California Freshwater Conservation Success Index:

An Assessment of Freshwater Resources in California, with focus on lands managed by the US Bureau of Land Management

Version 1.0, December 2013

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Cover photograph: Chinook salmon spawning habitat, Clear Creek, Redding Field Office

ABSTRACT

We describe the methods, structure, and results of the California Freshwater Conservation Success Index (CSI), an assessment tool focused on aquatic species and habitats, the condition of those habitats, and threats those resources will likely face in the future. The CSI uses a common conservation planning approach of subwatershed-scale data summary and scoring, synthesizing and interpreting spatial data for 43 metrics consolidated into 22 indicators. The Aquatic Species Status group of indicators summarizes the findings of a new database of over 400,000 records for 1550 aquatic-dependent species, including all 48 BLM Special Status Species that use freshwater habitats. The Aquatic Habitats Status indicators provide multiple summaries of a multi-source aquatic feature and land cover dataset. A group of Habitat Integrity indicators includes assessment of watershed condition, temperature conditions, habitat connectivity, water quality, water quantity, and land stewardship factors. Future threats are anticipated within indicators related to land conversion, resource extraction, climate change, water quality risk, and introduced species. The combined results map the pattern of relative condition of aquatic species, habitats, condition, and threats across a broad landscape. We provide an example interpretation of how the results of the California Freshwater CSI can be used to identify conservation strategies and discuss important considerations for using the assessment. The results are available as a web map and as a GIS database, allowing users to develop custom queries and configurations of the results for identifying specific opportunities or for evaluating projects.

INTRODUCTION

Trout Unlimited (TU) received funding through a BLM cooperative agreement to create a landscape-scale planning tool to meet two BLM-identified needs:

1) Identification of key areas for meeting population objectives for aquatic species/communities and habitat objectives, including the conservation of high aquatic biodiversity areas that are relatively intact and restoration opportunities within important biodiversity/species areas that are degraded
2) Provide consistent guidance and data for addressing aquatic dependent resources within Resource Management Plan processes and for evaluating action or project proposals.

To meet these needs, TU modified its watershed-scale assessment tool, the Conservation Success Index (CSI), to specifically accommodate factors of interest to the BLM such as climate change and BLM special status species. The CSI is a series of watershed-scale summaries of GIS datasets which are assigned scores that reflect the best understanding of how those data likely affect the viability of aquatic species and the condition of habitats. Additionally, we worked with The Nature Conservancy of California to develop a comprehensive database of aquatic species and aquatic habitat occurrence information. Data summaries of these two products are available as web-based maps and provide a means to describe the pattern of aquatic species and habitat occurrence and condition across California and access detailed information for every subwatershed in the state.

