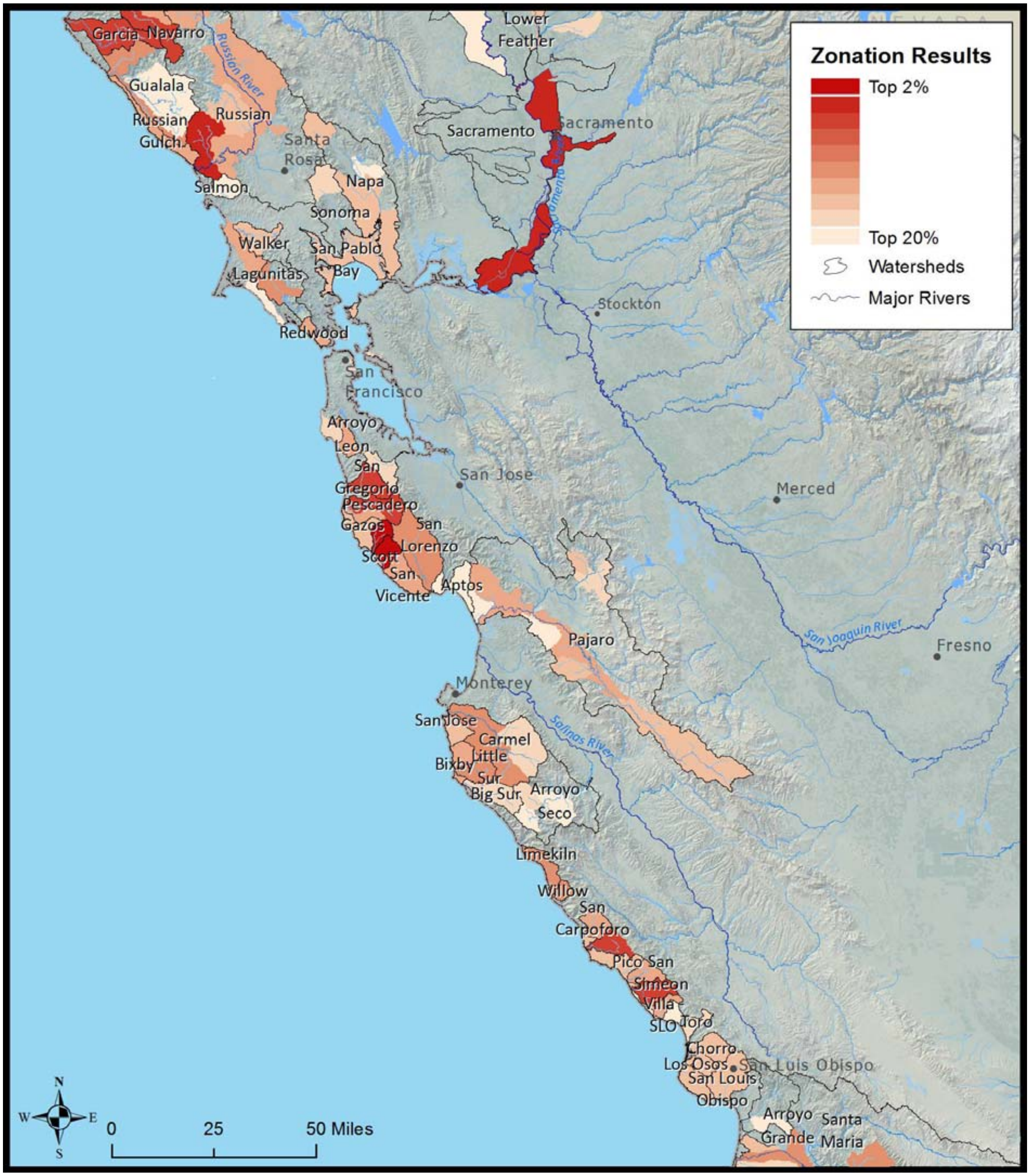
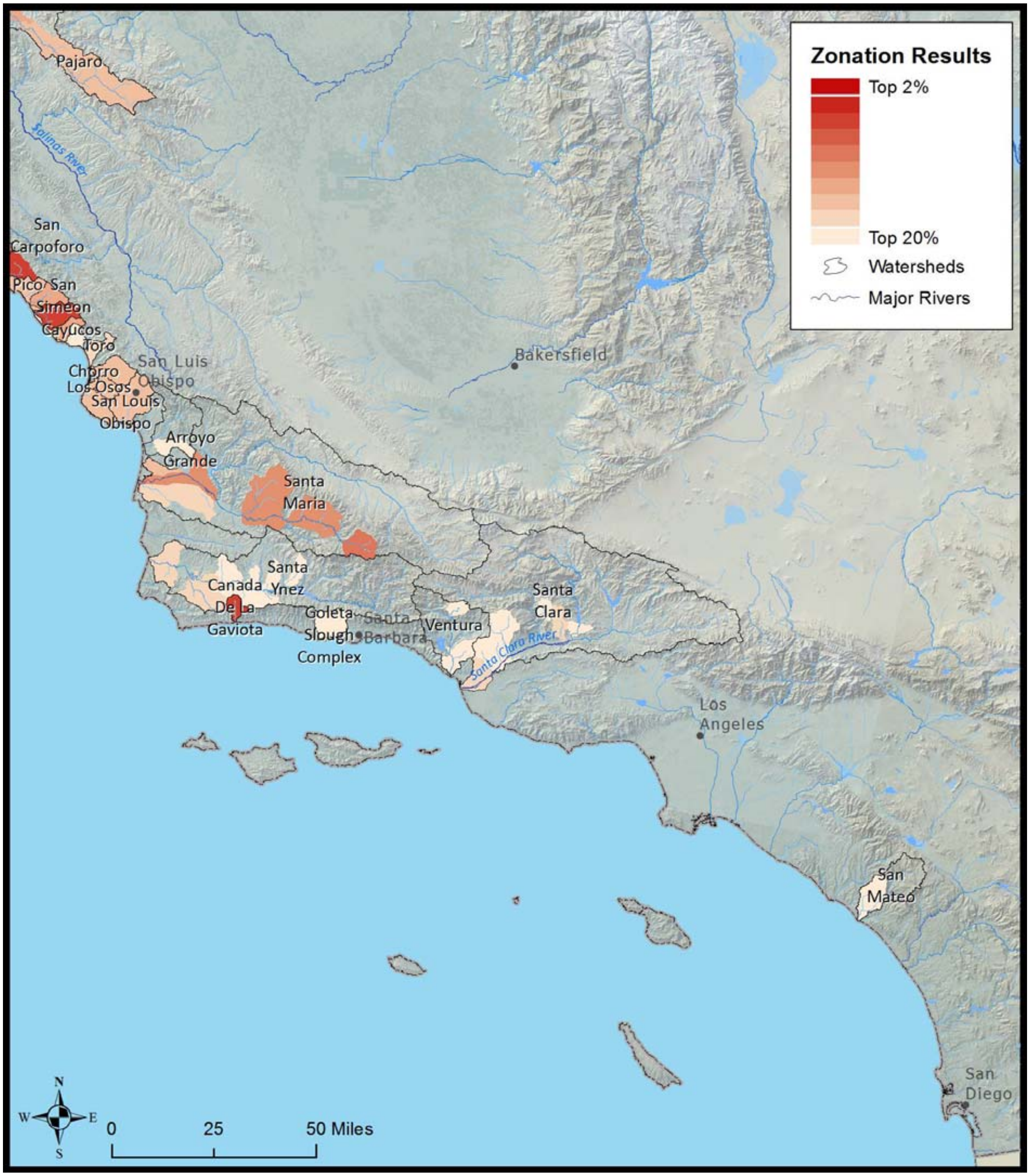


Figure 9: Top 20 percent of the south-central region of state identified as priority areas to protect and restore native salmonid diversity.



2.5 How the SalmonScape Compares to Agency Priorities

Different agencies have different priorities, different areas of focus, etc. For example, NOAA/NMFS is responsible for Endangered Species Act implementation for listed marine and anadromous species and has completed recovery plans for Central California Coast Coho, Southern California steelhead, Sacramento River winter-run Chinook, Central Valley spring-run Chinook and Central Valley steelhead. The USFWS Anadromous Fish Restoration Program focuses only on Central Valley fishes.

To understand how our SalmonScape compares with other agency and organization priority lists, we compiled a table of priority rivers for NOAA's National Marine Fisheries Service (NOAA), California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), and State Water Resources Control Board (SWRCB). As shown in Table 2, with the exception of Cow and Dye creeks, all the SalmonScape watersheds are also agency priorities.

3.0 Uses of Data and Analyses

3.1 Priority Places and the Salmon Lifecycle

To better understand the SalmonScape within the context of the salmon lifecycle, we categorized the priority populations into life cycle components - identifying estuaries, mainstems and tributary/ subwatershed habitat for the top 2% and top 5% of the SalmonScape (Table 3).

As detailed in Table 3, only 19 estuaries make up the top 5% of the SalmonScape including Arroyo de la Cruz, Big Salmon Creek, Eel River, Garcia River, Klamath, Mattole, Navarro, Noyo, Pescadero Creek, Pudding Creek, Redwood Creek, Russian River, Sacramento-San Joaquin Delta/SF Bay, Scott Creek, Ten Mile, Tillas Slough, Usal River Mouth, Waddell Creek and Wages Creek estuaries.

These estuaries link with 25 mainstem river channels including: Arroyo De La Laguna, Big Salmon Creek, Eel River, Garcia River, Lower Klamath River, Mattole River, Middle Fork Smith, Navarro, North Fork Smith, Noyo, Pescadero Creek, Pudding Creek, Redwood Creek, Russian River, Sacramento River, Salmon River, Scott Creek, Smith River, South Fork Smith, Ten Mile River, Trinity River, Usal Creek, Van Duzen River, Waddell Creek, and Wages Creek.

And in turn, these 25 mainstem systems link to 145 tributary/subwatershed units. By breaking down the priority places into lifecycle habitat components, we can see how multiple priority places can be impacted by the same mainstem and estuaries. Conservation work in specific estuaries and mainstems can therefore be leveraged to restore multiple priority populations.

Figure 10 illustrates how the salmon lifecycle links the priority places identified in this analysis from headwaters to the estuary in the Smith River watershed.

3.2 Stresses

In addition to delineating a priority salmon landscape, this analysis focused on identifying common habitat impacts (that could be potential bottlenecks) across the runs. The five habitat indicators we focused on – temperature, connectivity, sediment and instream condition, water quality, and flow regime – are part of the CSI. The index scores for these habitat indicators provide information on how these indicators act as stresses on the subwatersheds.

An example of how these habitat indicators can be used to highlight broad scale strategies is found in Coho streams. Figure 11 shows how the Central California Coast Coho populations score for the five habitat integrity indicators. Note that nearly all populations are ranked poor for instream condition and sedimentation. A lack of instream material has been identified as a critical factor for Coho populations in this region due to past industrial forest practices (NOAA Coho Recovery Plan 2010).

We divided the state into four regions – North Coast, Central-South Coast, Sacramento-San Joaquin and Klamath – to highlight how stresses differ between river systems (Figure 12). Figure 12 shows that connectivity and temperature are the biggest stresses identified for the Sacramento-San Joaquin region. Connectivity and instream condition are the biggest stressors to the Klamath and Central-South Coast streams. And instream condition is the greatest factor impacting the North Coastal streams. According to the CSI data, flow regime impacts the interior systems almost exclusively. Note, because the temperature indicator is based on temperature proxies (See Appendix 1), the effect of dams on water temperature below dams in the Central Valley may not be adequately captured.