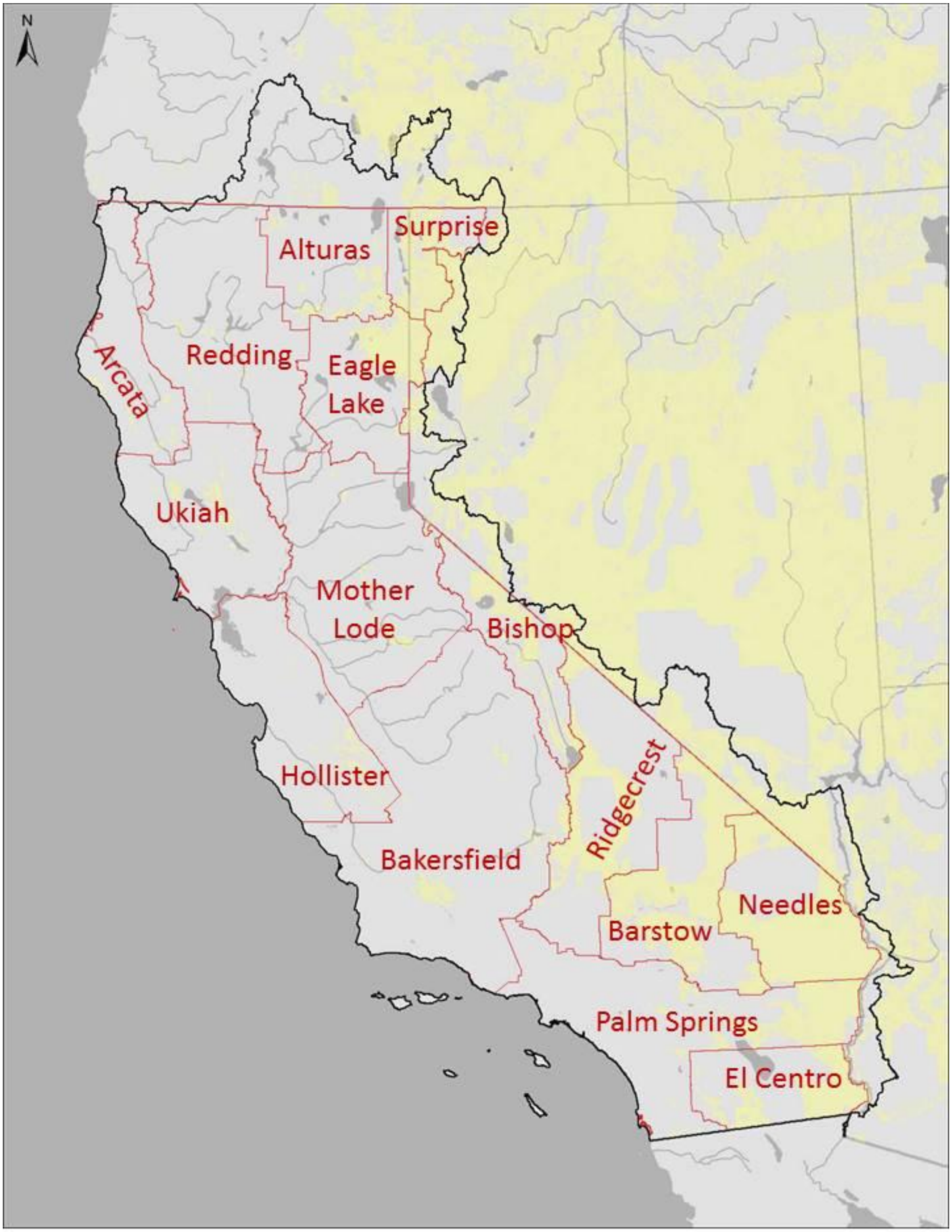
The area of analysis for the California Freshwater CSI includes all subwatersheds (12-digit hydrological unit code watersheds) hydrologically connected to the state of California or lands managed by California BLM (Figure 1). This area spans the administrative boundaries of California and includes watershed areas in Oregon, Nevada, and Arizona that drain into lands managed by California BLM.

METHODS

2.1 Conservation Success Index Background

Trout Unlimited developed the Conservation Success Index (CSI) to provide a strategic, landscape-scale planning tool for cold-water conservation that is focused on watersheds (see Williams et al. 2007). The CSI summarizes spatial (GIS) data at the subwatershed scale (12-digit hydrologic unit (NRCS, USGS, and EPA 2008), equivalent to approximately 10,000 acres) related to a broad suite of population metrics, anthropogenic stressors, and environmental conditions and assigns the summaries a categorical score (5 through 1, reflecting exceptional through poor condition) based on the best scientific understanding of the significance of the particular data

Figure 1: Freshwater assessment boundaries (in black) with California BLM field offices (in red) and BLM ownership



on aquatic species persistence and effects on habitat quality. The data considered are not intended to comprise a comprehensive list of factors affecting instream habitat or aquatic species, rather they include factors that exist as broadly available, mapped data. This watershed data "summary and scoring" approach is a standard conservation planning tool and is similar to products developed by other land management agencies and conservation partners, including the Watershed Condition Framework developed by the US Forest Service, the Northwest Forest Plan's Watershed Condition Status and Trend analyses, and the NFHAP Data System created by the National Fish Habitat Partnership.

As originally developed, the CSI is a species-specific assessment comprised of four groups of "indicators." Each indicator is a summary of several factors or metrics grouped thematically. For example, the Watershed Condition indicator includes summaries of data related to factors which affect instream habitat condition, especially through sedimentation: the footprint of road networks in watersheds, status of streams on EPA's 303d list for sediment impairment, and the presence of active sand and gravel mining operations in the riparian zone. Data summaries in some cases are normalized by watershed area or stream mileage within watersheds (e.g. percent agricultural land or diversions per stream mile) and in other cases summarized just for the riparian zone. Where data summaries are normalized by stream miles and for delineating a riparian zone, we used the NHD Plus dataset because its scale (1:100,000) is consistent with the quality of other data inputs and because of inconsistencies in the finer scale NHD High Resolution dataset (1:24,000; stream network densities often vary visibly within USGS quarter-quadrangle boundaries).

Each indicator receives a score and indicators are organized into groups that can be summed for overall scores related to Range-wide Conditions, Population Integrity, Habitat Integrity, and Future Security. Scores can be further organized to identify conservation strategies that may be appropriate in watersheds given the pattern of species occurrence, habitat condition, and likely future threats, providing a landscape-scale blueprint for management efforts on public and private lands.

2.2 Conservation Success Index Modifications

We modified the typical CSI approach for California BLM to encompass a multi-species perspective, with special emphasis on rare, Endangered Species Act-listed, and BLM Special Status Species, rather than a single species approach.[1] Groups for the California Freshwater CSI

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[1] Single-species CSI analyses are available at www.tu.org/csi for the following California native salmonids: Lahontan cutthroat trout; Paiute cutthroat trout; Eagle Lake rainbow trout; McCloud redband trout; Goose Lake redband trout; California golden trout; Little Kern golden trout; coho salmon; winter-run steelhead; summer-run steelhead; fall-run Chinook salmon; spring/summer-run Chinook salmon; and winter-run Chinook salmon

include Aquatic Species Status, Aquatic Systems Status, Habitat Integrity, and Future Security. As an additional modification for facilitating interpretation, we provide data summaries and interpreted scores of both individual factors and the grouped indicators at two scales – 1) the entire subwatershed scale for all factors and indicators and 2) for the footprint of BLM lands within subwatersheds when BLM lands comprise at least 10% of the subwatershed area for the majority of species, systems, and habitat integrity factors and indicators.

2.3 Aquatic Species Status

Rather than take the single species focus of the typical CSI, we used a multi-species approach that includes a consideration of any animal or plant species present within the study boundaries that relies on freshwater for at least one stage of their life history. We worked with The Nature Conservancy of California to create a list of 1,550 freshwater-dependent species and develop a database of spatial occurrence information for these species, including 48 BLM Special Status Species (Table 1) and 74 species formally listed on federal or state endangered species lists. The database includes current and historical observations, modeled distributions, management area designations such as USFWS Critical Habitat designations, and approximated range information from 140 data providers. Appendix A provides a detailed description of the methods and sources used to create the freshwater-dependent species list and database.

Table 1: California BLM Special Status Species within the freshwater-dependent species database and included in the California Freshwater CSI Aquatic Species Condition indicator. Status abbreviations: FE – Federally Endangered; FT – Federally Threatened; FC – Federal Candidate Species; ST – State Threatened; BLMS – BLM Sensitive Species

Taxonomic Group	Common Name	Scientific Name	Status
Reptiles	Two-striped Gartersnake	*Thamnophis hammondii*	BLMS
	Western Pond Turtle	*Actinemys marmorata*	BLMS
Amphibians	Black Toad	*Anaxyrus exsul*	ST
	California Tiger Salamander	*Ambystoma californiense*	FT
	Couch's Spadefoot	*Scaphiopus couchii*	BLMS
	Foothill Yellow-legged Frog	*Rana boylii*	BLMS
	Oregon Spotted Frog	*Rana pretiosa*	FC
	Western Spadefoot	*Spea hammondii*	BLMS
	Yavapai Leopard Frog	*Lithobates yavapaiensis*	BLMS
Fishes	Amargosa Canyon Speckled Dace	*Rhinichthys osculus ssp. 1*	BLMS
	Amargosa Pupfish	*Cyprinodon nevadensis amargosae*	BLMS
	Chinook Salmon - Sacramento Winter Run	*Oncorhynchus tshawytscha pop. 7*	FE
	Chinook Salmon - Sacramento-San Joaquin Spring Run	*Oncorhynchus tshawytscha pop. 6*	FT