Figure 13 provides an overview of stresses impacting specific river systems in the Sacramento-San Joaquin and the North Coast regions. Note that a number of stresses impact the interior river systems whereas instream condition and connectivity dominate in the North Coastal streams.

Figure 10: The context of the full life-cycle shown for the Smith River watershed.

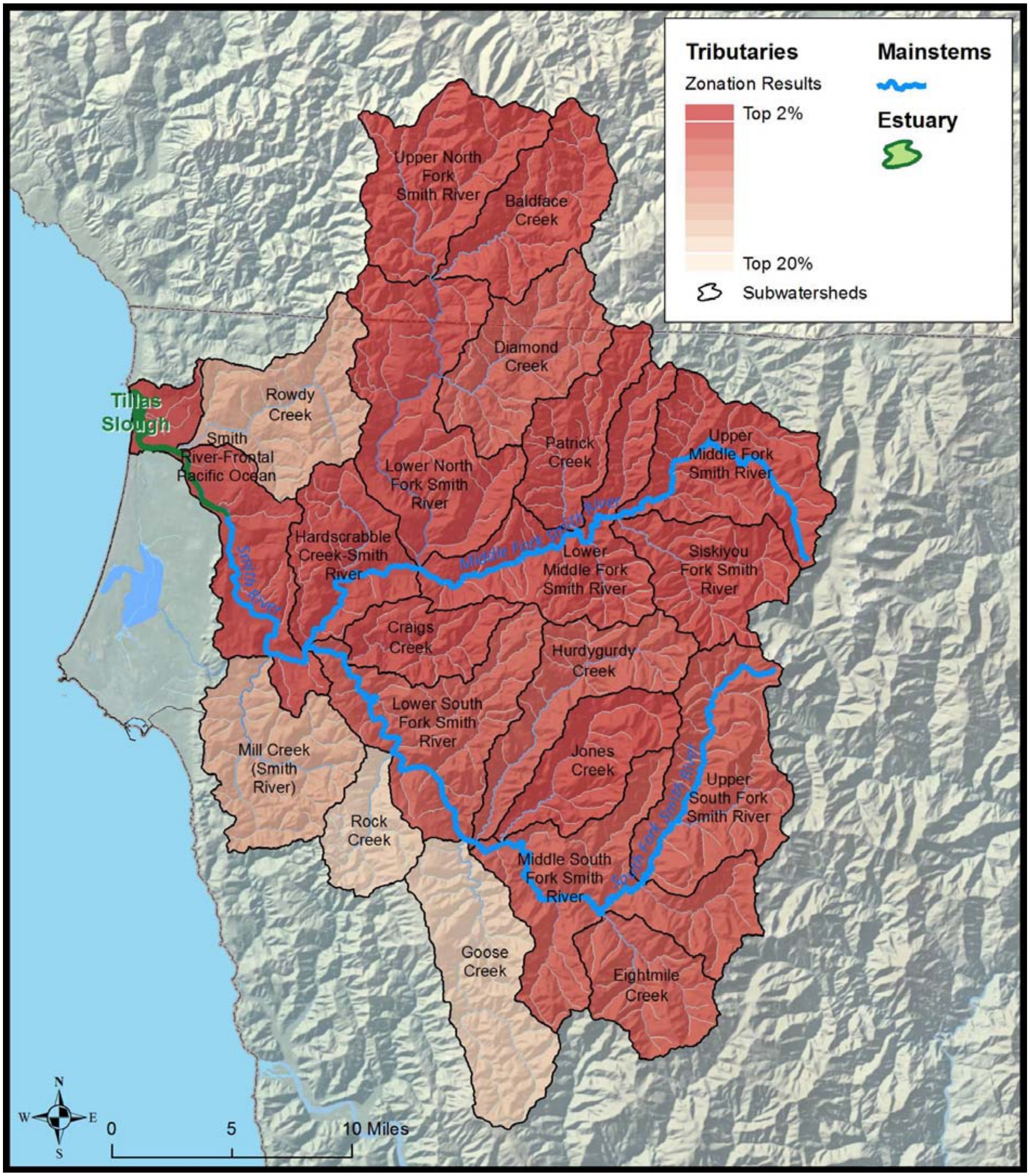


Figure 11: Habitat integrity scores for Central California Coast (CCC) Coho populations. Note that instream condition is poor for all CCC Coho populations.

	Habitat Integrity					
Central California Coast Coho Populations	**Instream Condition and Sediment**	**Temperature**	**Barriers**	**Water Quality**	**Flow**	**Overall Score**
Albion River	1.3	3.0	2.5	4.8	4.8	16
Big River	1.1	3.1	3.4	4.7	4.9	17
Big Salmon Creek	2.0	5.0	4.0	4.0	5.0	20
Caspar Creek	1.0	5.0	4.0	4.0	5.0	19
Cottaneva Creek	1.0	5.0	2.0	4.0	5.0	17
DeHaven Creek	1.0	5.0	4.0	5.0	5.0	20
Elk Creek	2.0	5.0	4.0	4.0	5.0	20
Garcia River	1.6	3.0	3.4	4.6	4.9	18
Gazos Creek	2.0	5.0	2.0	5.0	4.0	18
Gualala River	1.7	3.0	4.7	4.3	4.7	18
Hare Creek	1.0	5.0	2.0	4.0	5.0	17
Howard Creek	2.0	5.0	4.0	4.0	4.0	19
Lagunitas Creek	1.8	3.8	2.2	3.0	3.4	14
Little River - S	1.0	5.0	2.0	4.0	4.0	16
Navarro River	1.2	3.0	2.2	4.6	4.7	16
Noyo River	1.3	3.0	3.0	4.5	4.8	17
Pescadero Creek	1.6	4.8	2.2	4.2	3.8	17
Pudding Creek	1.5	3.0	3.5	4.0	4.5	17
Redwood Creek - Muir Woods	1.0	4.0	3.0	4.0	4.0	16
Russian Gulch - N	1.0	5.0	3.0	3.0	4.0	16
Russian Gulch - S	2.0	5.0	3.0	5.0	5.0	20
Russian River	1.2	2.8	2.1	3.2	3.2	13
Salmon Creek - S	1.8	3.8	3.3	4.5	4.0	17
San Gregorio Creek	2.0	4.3	2.0	3.3	4.0	16
San Lorenzo River	1.0	4.8	2.0	2.5	3.8	14
San Vicente Creek	3.0	5.0	2.0	4.0	4.0	18
Scott Creek	3.0	4.7	3.7	4.7	4.0	20
Soquel Creek	2.0	5.0	2.0	3.7	4.7	17
Ten Mile River	1.3	3.0	4.3	4.5	4.9	18
Usal Creek	1.0	5.0	4.0	4.0	5.0	19
Waddell Creek	2.0	5.0	3.0	5.0	4.5	20
Wages Creek	1.0	5.0	4.0	5.0	5.0	20
Walker Creek	1.7	2.0	3.7	3.0	4.7	15

Figure 12: Stresses impacting watersheds in the Sacramento-San Joaquin (purple), Central South Coast (green), Klamath (red) and North Coast (blue) regions that fall within the top 10 percent of the SalmonScape.Condition refers to the instream condition of various watersheds.

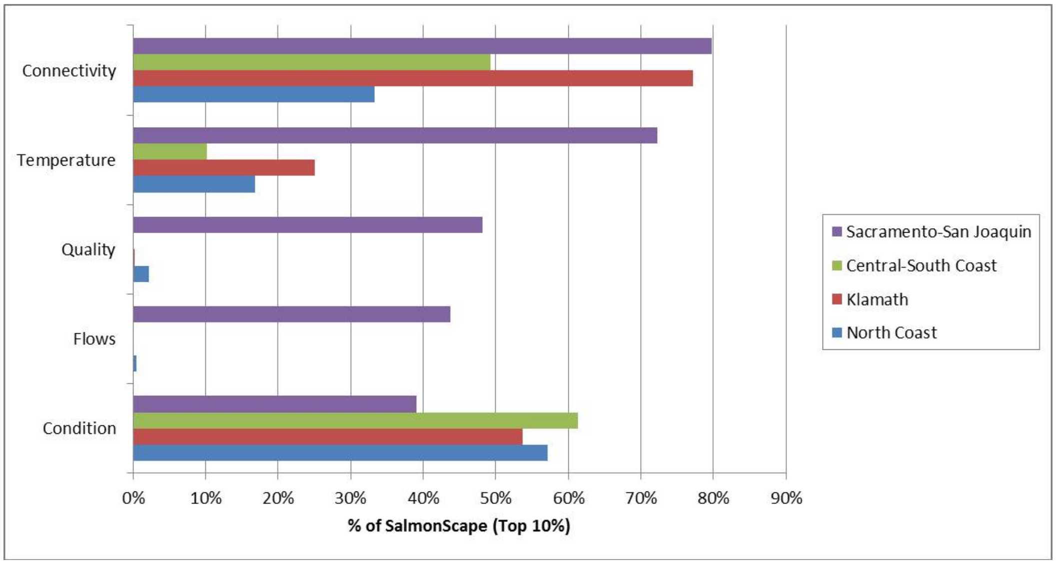
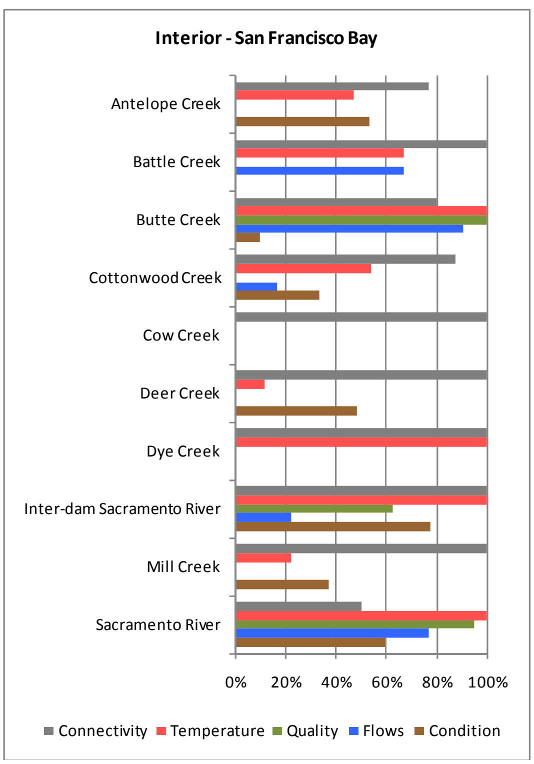
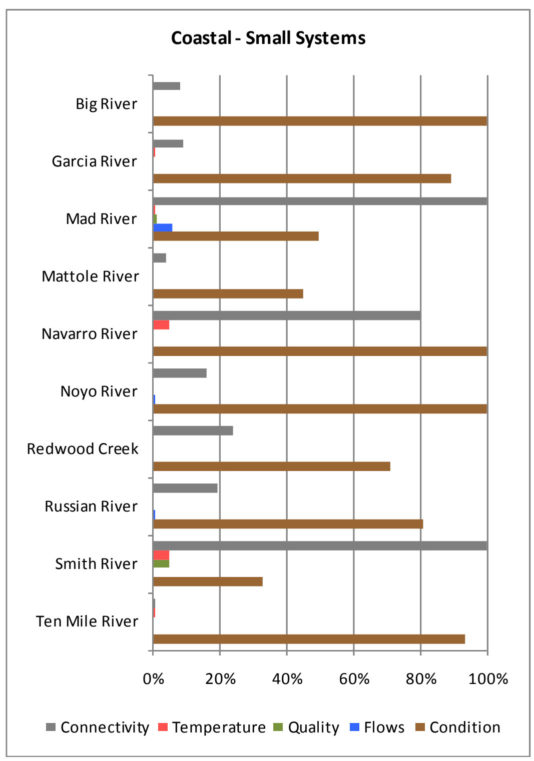


Figure 13: Examples of stresses to a subset of watersheds that fall within the top 10 percent of the SalmonScape. The left panel shows stresses impacting watersheds the Sacramento-San Joaquin region; the right panel shows stresses impacting the larger North Coastal watersheds. Note that the coastal systems are primarily impacted by instream condition and connectivity while the interior systems are impacted by multiple stresses.