Taxonomic Group	Common Name	Scientific Name	Status
Fishes, cont.	Coho Salmon - Central California Coast	*Oncorhynchus kisutch pop. 4*	FE
	Colorado Pikeminnow	*Ptychocheilus lucius*	FE
	Desert Pupfish	*Cyprinodon macularius*	FE
	Lost River Sucker	*Deltistes luxatus*	FE
	Modoc Sucker	*Catostomus microps*	FE
	Mohave Tui Chub	*Gila bicolor mohavensis*	FE
	Owens Pupfish	*Cyprinodon radiosus*	FE
	Owens Speckled Dace	*Rhinichthys osculus ssp. 2*	BLMS
	Owens Tui Chub	*Gila bicolor snyderi*	FE
	Pacific Lamprey	*Lampetra tridentata*	BLMS
	Razorback Sucker	*Xyrauchen texanus*	FE
	Red Hills Roach	*Lavinia symmetricus ssp. 3*	BLMS
	Rough Sculpin	*Cottus asperrimus*	ST
	Shortnose Sucker	*Chasmistes brevirostris*	FE
	Unarmored Threespine Stickleback	*Gasterosteus aculeatus williamsoni*	FE
	Wall Canyon Sucker	*Catostomus sp. 1*	BLMS
Invertebrates	Shasta Crayfish	*Pacifastacus fortis*	FE
Plants	Baker's Meadowfoam	*Limnanthes bakeri*	BLMS
	Baker's Navarretia	*Navarretia leucocephala ssp. bakeri*	BLMS
	Boggs Lake Hedge-hyssop	*Gratiola heterosepala*	BLMS
	California Orcutt Grass	*Orcuttia californica*	FE
	Contra Costa Goldfields	*Lasthenia conjugens*	FE
	Coulter's Goldfields	*Lasthenia glabrata ssp. coulteri*	BLMS
	False Venus'-looking-glass	*Legenere limosa*	BLMS
	Fleshy Owl's-clover	*Castilleja campestris ssp. succulenta*	FT
	Hairy Orcutt Grass	*Orcuttia pilosa*	FE
	Hoover's Broomspurge	*Chamaesyce hooveri*	FT
	La Graciosa Thistle	*Cirsium loncholepis*	FE
	Otay Mesamint	*Pogogyne nudiuscula*	FE
	Red Bluff Rush	*Juncus leiospermus*	BLMS
	San Joaquin Valley Orcutt Grass	*Orcuttia inaequalis*	FT
	Sanford's Arrowhead	*Sagittaria sanfordii*	BLMS
	Shippee Meadowfoam	*Limnanthes floccosa ssp. californica*	FE
	Slender Orcutt Grass	*Orcuttia tenuis*	FT
	Slough Thistle	*Cirsium crassicaule*	BLMS

For each subwatershed in the study area and for the portions of subwatersheds with BLM ownership when BLM ownership exceeds 10% of subwatershed area, we summarized the aquatic species richness, the count of BLM special status species present, and the count of federal or state listed species present for current observations in the database (i.e. we excluded historical and extirpated observations and historical range data). Each indicator provides a distinct means for evaluating aquatic biodiversity and is available for referencing against aquatic habitats available, habitat integrity, and future threats.

Table 2: Indicators and factors within the CSI Aquatic Species Status group and their scoring rules and datasources. All factors receive summaries for both the subwatershed and for the portions of subwatersheds with BLM ownership when BLM ownership exceeds 10% of watershed area.

Indicator	Factor	Data Source
Aquatic Species Richness	Count of aquatic species present	Species database
BLM Special Status Species Richness	Count of BLM Special Status Species present	Species database
Listed Species Richness	Count of federal or state listed species present	Species database
Introduced Species Richness	Count of introduced or exotic species present	Species database

2.4 Aquatic Systems Status

The California Freshwater CSI considers the presence of aquatic habitats in watersheds in addition to aquatic species information. To develop a comprehensive map of aquatic habitats in the study area, we worked with The Nature Conservancy of California to develop a database of freshwater-dependent habitats based on a combination of multiple, existing land cover maps. The resulting spatial database characterizes aquatic habitats through a reduced, common naming convention that results in complete coverage of the study area, regardless of the coverage of the existing land cover maps. Appendix B describes the methods and data sources used to generate the database in detail.

The spatial database contains line features representing streams and waterways, point features representing local habitats such as springs, seeps, and vernal pools, and polygon features representing waterbodies and habitat types influenced by the seasonal or year-round presence of freshwater, such as woody riparian vegetation, emergent wetland vegetation, and playas. Each stream or waterway feature is characterized by four factors – seasonality of flows (perennial, intermittent, or artificial), slope (pool/riffle, step pool, or cascade/colluvial form), flow volume (headwaters, creek/small river, or large river), and temperature (coolwater or warmwater). Each waterbody is characterized based on seasonality of water (perennial, intermittent, or artificial), size (small, medium, or large), shoreline complexity (simple, intermediate, or complex), and temperature (coolwater or warmwater).

Table 3: Indicators and factors within the CSI Aquatic Systems Status group and their scoring rules and datasources. All factors receive summaries for both the subwatershed and for the portions of subwatersheds with BLM ownership when BLM ownership exceeds 10% of watershed area.

Indicator	Factor	Data Source
Stream network	Miles of all streams from NHD Plus (1:100K)	NHD Plus
	Miles of all streams from NHD (1:24K)	NHD
Perennial stream network	Miles of perennial streams from NHD Plus (1:100K)	NHD Plus
	Miles of perennial streams from NHD (1:24K)	NHD
Intermittent stream network	Miles of intermittent streams from NHD Plus (1:100K)	NHD Plus
	Miles of intermittent and ephemeral streams from NHD (1:24K)	NHD
Waterbodies	Acres with perennial open water habitats	Habitats database
Presence of aquatic habitats	Acres with freshwater dependent habitats (excluding all open water habitats)	Habitats database
Presence of springs/seeps	Count of springs or seeps	Habitats database
Presence of vernal pools	Count of vernal pools	Habitats database

Aquatic system factors do not receive scoring, rather they are provided as summaries for referencing by subwatershed and by portions of subwatersheds with BLM ownership when BLM ownership exceeds 10% of watershed area. Table 3 provides a list of factors we report. In response to BLM interest in quantifying stream mileage under BLM management, we provide summaries of stream mileage characterized by seasonality of flow from two sources – the 1:100,000 scale National Hydrography Dataset Plus, a consistently mapped and thoroughly attributed dataset that we used in the aquatic habitats database, and the 1:24,000 scale National Hydrography Dataset, which has a finer spatial resolution, but inconsistent mapping quality. The aquatic habitats spatial database summaries are available upon request as in geodatabase format for reference within the web-mapped California Freshwater CSI results.

2.5 Habitat Integrity

The current condition of aquatic habitats is analyzed in the CSI through six Habitat Integrity indicators: Watershed Condition, Temperature, Watershed Connectivity, Water Quality, Water Quantity and Flow Regime. We summarized and scored individual metrics within each of these indicators, calculated the average and minimum score by indicator, and summed indicator scores for an overall Habitat Integrity score. Nearly all factors with these indicators are summarized and scored at two scales – the entire subwatershed and for just BLM lands within subwatersheds when BLM ownership exceeds 10% of the subwatershed area. We exclude factors from the BLM lands summary when the stressor falls outside of the footprint or purview of BLM management (e.g. agricultural or urban land use factors). Table 4 outlines the scoring rules and data sources used for each indicator and metric in the CSI Habitat Integrity component.

2.5.1 Watershed Conditions

Sedimentation is addressed through the Watershed Conditions indicator, which summarizes the miles of 303(d)-listed streams for sediment, the overall road density, the ratio of road miles within the riparian zone to stream miles in each subwatershed, and the count of active sand or gravel mines in the riparian zone. These factors reflect the presence of sediment in streams or the footprint of roads in watersheds, a source of fine sediments (Lee et al. 1997), which smother benthic invertebrates, embed spawning substrates, and increase turbidity (Lloyd 1987; Davies-Colley and Smith 2001). Sand and gravel mines within or near streams can disrupt downstream gravel recruitment required for spawning and eliminate instream habitats.

2.5.2 Temperature

The Temperature indicator assesses instream water temperatures by looking at the miles of stream 303(d)-listed for temperature, the average height of riparian vegetation, and the average August air temperature in subwatersheds. 303(d) impairment for temperature reflects a departure from anticipated natural water temperatures required to sustain aquatic biota. In California, August air temperatures of 21.5°C and 24°C have been described as important natural thresholds for temperature-sensitive salmonids (Agrawal et al 2005; NMFS 2004; NMFS 2005). Riparian vegetation provides stream shading and contributes structure to streams through large wood contributions.