3.3 Identifying Bottlenecks

Using the CSI dataset and the optimization results, we can identify the important areas for Salmon with the fewest stresses in the mainstem and headwater habitat based on the habitat indicators. These are areas where conservation actions focused on reducing primary stresses (instream condition, barriers, flow regime, temperature and water quality) could significantly improve habitat. Figure 14 ranks the watersheds in the interior and coastal regions by area in the top 10 percent of the SalmonScape and also shows how much of the area is affected by 2 or fewer stresses, and 3 or greater. Based on this information, reducing stresses in the Eel, Smith, Trinity and Klamath basins has the potential to greatly improve conditions in the SalmonScape.

While the CSI dataset does not include specific information on potential bottlenecks in the estuary and ocean lifestages, we can use the data to infer where these potential bottlenecks may exist. In Figure 5, two boxes in the matrix are coded as the "Restore Population" strategy because the integrity of the freshwater habitat (mainstem and tributary) is good, but the population integrity is relatively low. We can infer that a cause of low population integrity could be poor estuarine habitat and/or ocean conditions. Figure 15 ranks populations by the amount of area in the top 10% of the SalmonScape and also shows the count of the 6 species/runs that fall in the "Restore Population" strategy category. We have grouped the watersheds by estuaries they flow to. As Figure 15 shows, the numerous populations within the Eel River fall into the high habitat integrity and low population integrity categories – pointing to the Eel River estuary as a potential bottleneck to these populations. The Mattole River and Redwood Creek estuaries are also associated with multiple populations that fall into the high habitat and low population integrity categories.

Figure 14: Ranking of watersheds by area in the top 10% and the count of stresses in the mainstem and headwater habitat.

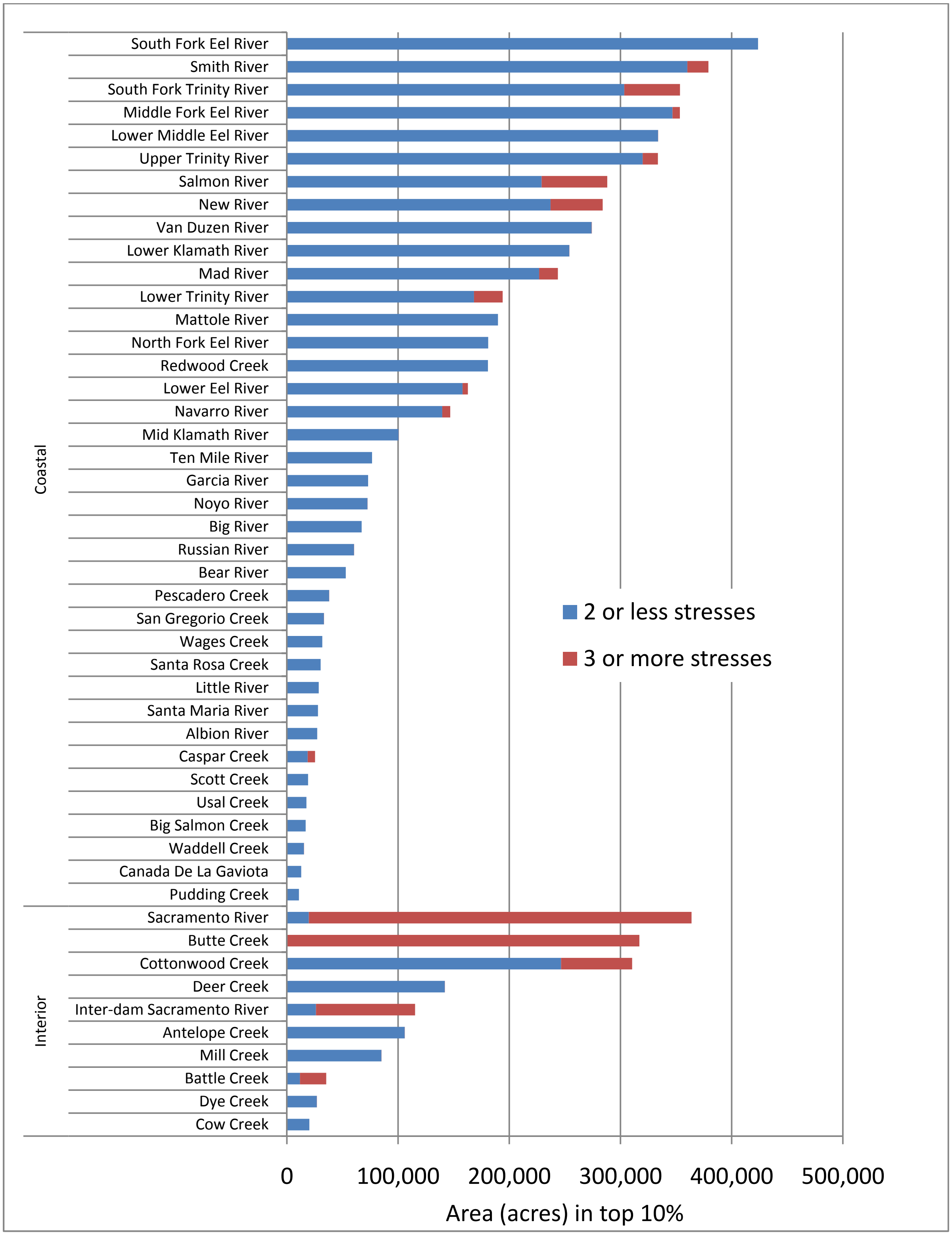
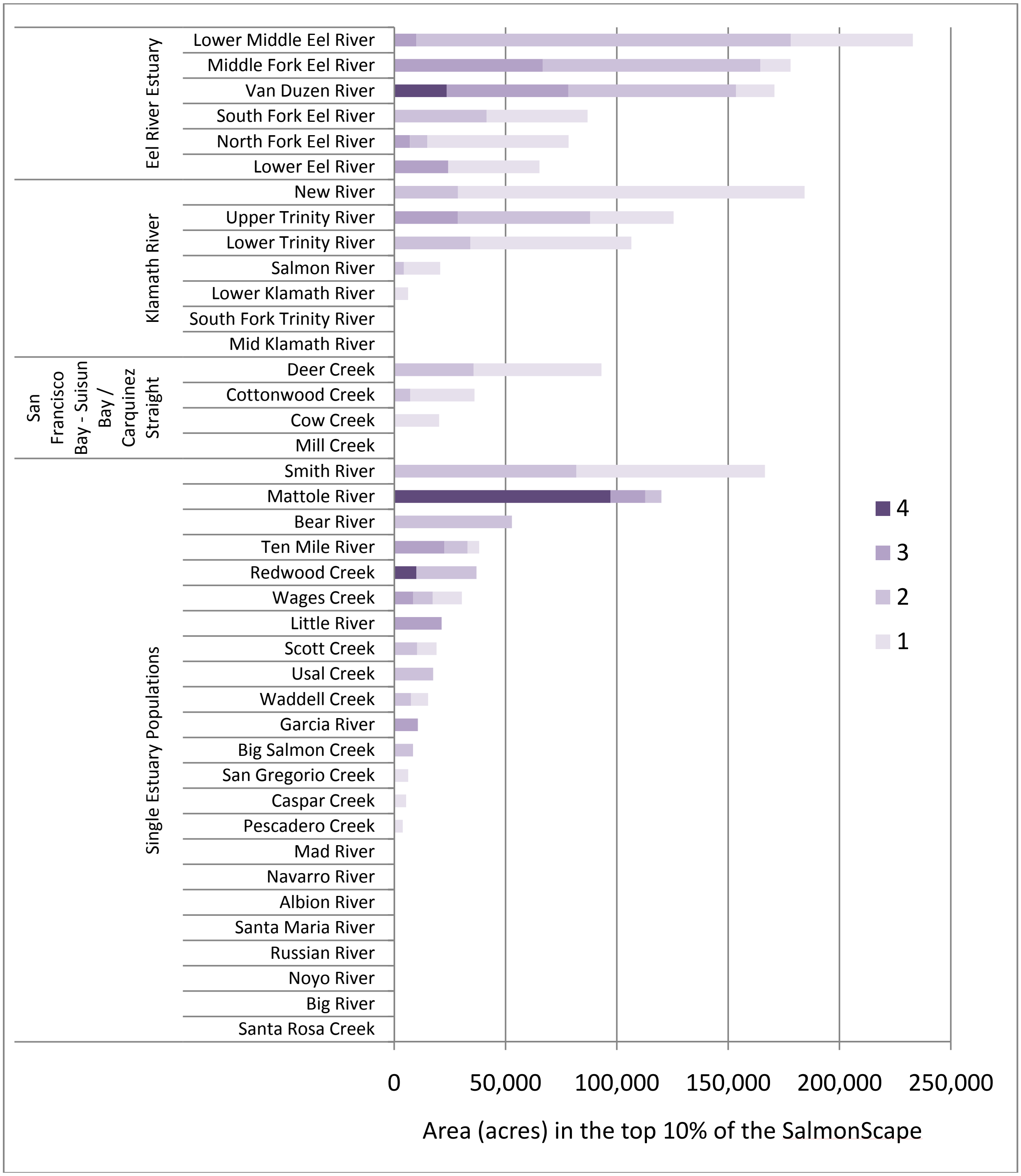


Figure 15: Estuaries and watersheds with 1 to 4 species / runs in the "Restore Population" strategy category in the top 10% of the SalmonScape.



4.0 Platform Sites

The Nature Conservancy currently engages salmon conservation in the Lassen Foothills, the Bay Delta, the North Coast, and the Sacramento, Salinas, Shasta and Santa Clara river watersheds (Figure 16). The aim at these sites is to develop solutions to common habitat bottlenecks that may in turn be leveraged across the SalmonScape to provide solutions at a broader scale (Table 4).

For example, the work to improve connectivity at Battle Creek, Ten Mile River, Salinas River, Arroyo Seco and Santa Clara River by removing barriers may be leveraged at other places where barriers are an impediment to salmon populations (Figure 17). Alternatively, Figure 18 illustrates where TNC is working to improve instream conditions at project sites. This work in turn may be applied more broadly across the region to restore habitat in the priority landscape where these same issues dominate. These examples demonstrate how this analysis can inform how work in a specific site might be designed to effect salmon conservation more broadly.

Figure 16: Current place-based salmon conservation projects of The Nature Conservancy.