2.5.3 Watershed Connectivity

The Watershed Connectivity factors compare the amount of currently connected habitat to the amount of historically connected habitat within the entire connected stream network within the range of anadromous species and within subwatersheds outside the range of anadromous species. Increased hydrologic connectivity provides more habitat area and better supports multiple life stages of aquatic species, an important viability criterion which increases their likelihood of persistence (McElhany et al. 2000).

2.5.4 Water Quality

The Water Quality indicator incorporates information on 303(d)-listed streams for toxicity and nutrients, the amount of agricultural land, number of active mines, number of oil and gas wells, and the intensity of grazing relative to perennial streams on BLM lands. Grazing intensity is assessed in two factors for BLM lands only: first, as animal unit months (AUMs) per perennial stream mileage from the high resolution NHD within active allotments (not including exclosures), with sheep AUMs are downweighted (x 0.75) relative to cattle, while horse and burro AUMs are weighted more heavily (x 1.5); second, as percent of perennial stream miles on BLM lands in an active allotment. For reference purposes, we also report acid deposition (kg H^+/ha). These values should be interpreted relative to location, snowpack/rainfall proportions and event size, elevation, geology, and vegetation (Takemoto et al. 2000). Impaired water quality, including reduced dissolved oxygen, increased turbidity, toxins, and nutrients associated with land uses and other sources reduces aquatic habitat suitability.

2.5.5 Water Quantity

The Water Quantity indicator represents the count of dams and their storage capacity in each subwatershed, the miles of canals that divert water from streams, the count of diversions per stream mile, the amount of dense, early successional forest habitat, and the amount of private land in rural residential land use. Natural flow regimes are critical to proper aquatic ecosystem function (Poff et al. 1997) and dams, reservoirs, diversions, and canals alter flow regimes (Benke 1990). Overstocked forest stands have high water use that may affect base flows and water yields (Bales et al. 2011). In California, private, rural, residential land ownership is often associated with marijuana cultivation and unregulated water use (O’Hare et al. 2013).

2.5.6 Land Stewardship

The Land Stewardship indictor represents the fraction of each subwatershed with lands in a protected status. Protected lands have a mandate for conservation via federal, state, or other conservation ownership with additional regulatory or congressionally-established protections (e.g., Wilderness Areas, ACEC, etc.). Stream habitats and watersheds with higher portions of protected lands are likely to experience less anthropogenic disturbance than other lands.

Table 4: Indicators and factors within the CSI Habitat Integrity Group and their scoring rules and datasources. All subwatersheds receive summaries and scores; factors in blue italics receive summaries and scores for both the subwatershed and for the portions of subwatersheds with BLM ownership when BLM ownership exceeds 10% of watershed area; factors in black italics are only scored for the portions of subwatersheds with BLM ownership when BLM ownership exceeds 10% of watershed area.

Indicator	Factor	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5	Data Source
Instream habitat	*Miles 303d listed for sediment*			> 0.1% of streams		0%	CA Water Resources Control Board, 2010; OR Dept. of Env. Quality, 2004/06; NV Dept. of Env. Protection 2006
	Road density (miles/miles²)	>= 4.7	4.7 - 3	3 - 2.5	2.5 - 1.6	< 1.6	US Census Bureau TIGER 2000; USFS CA Northwest Forest Plan Transportation; BLM OR Ground Transportation 2009
	Roads in riparian zone (miles road within 200m of streams/miles stream)	1 - 0.5	0.5 - 0.25	0.25 - 0.1	0.1 - 0.05	0.05 - 0	EPA NHD Plus (1:100K); US Census Bureau TIGER 2000; USFS CA NWFP Transp.; BLM OR Ground Transp. 2009
	Sand/gravel mine in riparian zone	> 3		1 - 3		0	EPA NHD Plus (1:100K) 200m buffer; CA Dept. of Cons. Aggregate Mines 2006; USGS Minerals Resources Data System (Active) 2005
Temperature	*Miles 303d listed for temperature*			> 0.1% of streams		0%	CA Water Resources Control Board, 2010; OR Dept. of Env. Quality, 2004/06; NV Dept. of Env. Protection 2006
	Mean riparian vegetation height (m)	0 - 1	1 - 5	5 -10	10 -20	>20	EPA NHD Plus (1:100K) 200m buffer; USFS/USGS LANDFIRE Existing Vegetation Height (Rapid Refresh) 2008
	Mean August air temperature	> 24°C	21.5 - 24°C	20 - 21.5°C	18 - 20°C	< 18°C	PRISM Group, Oregon State (1971 - 2000)
Connectivity	% stream miles accessible (anadromous)	0%	0 - 30%	30 - 50%	50 - 90%	> 90%	CDFW CA Passage Assessment Database 2011; ODFW OR Fish Passage Barriers 2011

Indicator	Factor	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5	Data Source
Connectivity, continuted	Barrier count downstream (anadromous)		>= 4	3 -2	1	0	CDFW CA Passage Assessment Database 2011; ODFW OR Fish Passage Barriers 2011
	Ratio of current maximum stream network connectivity (mi) to historical (inland)	< 50%	50 - 75%	75 - 90%	90 - 95%	> 95%	CDFW CA Passage Assessment Database 2011; ODFW OR Fish Passage Barriers 2011; USFWS NV Passage Assessment Database 2013
	Barrier count (inland)	>= 12	8 - 11	5 - 7	1 - 4	0	CDFW CA Passage Assessment Database 2011; ODFW OR Fish Passage Barriers 2011; USFWS NV Passage Assessment Database 2013
Water quality	*Miles 303d listed for toxins or nutrients*			> 0.1% of streams		0%	CA Water Resources Control Board, 2010; OR Dept. of Env. Quality, 2004/06; NV Dept. of Env. Protection 2006
	% urban or agricultural land use	58 - 100%	28 - 58%	15 - 28%	5 - 15%	0 - 5%	USGS National Landcover Dataset 2006
	Active mine count	>= 10	7 - 9	4 - 6	1 - 3	0	USGS Minerals Resources Data System (Active) 2005
	Active oil/gas well count	>= 400	300 - 400	200 - 300	50 - 200	0 - 50	USGS Western Oil and Natural Gas Wells 2004
	Grazing intensity – AUM per perennial stream mile (BLM only)	> 240	80 – 150	20 – 80	0 – 20	0	CA BLM allotments and pastures GIS v10; BLM Rangeland Administration System data Nov. 2013; NHD (1:24k) perennial streams
	Grazing distribution - % of perennial stream miles in active allotment	> 50%	25 – 50%	10 – 25%	1 – 10%	0%	CA BLM allotments and pastures GIS v10; BLM Rangeland Administration System data Nov 2013; NHD (1:24k) perennial streams
	Acid deposition in H^+ kg/ha	-	-	Not scored	-	-	National Atmospheric Deposition Program Annual H^+ Deposition 2011
Water quantity	*Dam count*	>= 5	3 - 4	2	1	0	USACE National Inventory of Dams 2008

Indicator	Factor	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5	Data Source
Water quantity, continued	*Ratio of dam storage (ac-ft) to stream miles*	>= 2500	1000 - 2499	250 -999	1 - 249	0	EPA NHD Plus (1:100K); USACE National Inventory of Dams 2008
	Miles canal	>= 20	10 - 20	5 - 10	1 - 5	0 - 1	EPA Nat'l Hydrography Dataset Plus (1:100K)
	Diversions per stream mile	> 1	0.6 - 1	0.4 - 0.6	0.2 - 0.4	0 - 0.2	EPANat'l Hydrography Dataset Plus (1:100K); CA Water Resources Control Board eWRIMS 2009
	% in pole or small tree size class with 60-100% canopy closure	80 - 100%	60 - 80%	40 - 60%	20 - 40%	0 - 20%	CA Dept. of Forestry FRAP 2006
	% in rural residential (non-urban private land)	80 - 100%	60 - 80%	40 - 60%	20 - 40%	0 - 20%	CA Dept. of Forestry FRAP 2006
Land status	% public ownership	0%	0 - 30%	30 - 50%	50 - 90%	> 90%	USGS Protected Areas Database 1.3 2012
	% BLM ownership	0%	0 - 30%	30 - 50%	50 - 90%	> 90%	BLM Surface Estate v10
	% public ownership with protected status	0%	0 - 30%	30 - 50%	50 - 90%	> 90%	USGS Protected Areas Database 1.3 2012
	% BLM ownership with protected status	0%	0 - 30%	30 - 50%	50 - 90%	> 90%	USGS Protected Areas Database 1.3 2012
	% conservation easement or other private conservation status	0%	0 - 30%	30 - 50%	50 - 90%	> 90%	USGS Protected Areas Database 1.3 2012

2.6 Future Security

Threats to aquatic habitats are addressed in the CSI through five Future Security indicators - Land Conversion, Resource Extraction and Development, Climate Change, Water Quality, and Introduced Species – which are evaluated at the subwatershed scale only (Table 5). We summarized and scored individual metrics within each of these indicators, calculated the average and minimum score by indicator, and summed indicator scores for an overall Future Security score at the subwatershed scale. Table 5 outlines the scoring rules and data sources used for each indicator and metric.