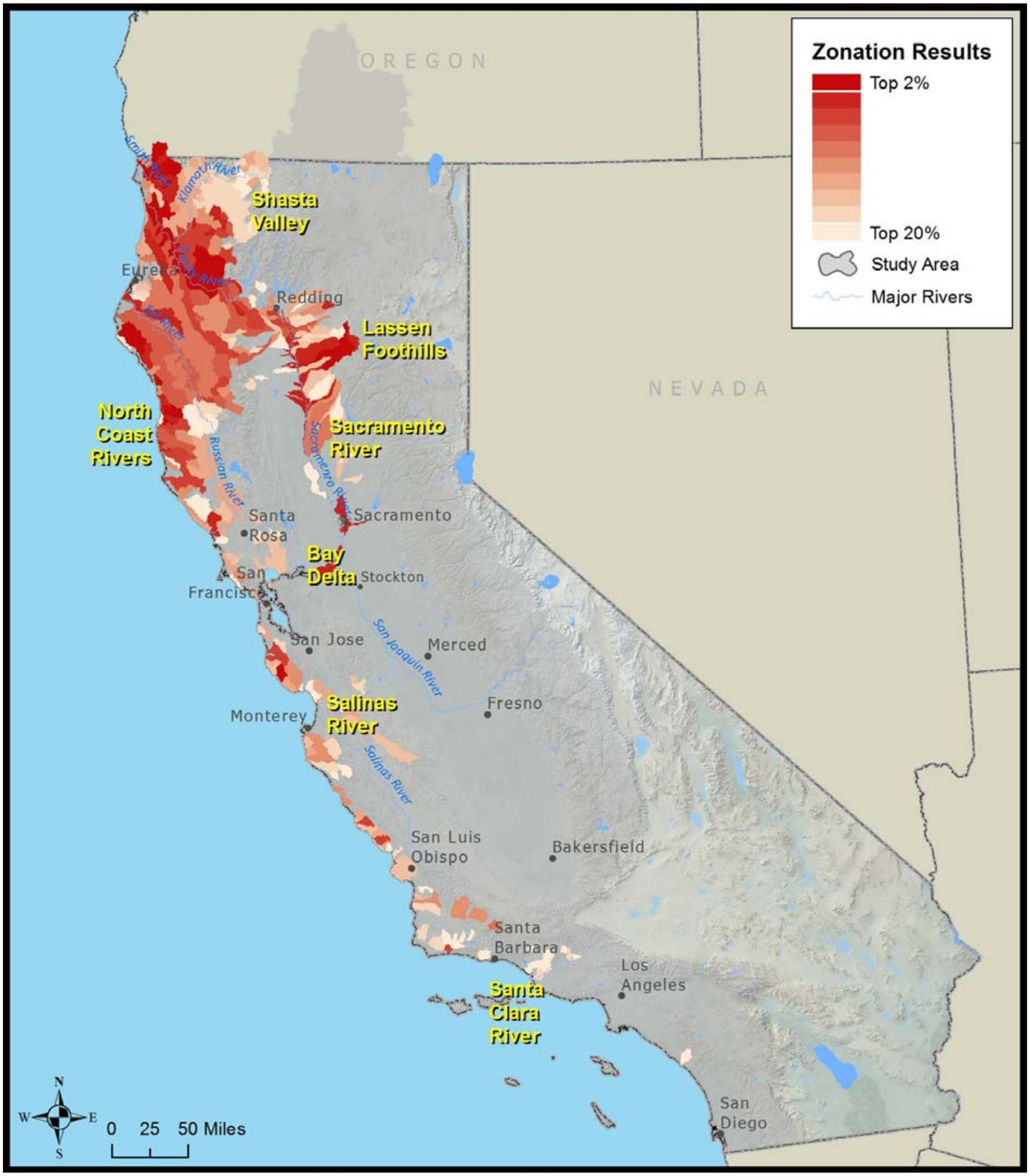
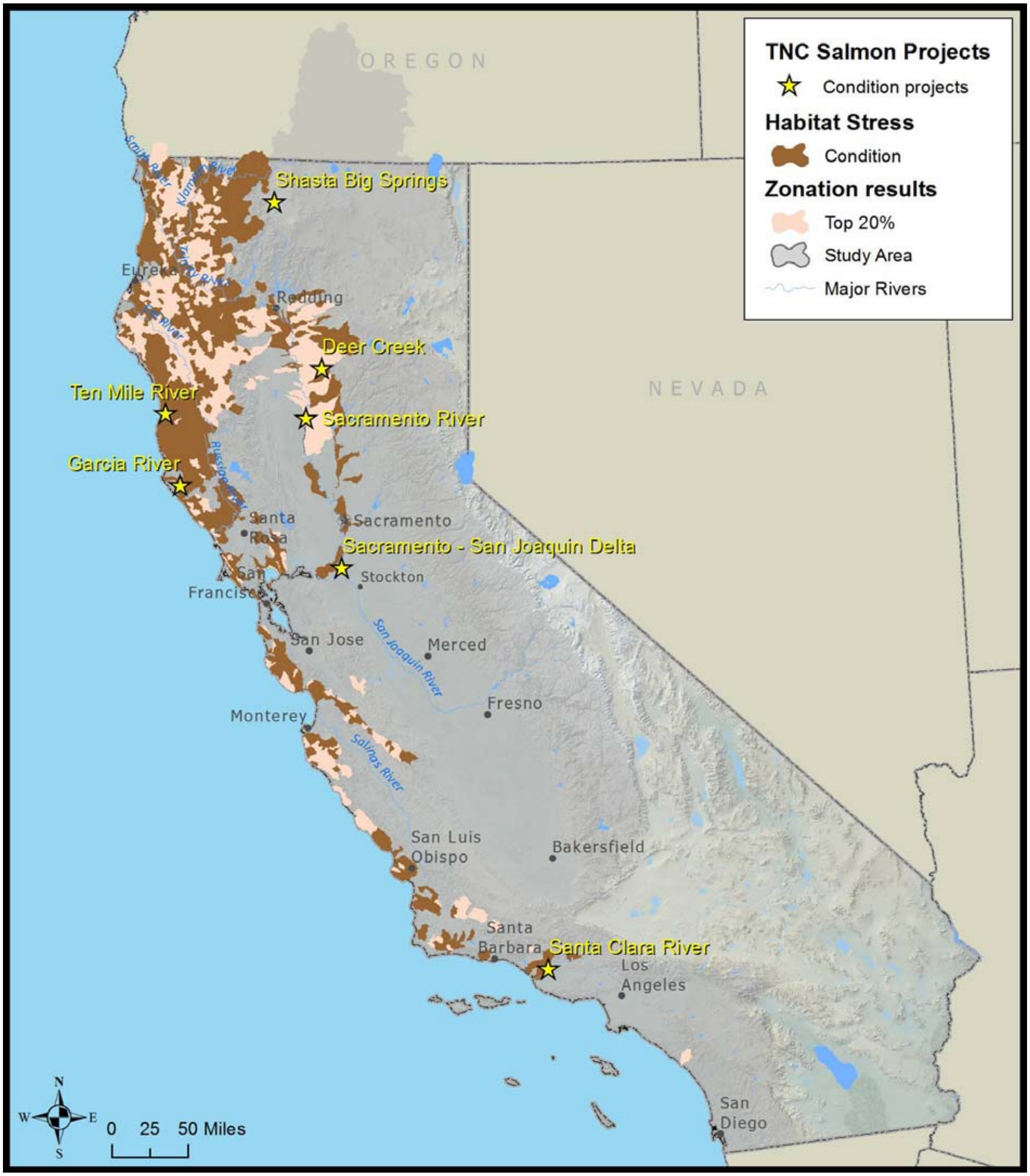


Figure 17: Sites where The Nature Conservancy's restoration activities include removing instream barriers. These practices may be leveraged across SalmonScape in areas impacted by poor connectivity, depicted as the gray areas.

Figure 18: Sites where The Nature Conservancy is engaged in restoring instream conditions by riparian restoration, forest management, large woody debris inputs and general sediment reduction. These practices may be leveraged across SalmonScape in areas impacted by poor sediment and instream conditions, depicted in brown.



5.0 Conclusions and Future Directions

This analysis of salmon population, habitat, and future security indicators generated a list of priority sites for conservation action and assessments of the protection and restoration needs along the freshwater portion of the lifecycle of priority California salmon populations.

The prioritization analyses are based on a rich data set developed by Trout Unlimited. The CSI indicators are composed of a variety of data sources synthesized into a GIS database for all 6 runs of salmon and trout in the state. The data that make up each of the 17 indicators are available to practitioners and scientists, to help inform efforts to improve habitat and population conditions at subwatershed, population, and system-wide scales. Although not included in this analysis, the future security indicators can be used to evaluate future threats. The prioritization analysis helps illuminate how work in a specific place can fit within a broader landscape and conservation strategy – and can inform how best to invest limited resources to advance conservation of salmonids.

This analysis was designed to address a specific question, of where would the strategies of habitat restoration lead to greatest gains in protection of salmonid diversity in California. The assembled database can also be utilized to conduct additional analyses. For example, the optimization model could be run separately for each of the three hydrologic regions in California: Central Valley (Sacramento and San Joaquin), North Coast (Klamath and North Coastal systems), and Central and South Coast. Regional analyses would highlight the top 2-5% of those individual regions to help inform regional strategies. Zonation runs could also be conducted to help identify potential priorities for reintroduction, by focusing on areas with extirpated populations that rank medium and high for habitat integrity (Fig.19).

We can also use the SalmonScape database to determine how much habitat can be made available by removing subwatershed barriers, using newly developed software program called the Barrier Assessment Tool to identify those places that provide the greatest return on investment by removing barriers. Finally, using the CSI Future Security groupings (Figure 4), we could analyze the vulnerability of the SalmonScape to land conversion, resource extraction, climate change, and sedimentation.

Figure 19: Population and habitat integrity matrix highlighting priorities for reintroduction i.e. extirpated populations that rank medium and high for habitat integrity.

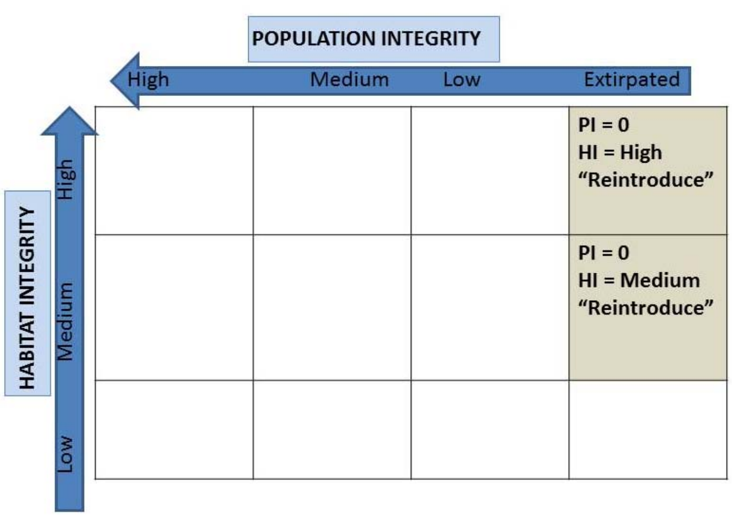


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Table 1: Watersheds that make up top 2, 5, 10 and 20 percent of the study area identified as the priority places to protect the strongest populations and best remaining habitat, restore habitat and populations to create and maintain viable populations. Watersheds listed in bold are places where The Nature Conservancy is currently engaged.

Top 2%	**Top 5%**	**Top 10%**
Deer Creek	**Antelope Creek**	Albion River
Lower Klamath River	Arroyo de la Laguna	**Battle Creek**
Lower Trinity River	Big Salmon Creek	Bear River
Mattole River	Butte Creek	Big River
Mill Creek	Cow Creek	Canada De La Gaviota
New River	**Dye Creek**	**Cottonwood Creek**
Pudding Creek	**Garcia River**	Caspar Creek
Scott Creek	**Inter-dam Sacramento River**	Little River
Smith River	Lower Eel River	Lower Middle Eel River
Ten Mile River	Navarro River	Mad River
Upper Trinity River	Noyo River	Mid Klamath River
Usal River	Pescadero Creek	Middle Fork Eel River
Waddell Creek	Redwood Creek	North Fork Eel River
	Russian River	San Gregorio Creek
	Sacramento River	Santa Maria River
	Salmon River	Santa Rosa Creek
	South Fork Trinity River	South Fork Eel River
	Van Duzen River	
	Wages Creek	

Top 20%		
Aptos Creek	Limekiln Creek	**Santa Clara River**
Arroyo Grande Creek	Little Sacramento	Santa Rosa Creek
Arroyo Leon	Little Sur River	Santa Ynez River
Arroyo Seco	Los Osos Creek	Scott River
Ash Creek	Lower Eel River	**Shasta River**
Bear Creek	Lower Feather River	Singer Creek
Big Chico Creek	Maple Creek	Sonoma Creek
Big Sur River	Napa River	Thomes Creek
Bixby Creek	**Pajaro River**	Tomales Bay
Carmel River	Paynes Creek	Toomes Creek
Cayucos Creek	Pico Creek	Toro Creek
Chorro Creek	Redwood Creek - Muir Woods	Upper Bear River
Clear Creek	Russian Gulch	Upper Klamath River
Coast Creek	Salmon Creek	Upper Middle Eel River
Cooksie Creek	Salt Creek	Upper Trinity River
Cottaneva Creek	San Carpoforo Creek	Upper Yuba River
Denniston Creek		Ventura River
Elk Creek	San Francisquito Creek	Villa Creek - SLO
Gazos Creek	San Jose Creek	
Goleta Slough Complex	San Lorenzo River	Walker Creek
Greenwood Creek	San Luis Obispo Creek	Willow Creek
Gualala River	San Mateo Creek	Islay Creek
Hare Creek	San Pablo Bay	Lagunitas Creek
Humboldt Bay Creeks	San Simeon Creek	
Inks Creek	San Vicente Creek	

Table 2: Comparison of SalmonScape watersheds to National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), United States Fish and Wildlife Service (USFWS) and State Water Regional Control Board (SWRCB) priority rivers *(NMFS 2010a, 2010b, 2010c, NMFS 2009a, 2009b, 2009c, DFG 2004, USFWS 2001, SWRCB 2010).*

Category	ESU	SalmonScape Watershed	NOAA Priority or Core 1 Watersheds (2009, 2010)	DFG Coho (2004)	USFWS CVPIA (1991)	SWRCB (2010)
Top 2%	CV	Deer Creek	X		X	
Top 2%	SONCC	Lower Klamath River	X	X		X
Top 2%	SONCC	Mattole River	X	X		X
Top 2%	CV	Mill Creek	X		X	
Top 2%	SONCC	New River (in Lower Trinity River)	X	X		X
Top 2%	CCC	Pudding Creek	x	X		
Top 2%	CCC	Scott Creek	x	X		
Top 2%	SONCC	Smith River	X	X		
Top 2%	CCC	Ten Mile River	x			
Top 2%	CCC	Usal River	x			
Top 2%	CCC	Waddell Creek	x			
Top 5%	CV	Antelope Creek	X		X	
Top 5%	CCC	Big Salmon Creek	x			
Top 5%	CV	Butte Creek	X		X	
Top 5%	CV	Cow Creek				
Top 5%	CV	Dye Creek				
Top 5%	CCC	Garcia River	x	X		X
Top 5%	CV	Inter-dam Sacramento River				
Top 5%	SONCC	Lower Eel River		X		X
Top 5%	SONCC	Lower Trinity River	X	X		X
Top 5%	CCC	Navarro River	x	X		X
Top 5%	CCC	Noyo River	x			X
Top 5%	CCC	Pescadero Creek	x			
Top 5%	SONCC	Redwood Creek	x	X		
Top 5%	CCC	Russian River	x	X		X
Top 5%	CV	Sacramento River				
Top 5%	SONCC	Salmon River				
Top 5%	SONCC	South Fork Trinity River	X	X		X
Top 5%	SONCC	Van Duzen River		X		X

Top 5%	CCC	Wages Creek	x			
Top 10%	CCC	Albion River	x	X		X
Top 10%	CV	Battle Creek	X		X	
Top 10%	SONCC	Bear River				X
Top 10%	CCC	Big River	x			X
Top 10%	SC	Canada De La Gaviota				
Top 10%	CCC	Caspar Creek	x	X		
Top 10%	CV	Cottonwood Creek				
Top 10%	CCC	Little River				X
Top 10%	SONCC	Lower Middle Eel River	X			X
Top 10%	SONCC	Mad River	X	X		
Top 10%	SONCC	Mid Klamath River		X		X
Top 10%	SONCC	Middle Fork Eel River		X		X
Top 10%	SONCC	North Fork Eel River		X		
Top 10%	CCC	San Gregorio Creek	x			X
Top 10%	SC	Santa Maria River	X			X
Top 10%	SCC	Santa Rosa Creek	X			
Top 10%	SONCC	South Fork Eel River	X	X		X

x=priority; X=Core 1

Table 3: List of estuaries, mainstems and tributaries that make up the top 5% of the priority SalmonScape.

Estuary	Mainstem(s)		Tributary/Subwatershed
Arroyo de la Cruz	Arroyo De La Laguna		Arroyo De La Laguna; Burnett Creek
Big Salmon Creek	Big Salmon Creek		Big Salmon Creek-Frontal Pacific Ocean
Eel River Estuary	Van Duzen River	Eel River	Butte Creek; Cummings Creek; Grizzly Creek; Hoagland Creek; Little Larabee Creek; Little Van Duzen River
	Eel River		Strongs Creek-Eel River
Garcia	Garcia		Lower Garcia River; Upper Garcia River
Klamath	Lower Klamath River		Ah Pah Creek; Crescent City Fork; Lower Blue Creek; McGarvey Creek; Mettah Creek; Middle Blue Creek; Tully Creek; Turwar Creek; Campbell Creek
	Lower Klamath River	Trinity River	Cedar Creek; Deerhorn Creek; Horse Linto Creek; Soctish Creek; Bell Creek; Big Bar Creek; Big Creek; Big French Creek; Devils Canyon; Don Juan Creek; East Fork New River; Little French Creek; McDonald Creek; Quinby Creek; Sharber Creek; Slide Creek; Virgin Creek; Happy Camp Creek-South Fork Trinity River; Little Bear Wallow Creek-South Fork Trinity River; Mingo Creek-South Fork Trinity River; Pelletreau Creek-South Fork Trinity River; Shell Mountain Creek-South Fork Trinity River; Smoky Creek-South Fork Trinity River; Sulphur Glade Creek-South Fork Trinity River; Conner Creek Trinity River; East Fork North Fork Trinity River; Indian Creek; Lower North Fork Trinity River; Middle North Fork Trinity River; Rattlesnake Creek; Reading Creek; Rush Creek; Upper North Fork Trinity River
		Salmon River	Big Bend Creek-South Fork; Butler Creek; Garden Gulch-South Fork; Grant Creek-North Fork; Olsen Creek-North Fork; Right Hand Fork North Fork; Somes Creek; Upper Wooley Creek; Whites Gulch-North Fork; Yellow Dog Creek-North Fork
Mattole	Mattole		Bear Creek; Headwaters Mattole River; Honeydew Creek; Lower Mattole River; Middle Mattole River; North Fork; Mattole River; Squaw Creek; Upper Mattole River; Upper North Fork Mattole River
Navarro	Navarro		Lower Navarro River; Lower Rancheria Creek; Upper Navarro River; Upper Rancheria Creek
Noyo	Noyo		Lower Noyo River; North Fork Noyo River; South Fork Noyo River; Upper Noyo River
Pescadero Creek	Pescadero Creek		Lower Pescadero Creek; Upper Pescadero Creek
Pudding	Pudding Creek		Pudding Creek
Redwood Creek	Redwood Creek		Bridge Creek; Lacks Creek; McArthur Creek; Minor Creek; Noisy Creek
Russian River	Russian River		East Austin Creek; Ward Creek-Austin Creek; Willow Creek-Russian River

Sacramento-San Joaquin Delta/SF Bay	Sacramento River		Little Antelope Creek; North Fork Antelope Creek; South Fork Antelope Creek; Upper Antelope Creek; Little Chico Creek; Upper South Cow Creek; Big Smoky Creek-Deer Creek; Cub Creek-Deer Creek; Delaney Slough-Deer Creek Gurnsey Creek; Lost Creek-Deer Creek; Sulphur Creek-Deer Creek; Dye Creek; Sevenmile Creek-Sacramento River; Spring Creek-Sacramento River; Lower Mill Creek; Middle Mill Creek; Upper Mill Creek; Beaver Lake-Sacramento River; Butler Slough-Sacramento River; Deadmans Reach-Sacramento River; Hoag Slough-Sacramento River; Lake Greenhaven-Sacramento River; Lower Antelope Creek; Murphy Slough-Sacramento River; Natomas Main Drainage Canal-Sacramento River; Packer Lake-Sacramento River; Rodeo Creek-Sacramento River; The Lagoon-Sacramento River; Threemile Slough-Sacramento River
Scott Creek	Scott Creek		Scott Creek
Ten Mile	Ten Mile		Middle Fork Ten Mile River; South Fork Ten Mile River; North Fork Ten Mile River
Tillas Slough	Smith River	Middle Fork Smith	Lower Middle Fork Smith River; Patrick Creek; Siskiyou Fork Smith River; Upper Middle Fork Smith River
		North Fork Smith	Baldface Creek; Diamond Creek; Lower North Fork Smith River; Upper North Fork Smith River
			Hardscrabble Creek-Smith River; Smith River-Frontal Pacific Ocean
		South Fork Smith	Craigs Creek; Eightmile Creek; Hurdygurdy Creek; Jones Creek; Lower South Fork Smith River; Middle South Fork Smith River; Upper South Fork Smith River
Usal River Mouth	Usal Creek		Usal Creek
Waddell	Waddell Creek		Waddell Creek
Wages	Wages Creek		Wages Creek-Frontal Pacific Ocean

Table 4: Current place-based salmon conservation projects of The Nature Conservancy.

Project Site	**Watershed**	**Habitat**	**Activity**
Lassen Foothills	Antelope Creek	Headwaters	• Conservation Easements and Fee Ownership
Lassen Foothills	Battle Creek	Headwaters	• Conservation Easements and Fee Ownership • Barrier Removal • Flow restoration
Lassen Foothills	Mill Creek	Headwaters	• Conservation Easements and Fee Ownership • Water rights for instream benefits
Sacramento	Cottonwood Creek	Headwaters	• Conservation Easements and Fee Ownership
Lassen Foothills	Deer Creek	Headwaters	• Conservation Easements and Fee Ownership • Floodplain and Riparian Restoration
Sacramento	Sacramento River	Mainstem	• Floodplain and Riparian Restoration • Ecological Flows Tool
Delta	Sacramento-San Joaquin Delta	Estuary	• Habitat restoration • Conservation Policy
Klamath	Shasta Big Springs	Headwaters	• Riparian Restoration • Irrigation improvements and tailwater reduction • Monitoring and research • Water lease/purchase
North Coast	Garcia River	Mainstem	• Habitat and fish population monitoring • Large woody material inputs – instream restoration
North Coast	Garcia River	Estuary	• Habitat and fish population monitoring • Easement
North Coast	Garcia River	Headwaters	• Habitat and fish population monitoring • Large woody material inputs – instream restoration
North Coast	Ten Mile River	Estuary	• Monitoring • Dam management
North Coast	Ten Mile	Mainstem	• Easements • Forest Management • Monitoring
North Coast	Ten Mile	Headwaters	• Forest Management • Monitoring
Salinas	Arroyo Seco	Headwaters	• Barrier removal • Conservation Easements • Monitoring
Salinas	Salinas River	Mainstem	• Food Safety Policy
Salinas	Salinas River	Estuary	• Barrier management (sand bar management)
Santa Clara	Santa Clara River	Estuary	• Water quality issues • Conservation Easements and Fee Ownership • Wetlands and riparian restoration
Santa Clara	Santa Clara River	Mainstem	• Floodplain protection • Minimum instream flow protection • Riparian restoration • Monitoring
Santa Clara	Santa Clara River	Headwaters	• Barrier removal • Monitoring • Riparian restoration

Appendix 1: Conservation Success Index: California and Southern Oregon Salmon (Coho, Winter Steelhead, Summer Steelhead, Fall Chinook, Spring/Summer Chinook, and Winter Chinook) Scoring and Rule Set

Introduction:

The CSI is an aggregate index comprised of four different component groups: Range-wide Condition; Population Integrity; Habitat Integrity; and Future Security. Each CSI group contains indicators that describe a specific component of each group. Each indicator is scored from 1 to 5 for each watershed (whether subwatershed (HUC12) or planning watershed (CalWater PW)), with a score of 1 indicating poor condition and a score of 5 indicating good condition. Indicator scores are then added to obtain the watershed condition for a Group, and Group scores are added for a CSI score for a watershed (Figure 1). CSI scores can then be summarized to obtain the general range of conditions within the historical or current distribution of the species.

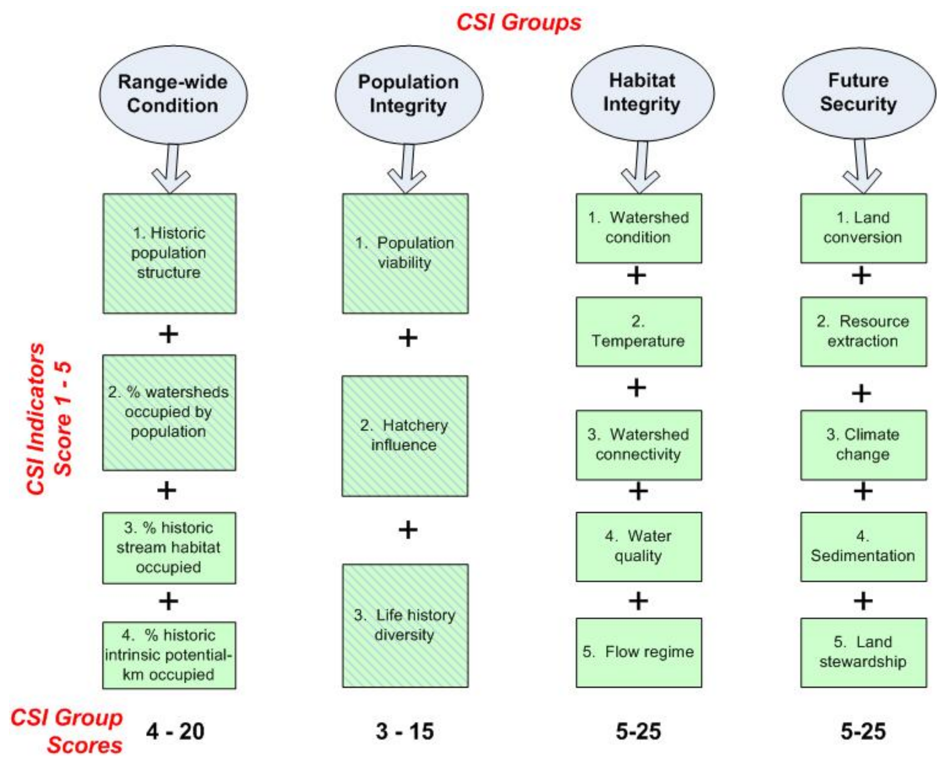

Figure 1: Each indicator is scored from 1 to 5 across 17 indicators within four main groups. Solid green indicator boxes reflect watershed scale summaries; larger striped green indicators reflect population scale summaries. Indicator scores are added per group to obtain an overall group score.

Indicator scoring by species:

Each indicator is not calculated for all species. The matrix below describes which Rangewide Condtion indicators are calculated for each species, as well as the maximum possible score for indicator totals by species. Although data may be available at the ESU scale, certain data are not available the watershed scale; scores equaling zero indicate that data is not available. Consult the information on "watersheds included" in the indicator descriptions.

SPECIES/RUN	ESU	RW1	RW2	RW3	RW4	Max RW score	Max PI score	Max HI score	Max FS score
Coho	Central CA Coast	x	x	x	x	20	15	25	25
	Southern OR/Northern CA Coast	x	x	x	x	20	15	25	25
Winter steelhead	Central CA Coast	x	x	x	x	20	15	25	25
	Central Valley	x	x	x		15	15	25	25
	Klamath Mountains Province	x	x	x	x	20	15	25	25
	Northern CA	x	x	x	x	20	15	25	25
	South-central CA Coast	x	x	x		15	15	25	25
	Southern CA	x	x	x		15	15	25	25
Summer steelhead	Northern CA	x				5	15	25	25
	Klamath Mountains Province					0	15	25	25
Fall chinook	CA coastal	x	x	x	x	20	15	25	25
	Central Valley		x	x		10	15	25	25
	Southern OR/Northern CA Coast	x	x	x	x	20	15	25	25
	Upper Klamath - Trinity Rivers	x	x	x	x	20	15	25	25
Spr/summ chinook	CA coastal					0	15	25	25
	Central Valley		x	x		10	15	25	25
	Southern OR/Northern CA Coast					0	15	25	25
	Upper Klamath - Trinity Rivers					0	15	25	25
Winter chinook	Central Valley		x	x		10	15	25	25

Rangewide Condition Indicator 1: Historical population structure OR historical habitat extent by population

Indicator Scoring:

Historical population structure	Maximum historical habitat extent	CSI Score
Ephemeral	< 10 km	1
Dependent	10 – 30 km	2
Potentially independent	30 – 60 km	3
		4
Functionally independent	> 60 km	5

Scored at the population scale

Explanation: Historical population structure at the population scale. In the absence of historical population structure information, the maximum historical habitat extent is used as a proxy.

Rationale: Population boundaries, identities, and status based on similar environmental conditions, genetic and spatial relationships, and IP-km. Functionally independent populations are viable in the absence of other populations, while dependent populations require dispersers to supplement their abundance and genetic diversity.[1]

Watersheds included: Currently occupied watersheds (containing >0.1 miles of occupied habitat) for all coho; all winter steelhead; Northern CA summer steelhead; CA coastal, Southern OR/Northern CA, and Upper Klamath-Trinity Rivers fall chinook.
Watersheds excluded: Currently unoccupied watersheds (extirpated and contributing) for all species/runs; Klamath Mountains summer steelhead; Central Valley fall chinook; all spring/summer Chinook; winter Chinook

Scale: Population. The CSI score is the same for all currently occupied watersheds within a population.

Data Sources: Coho, Chinook, and steelhead historical population structure in the North Central California Coast recovery domain from Bjorkstedt et al 2005;[1] coho population structure in the Southern Oregon/Northern California ESU from Williams et al 2006.[2]

Historic Northern California and Klamath Rivers Province winter steelhead distribution approximated from intrinsic potential models where IP > 0 and excluding areas with a mean gradient > 12%[3]; historic Central Valley winter steelhead distribution approximated from intrinsic potential models where or IP = 1 and excluding areas with a mean August temperture > 24°C;[4] Southern Oregon/Northern California Coast fall chinook historic distribution approximated from intrinsic potential models, where IP > 0;[5] Central Valley fall, spring/summer, and winter chinook historic distributions based on historic accounts.[6]

<u>**Rangewide Condition Indicator 2:**</u> Percent of historic watersheds occupied by populations

Indicator Scoring:

Occupied watersheds	CSI Score
< 20%	1
20 – 39%	2
40 – 59%	3
60 – 79%	4
≥ 80%	5

Explanation: The percentage of historically occupied watersheds currently occupied by population, based on sampling data and intrinsic potential models. Fine-scale intrinsic potential data was coarsened to match the 1:100,000 scale of current distribution data. Populations not predicted to have been historically occupied but are currently occupied receive a score of 5.

Rationale: Species that occupy a larger percentage of their historic stream habitat are likely to persist.

Watersheds included: Currently occupied watersheds (containing >0.1 miles of occupied habitat) for all coho; all winter steelhead; all fall chinook; Central Valley spring/summer chinook
Watersheds excluded: Currently unoccupied watersheds (extirpated and contributing) for all species/runs; all summer steelhead; Central California Coast and Southern Oregon/Northern California spring/summer Chinook; winter Chinook

Scale: Population. The CSI score is the same for all currently occupied watersheds within a population.

Data Sources: *Historic distributions:* Historic coho distribution approximated from intrinsic potential models, where IP > 0 and excluding areas with mean August temperature > 21.5ºC;[5] historic South

Central Coast and Southern California winter steelhead distribution approximated from intrinsic potential models where IP = 1 (95% envelope)[7;8]; historic Central California Coast, Northern California, and Klamath Rivers Province winter steelhead distribution approximated from intrinsic potential models where IP > 0 and excluding areas with a mean gradient > 12%[3]; historic Central Valley winter steelhead distribution approximated from intrinsic potential models where or IP = 1 and excluding areas with a mean August temperture > 24°C;[4] Central California Coast and Southern Oregon/Northern California Coast fall chinook historic distribution approximated from intrinsic potential models, where IP > 0;[5] Central Valley fall, spring/summer, and winter chinook historic distributions based on historic accounts;[6] historic winter steelhead and fall chinook distribution in the Upper Klamath River from Hamilton et al 2005.[9]

Current distributions: Current coho distribution from Calfish[10] in California and Streamnet[11] in Oregon; current winter and summer steelhead distribution from Calfish[12;13] in California and Streamnet[11] in Oregon; current fall chinook distribution from Calfish[14] and NOAA[15] in California and Streamnet[11] in Oregon; current spring/summer chinook distribution from Calfish[14] and NOAA[16;17] in California and Streamnet[11] in Oregon; current winter Chinook distribution from NOAA.
Species must occupy at least 0.1 miles to be considered currently or historically present.

Subwatersheds based on NRCS data;[18] planning watersheds based on CalWater 2.2.1.[19]

Rangewide Condition Indicator 3: Percent of historic stream habitat occupied by watershed

Indicator Scoring:

Occupied stream habitat	CSI Score
< 20%	1
20 – 39%	2
40 – 59%	3
60 – 79%	4
≥ 80%	5

Explanation: The percentage of historically occupied streams currently occupied by the species, based on sampling data and intrinsic potential models. Fine-scale intrinsic potential data is coarsened to match the 1:100,000 scale of current distribution data. Watersheds not predicted to have been historically occupied but are currently occupied receive a score of 5.

Rationale: Species that occupy a larger percentage of their historic stream habitat are likely to persist.

Watersheds included: Currently occupied watersheds (containing >0.1 miles of occupied habitat) for all Coho; all Winter Steelhead; all Fall Chinook; Central Valley Spring/Summer Chinook; Winter Chinook
Watersheds excluded: Currently unoccupied watersheds (extirpated and contributing) for all species/runs; all summer steelhead; Central California Coast and Southern Oregon/Northern California spring/summer chinook

Scale: Watershed. Only currently occupied watersheds receive CSI scores.

Data Sources: See data sources for Rangewide Condition Indicator 2

<u>**Rangewide Condition Indicator 4:**</u> Percent historic intrinsic potential-kilometers currently occupied by watershed

Indicator Scoring:

Current IP-km/Historic IP-km	CSI Score
< 20%	1
20 – 39%	2
40 – 59%	3
60 – 79%	4
≥ 80%	5

Explanation: The ratio of the sum of IP-km for a species'current distribution vs. historical distribution. Watersheds not predicted to have been historically occupied (and thus receiving no IP score) but are currently occupied receive a score of 5.

Rationale: The ratio of current to historical IP-km reflects the habitat quality of the habitat occupied, especially when compared to the % historical distribution by watershed.

Watersheds included: Currently occupied watersheds (containing >0.1 miles of occupied habitat) for all coho; Central CA coast, Klamath Mountains, and Northern CA winter steelhead; CA coastal, Southern OR/Northern CA, and Upper Klamath-Trinity Rivers fall chinook.
Watersheds excluded: Currently unoccupied watersheds (extirpated and contributing) for all species/runs; Central Valley, South-central, and Southern winter steelhead; all summer steelhead; Central Valley fall chinook; all spring/summer Chinook; winter Chinook

Scale: Watershed. Only currently occupied watersheds receive CSI scores.

Data Sources: *Historic distributions:* Historic coho distribution and habitat quality approximated from intrinsic potential models, where IP > 0 and excluding areas with mean August temperature > 21.5ºC;[5] historic Central California Coast, Northern California, and Klamath Rivers Province winter steelhead distribution and habitat quality approximated from intrinsic potential models where IP > 0 and excluding areas with a mean gradient > 12%[3]; Central California Coast and Southern Oregon/Northern California Coast fall chinook historic distribution approximated from intrinsic potential models, where IP > 0.[5]

Current distributions: Current coho distribution from Calfish[10] in California and Streamnet[11] in Oregon; current winter steelhead distribution from Calfish[12] in California and Streamnet[11] in Oregon; current fall chinook distribution from Calfish[14] and NOAA[15] in California and Streamnet[11] in Oregon.

Subwatersheds based on NRCS data;[18] planning watersheds based on CalWater 2.2.1.[19]

Population Integrity Indicator 1: Population viability.

Indicator Scoring:

Viability: productivity or abundance	CSI Score
Critically low	1
Below average	2
Moderate	3
Above average	4
High	5

Explanation: Expert opinion estimates of population viability, as a function of abundance or productivity.

Rationale: Small populations are more vulnerable to extirpation.[20]

Scale: Population. The CSI score is the same for all currently occupied watersheds within a population.

Data Sources: North American Salmon Stronghold Partnership California population database.

Population Integrity Indicator 3: Hatchery influence.

Indicator Scoring:

% Natural Origin Spawners	CSI Score
0 – 24 %	1
25 – 49 %	2
50 – 74 %	3
75 – 95 %	4
> 95 %	5

Explanation: Categorizes populations based on the absence/presence of hatcheries by management regime.

Rationale: Hatchery fish exhibit less genetic diversity and reduced fitness relative to wild fish.[21] Transplanted stocks lack local adaptations.

Scale: Population. The CSI score is the same for all currently occupied watersheds within a population.

Data Sources: Percent natural origin spawner categorical scores from North American Salmon Stronghold Partnership California population database.

<u>Population Integrity Indicator 5:</u> Life history diversity.

Indicator Scoring:

Life History Diversity	CSI Score
Extremely simplified or single life history strategy	1
Few life histories present and significantly simplified from historical	2
Few life histories present and modest representation of historical	3
Robust, multiple, and/or rare life histories, with majority of historical present	4
All life history strategies present	5

Explanation: The variety of life histories – age/year classes, sizes, fecundity, run timing, and other traits - present in a population.

Rationale: The variety of life histories present in a population contributes to genetic variation essential for responding to environmental changes and facilitates the ability to occupy a greater variety of habitats, mitigating risks across space and time.[22]

Scale: Population. The CSI score is the same for all currently occupied watersheds within a population.

Data Sources: North American Salmon Stronghold Partnership California population database.

<u>Habitat Integrity Indicator 1:</u> Watershed conditions and instream habitat

Indicator Scoring:

Miles 303(d) listed for sediment	Road density (miles/miles²)	Road mi/ Stream mi	CSI Score
	≥ 4.7	0.5 – 1.0	1
	3 – 4.7	0.25 – 0.49	2
> 0.1	2.5 - 3	0.10 - 0.24	3
	1.6 – 2.5	0.05 – 0.09	4
	< 1.6	0 – 0.04	5

Score for worst case

Subtract 1 point for ≥ 3 instream sand or gravel mines present within 200 meters of perennial or intermittent streams in the watershed

Explanation: The presence of 303(d) listed streams for sediment, road density in miles/miles², miles of road within 100 meters of all perennial, intermittent, and ephermeral streams, and presence of sand or gravel mines in a watershed.

Rationale: Fine sediments smother benthic invertebrates, embed spawning substrates, and increase turbidity.[23;24] Roads are a common contributor of sediments. Areas of high road densities may also reflect a history of intensive logging, an additional contributor of sediments to streams. Lee et al.[25] recognized 6 road density classifications as they related to aquatic habitat integrity and noted densities of 1.7 and 4.7 mi/mi^2 as important thresholds. NOAA's California Coho Recovery Plan identifies road densities of 1.6, 2.5, and 3.0 as important indicators of habitat integrity. Sand and gravel mines within 200 meters of the streams alter flows, disrupt downstream gravel recruitment, and eliminate habitat.

Scale: Watershed

Data Sources: Aggregate rock, sand, gravel mines from California Department of Conservation.[26] 2006 303(d) listed streams data from USEPA.[27;28] Road data is a composite of USFS Northwest Forest plan,[29] Oregon BLM,[30] US Census Bureau TIGER data,[31] and USFS CA National Forest data.[32-41] Streams from the National Hydrography Dataset (NHD Plus).[42]

<u>Habitat Integrity Indicator 2:</u> Temperature

Indicator Scoring:

Miles 303(d) listed for temperature	Percent stream habitat above temperature threshold	Mean Riparian vegetation height (m)	CSI Score
	81 – 100%	0 - 1	1
	61 – 80%	1 - 5	2
> 0.1	41 - 60%	5 – 10	3
	21 - 40%	10 – 20	4
	0 – 20%	> 20	5

Score for worst case

Explanation: Miles of 303(d) listed streams for temperature within each watershed and percent of stream habitat identified by a 21.5°C (coho) or 24°C (steelhead and chinook) August mean air temperature mask.

Rationale: 303(d) impairment for temperature reflects a departure from anticipated natural water temperatures that sustain coldwater fish. Impairment is often a function of poor riparian condition, disruption of natural flows, or altered hydrology. Intrinsic potential models identify an August mean air temperature of 21.5°C as corresponding to the natural limit of historic coho distribution, 24°C as the limit of historic steelhead distribution.[3;4;7;8] Riparian vegeation provides shading and contributes large woody debris.

Scale: Watershed

Data Sources: 2006 303(d) listed streams data from USEPA.[27;28] Mean August temperature data for the period between 1960 and 1990 from PRISM dataset.[43] Existing vegetation height data from Landfire.[44]

Habitat Integrity Indicator 3: Watershed connectivity.

Indicator Scoring:

Passage status	Barriers within WS	Barriers downstream	CSI Score
Extirpated above barrier			1
Accessible	≥ 12	> 4	2
Accessible	5 -11	2 -3	3
Accessible	1 – 4	1	4
Accessible	0	0	5

Score for worst case
Those watersheds that were not historically accessible by anadromous fish (Passage status = "Contributing") are scored solely on the basis of barriers within watershed

Explanation: The count of all barriers (complete and partial, anthropogenic and natural) within each watershed, the counts of partial barriers along the mainstem between the bottom of the watershed and the terminus of the river system at the ocean, and the portion of historic habitat isolated above complete anthropogenic barriers.

Rationale: Increased hydrologic connectivity provides more habitat area and better supports multiple life stages, an important viability criteria which increases the likelihood of persistence.[22] Diversions, even when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks.

Scale: Watershed and connected downstream stream network

Data Sources: Barriers data from the May 2009 California Fish Passage Assessment Database[45] and Oregon's Fish Passage Barriers dataset.[46] Stream data and additional natural barriers from National Hydrography Dataset (NHD Plus).[42]

Habitat Integrity Indicator 4: Water quality.

Indicator Scoring:

Miles 303(d) listed for toxins or nutrients	Agricultural and Urban Land	Number Active Mines	Number Active Oil/Gas Wells	CSI Score
	58-100%	≥10	≥ 400	1
	28-57%	7-9	300 - 399	2
>0.1	16-27%	4-6	200 - 299	3
	6-15%	1-3	50 - 199	4
	0-5%	0	0 - 49	5

Score for worst case.

Explanation: The presence of 303(d) impaired streams for nutrients or toxins, active mines, active oil and gas wells, and percentage urban and agricultural land. Converted lands in estuary habitats are counted twice towards agricultural and urban percentages.

Rationale: Impaired water quality, including reduced dissolved oxygen, increased turbidity, and the presence of pollutants from agricultural and urban runoff, reduces habitat suitability for salmon. Agricultural and urban land can impact aquatic habitats by contributing nutrients and depleting dissolved oxygen. Mining activity can deteriorate water quality through leachates and sediments.

Scale: Watershed

Data Sources: The National Land Cover Database[47] was used to identify urban and agricultural lands; Hay/Pasture and Cultivated Crops were defined as agricultural land. Land areas with an elevation ≤ 5 meters are considered historic estuary habitats. Active mines were identified by using the Mineral Resources Data System.[48] 2006 303(d) listed streams data from USEPA.[27;28] Active oil and gas wells from USGS.[49]

Habitat Integrity Indicator 5: Flow regime.

Indicator Scoring:

Number of dams	Miles of canals	Storage (acre-ft)/stream mile	CSI Score
≥5	≥20	≥2,500	1
3 – 4	10 – 19.9	1,000 – 2,499	2
2	5 – 9.9	250 – 999	3
1	1 – 4.9	1- 249	4
0	0 – 0.9	0	5

Score for worst
Subtract 1 point if the watershed ratio of diversions to perennial/intermittent stream miles exceeds 0.4 (the watershed mean for the CA/OR analysis area)

Explanation: Number of dams, miles of canals, acre-feet of reservoir storage per perennial and intermittent stream mile, and diversion count per perennial and intermittent stream mile by watershed.

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function.[50] Dams, reservoirs, diversions, and canals alter flow regimes.[51] Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Scale: Watershed

Data Sources: The National Inventory of Dams[52] provided data on dams and storage capacity. Perennial and intermittent streams and canals data from the National Hydrography Dataset (NHD Plus).[42] California water rights data from the State Water Resources Control Board.[53] Oregon water rights data from Water Resources Department.[54]

<u>Future Security Indicator 1:</u> Land conversion.

Indicator Scoring:

Land Vulnerable to Conversion	CSI Score
81 – 100%	1
61 – 80%	2
41 - 60%	3
21 - 40%	4
0 – 20%	5

Explanation: The potential for future land conversion for urban, exurban, or agricultural (vineyard) purposes. Public land, lands currently converted, redwood or Pacific Douglas Fir forest types, or private lands encumbered by conservation easements are not available for conversion.

Rationale: Conversion of land from its natural condition will reduce aquatic habitat quality and availability.[55]

Scale: Watershed

Data Sources: Urban and exurban development in 2030 using the Spatially Explicit Regional Growth Model v3 for the US Forests on the Edge project.[56] Vineyard development is predicted as a function of topographic suitability (slope, elevation, and aspect values derived from the National Elevation Dataset[57]), soil suitability (drainage class, available water content, depth to restrictive layer, frost free days, and pH from US General Soil Map (STATSGO2)[58]), and climate suitability (growing degree days based on PRISM data provided by Oregon State University's Integrated Plant Protection Center[59]).[60;611] Land cover was determined from the National Land Cover Database[47] (all land cover classes except developed areas, open water, and cultivated crops cover types were considered for potential conversion), redwood and Pacific Douglas fir forest types from Landfire Existing Vegetation Type,[44] land

[1] Topographic suitability for vineyard production is the mean of elevation, slope and aspect suitability, where: Elevation (0 – 400 m = 10; 400 – 800 m = 6; > 800 m = 3), Slope (0 – 1% = 0; 1 – 5% = 3; 5 – 15% = 6; 15 – 20% = 3; 20 – 30% = 0; > 30% = NULL), Aspect (-1 - 90º = 0; 90 - 135º = 3; 135 - 225º = 6; 225 - 270º = 3; 270 - 360º = 0).

Climatic suitability is the mean of growing degree day (30 year normals from April 1 – October 31, base 50º F) and frost-free day suitability, where: Growing Degree Days (< 2500 = 3; 2500 – 3500 = 10; 3500 – 4400 = 3), Frost-free Days (< 140 = NULL; 140 – 160 = 0; 160 -180 = 3; 180 – 200 = 6; > 200 = 10).

Soil suitability is the mean of pH, drainage class, depth to restrictive layer (double weighted), and available water-holding capacity suitability, where: pH (< 5.5 = 3; 5.5 – 8.0 = 10; > 8.0 = 3), Depth to Restrictive Layer in cm (< 40cm = 0; 40 – 80cm = 3; 80 – 120cm = 6; > 120cm = 10), Drainage Class (very poorly drained = 0; poorly drained = 2; somewhat poorly drained & excessively drained = 5; moderately well drained & somewhat excessively drained = 8; well drained = 10), Available Water-holding Capacity (< 0.15 cm water/cm soil = 6; >= 0.15 inch water/inch soil = 10).

Final model takes the mean of topographic, climatic, and soil suitability models. Areas vulnerable to vineyard conversion have means scores >= 7.

ownership using Public, Conservation, and Trust Lands v05.2,[62] and conservation easement data from the California Protected Areas Database[63] and Oregon TNC.

<u>Future Security Indicator 2:</u> Resource extraction and development.

Indicator Scoring:

Percent subject to forest management or energy/mineral development	New Dams in subbasin	New Dams in WS	CSI Score
51 -100%	≥0	≥1	1
26-50%	> 5		2
11-25%	3 - 5		3
1 – 10%	1 - 2		4
0%	0		5

Score for worst case

Explanation: Total percentage of watershed zoned for industrial timber production on private land or possessing energy or hard metal mineral resources or the number of dam sites located for potential development outside of protected areas. Protected lands are federal or state lands with regulatory or congressionally-established protections, such as: National or State Parks and Monuments, National Wildlife Refuges, Wild and Scenic River designations, designated wilderness areas, inventoried roadless areas, Research Natural Areas, Areas of Critical Environmental Concern, others areas of special protective designations (including Late Successional Reserves), or private ownership designated for conservation purposes. Total acreage for private land is reduced by half on private lands with Habitat Conservation Plans (HCP) in place. Acreage on public lands without protection is reduced by three quarters.

Rationale: Increased resource development will increase road densities, modify natural hydrology, and increase the likelihood of pollution to aquatic systems. Protected lands will experience less anthropogenic disturbance than other lands. Timber harvest and their associated disturbance is most significant (in decreasing likelihood) on industrial timberlands, industrial timberlands with HCPs in place, and on unprotected public lands. Dam construction is likely to be associated with habitat loss, changes in natural flow regimes, reduced habitat suitability for salmon, and increased likelihood of invasion by non-native species.

Scale: Watershed

Data Sources: Timber management potential identifies private forests zoned for timber production in the North Coast County Timber Production Zones[64] dataset. For private lands elsewhere in California and in Oregon, timber management potential identifies productive forest types from the Existing Vegetation Type in Landfire[44] in contiguous patches ≥ 40 acres without formal protection as protected areas, Late Successional Reserves under the Northwest Forest Plan,[65] or enrolled under a Habitat Conservation Plan. Wind resources ("Good" and better) from Wind Powering America/National Renewable Energy Lab (NREL)[66] and limited by elevational and slope thresholds. Geothermal resource areas include nominations, authorized agreements, known leasing areas, and producing and nonproducing leases; oil and gas resource acres include oil and gas leases and agreements from BLM Geocommunicator.[*67] The number of mining claims was determined using Bureau of Land Management data,[68] and each claim was assumed to potentially impact 20 acres. Solar resource areas have annual average direct normal irradiance of 600 KwH/m²/day,[69] slopes less than 5%,[57] existing vegetation heights less than 10 meters,[44] and occur within contiguous patches of at least 160 acres. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas,[70] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[71] Potential dam sites are based on Idaho National Laboratory national hydropower potential data.[72]

Future Security Indicator 3: Habitat loss from climate change

Indicator Scoring:

TU Climate Change Analysis	
Climate Risk Factors	**CSI Score**
High, Any., Any	1
Mod., Mod., Mod.	2
Mod., Mod., Low	3
Low, Low, Mod.	4
Low, Low, Low	5

Explanation and Rationale: Vulnerability of salmon to climate change is based on a composite analysis of the following three risk factors related to climate change:

a. Increased Summer Temperature: Increasing air temperatures will increase water temperatures, displacing species from portions of their current distribution. For each watershed, we calculate the mean risk of exceeding a species-specific temperature threshold at current climate and forecast for 2050. The Coho salmon threshold for rearing juvenile fish is an August mean air temperature of 21.5ºC.[3] The steelhead and Chinook threshold for rearing juvenile fish is an August mean air temperature of 24ºC.

Warming status	Warming risk
Currently exceeding threshold	High
Exceeding in 2050	Moderate
Not exceeding in 2050	Low

* Several geospatial data types are available from Geocommunicator, and they have the following definitions:
Lease: Parcel leased for oil and gas production.
Agreement: An 'agreement' between operator and host (private or public) to evaluate geological, logistic, geophysical, etc issues involving a concession. The agreement essentially allows a technical evaluation of lease feasibility.
Unit Agreements: Multiple entities go in collectively on an agreement. Implied: there are limits to the number of agreements that one individual entity can have outstanding, and a unit agreement allows them to get around the limit.
Communitization: Combining smaller federal tracts to meet the necessary minimum acreage required by the BLM (for spacing purposes).
Authorized: Bid on and sold lease or authorization, ready for production.
Lease Sale Parcel: Parcel slated for auction but not yet sold.
Closed: Not retired, just expired and may become available and open to resubmittal.
Other Agreements: Catch-all for other agreement types.

b. Changes in flow volume: Changes in precipitation will be most pronounced in systems with surface runoff flow regimes. For each watershed, base flow index (BFI) is summarized (where surface flows have a BFI < 50 and groundwater/snow systems have a BFI >= 50) and adjusted by predicted annual precipitation change in 2050 to predict flow risk.

Current base flow regime type	Predicted annual precipitation change	Flow Risk
Surface	Decrease > 10%	High
Groundwater/snow	Decrease >10%	Moderate
Surface	Increase or decrease < 10%	Moderate
Groundwater/snow	Increase or decrease < 10%	Low
Surface	Increase > 10%	Low

c. Changes in precipitation and flow regime: Transitions in California and Oregon's winter precipitation regimes may be associated with changes in spring peak flow timing and magnitude, summer low flow magnitude, and increased likelihood of rain-on-snow events. For each watershed, we predict the transition in precipitation regime, where regimes include snow-dominated (Dec – Feb mean temp < - 1ºC), mixed (Dec – Feb mean temp between – 1ºC and 1ºC), and rain-dominated (Dec – Feb mean temp > 1ºC), based on current climate and 2050 forecasts.

Precipitation regime transition type	Precipitation regime risk
Snow to rain	High
Snow to mixed	High
Mixed to rain	Moderate
Mixed to mixed	Moderate
Rain to rain	Low
Snow to snow	Low

Scale: Watershed

Data Sources: Mean August temperature data for the period between 1960 and 1990 from PRISM dataset.[43] Temperature and precipitation predictions provided by The Nature Conservancy's climatewizard.org.[73;74] Base flow index grid from USGS.[75]

Future Security Indicator 4: Sedimentation and scour risk

Indicator Scoring:

TU Geomorphic Risk Analysis	
Landslide Risk Factors	**CSI Score**
High, Any., Any	1
Mod., Mod., Mod.	2
Mod., Mod., Low	3
Low, Low, Mod.	4
Low, Low, Low	5

Inherent geomorphic risk	Risk
> 30%	High
15 – 30%	Moderate
0 – 15%	Low

Mean Fire Regime Condition Class within unstable patches	Risk
> 70	High
31 – 70	Moderate
< 30 or inherent risk “Low”	Low

Percent of unstable slope patches traversed by roads	Risk
>70%	High
30 – 70%	Moderate
< 30% or inherent risk “Low”	Low

Explanation: Percent of each watershed identified as having a inherent high geomorphic risk (shallow slope landslides only), the mean Fire Regime Condition Class (FRCC) within those unstable patches (where high FRCC scores reflect high departure from expected fire regime), and the percent of high geomorphic risk patches traversed by roads.

Rationale: Landslides contribute debris and sediment detrimental to salmon. Landslide frequency may increase with road construction on landslide-prone slopes, changes in precipitation intensity and seasonality associated with climate change, and changes in typical fire intensity due to fuel build up.

Scale: Watershed

Data Sources: Elevation data were obtained from the National Elevation Dataset.[57] Relative potential for shallow landslides predicted using the SMORPH model, where high risk areas have value = 3.[76] FRCC data from LANDFIRE.[44] Road data is a composite of USFS Northwest Forest plan,[29] Oregon BLM,[30] US Census Bureau TIGER data,[31] and USFS CA National Forest data.[32-41]

<u>Future Security Indicator 5:</u> Land stewardship.

Indicator Scoring:

Stream habitat protection	Watershed protection	CSI Score
none	any	1
1 – 9%	<25%	1
1 – 9%	≥25%	2
10 – 19%	<25%	2
10 – 19%	≥25%	3
20 – 29%	<50%	4

20 – 29%	≥50%	5
≥30%	any	5

Explanation: The percent of stream habitat and percent watershed with a formal protected status. Protected lands are federal or state lands with regulatory or congressionally-established protections, such as: National or State Parks and Monuments, National Wildlife Refuges, Wild and Scenic River designations, designated wilderness areas, inventoried roadless areas on federal lands, Research Natural Areas, Areas of Critical Environmental Concern, others areas of special protective designations, or private ownership designated for conservation purposes.

Rationale: Stream habitat and watersheds with higher proportions of protected lands will experience less anthropogenic disturbance than other lands.

Scale: Watershed

Data Sources: Perennial and intermittent streams from National Hydrography Dataset (NHD Plus);[42] protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[70] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[71] Late Successional Reserves from the Northwest Forest Plan.[77]

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