2.6.1 Land Conversion

The Land Conversion indicator evaluates the risk of unconverted private land being developed for residential purposes and vineyards. Such changes will likely reduce aquatic habitat quality and availability through land disturbances and changes in water use (Grantham et al. 2010; Stephens et al. 2008).

2.6.2 Resource Extraction

The Resource Extraction indicator includes information on the amount of oil and gas leases, hard rock mineral claims, renewable energy development resources, and potential dam sites. Increased resource development will increase road densities, modify natural hydrology, increase water uses associated with development, and increase the likelihood of pollution to aquatic systems. Dam construction is likely to be associated with habitat loss, changes in flow regimes and habitat suitability, and increased likelihood of invasion by non-native species.

2.6.3 Climate Change

The Climate Change indicator includes several factors assessing the vulnerability of aquatic habitats to climate change based on a composite analysis of six risk factors: changes in precipitation and flow regime based on winter precipitation type (snow vs. rain); increasing summer air temperatures based on temperature models for 2050; changes in flow volume based on precipitation models for 2050; ability of watersheds to buffer changes in flow through base flow condition (groundwater vs. surface flows); heat-related moisture loss measured through the Palmer Drought Severity Index; and changes in fire regime associated with earlier spring warming.

2.6.3.1 Winter Precipitation Regime Change

The California Freshwater CSI identifies areas vulnerable to changes in flow timing and magnitude related to climate change. Transitions in winter precipitation regimes throughout the western United States – especially from snow to rain - may be associated with changes in spring peak flow timing and magnitude, summer low flow magnitude, and increased likelihood of rain-on-snow events (Williams et al. 2009; Mantua et al. 2010). For each watershed, we predict the transition in precipitation regime, where regimes include snow-dominated (December through February mean temperature < - 1°C), mixed (December through February mean temperature between – 1°C and 1°C), and rain-dominated (December through February mean temperature > 1°C), based on current climate and forecasts for 2050.

2.6.3.2 Increasing Summer Temperatures

Increasing air temperatures will increase water temperatures, displacing species from portions of their current distribution (Williams et al. 2009; Mantua et al. 2010). The CSI calculates the average risk of exceeding two important salmonid temperature thresholds (21.5°C and 24°C; Agrawal et al 2005; NMFS 2004; NMFS 2005) using forecasts for 2050 (Maurer et al. 2007).

2.6.3.3 Precipitation Volume Change

The California Freshwater CSI summarizes total annual precipitation forecasts for 2050 (Maurer et al. 2007) and characterizes watersheds with a 10% or greater forecast increase in precipitation volumes as low risk, stable precipitation volumes as moderate risk, and any forecast decrease in precipitation greater than 10% as high risk.

2.6.3.4 Base Flow Condition

Base Flow Index measures the ratio of base flows to total stream flows expressed as a percentage (Wolock 2003). High base flow watersheds have groundwater or snow melt dominated flows, while low base flow watersheds have surface run-off dominated flows. Watersheds with large components of their annual flow provided by stable sources such as groundwater or snow are likely to have lower fluctuations in flow in response to climate variability.

2.6.3.5 Drought

Heat-related moisture loss is forecast to overwhelm any increase in precipitation in much of the interior western United States anticipated with changing climate causing a perpetual state of drought (Hoerling and Eischeid 2007). Areas with low total annual precipitation volumes and high temperatures will be especially at risk and likely to have less water available for instream flows (Haak et al. 2010).

2.6.3.6 Fire Regime Change

Earlier spring snowmelt coupled with warmer spring temperatures are forecast to increase the duration, extent, and severity of wildfire seasons as climates change, affecting instream habitats directly through burning and indirectly through post-fire flooding and debris flow

(Williams et al. 2009). Fire regime changes in the western United States are likely to be particularly amplified in mid-elevation watersheds currently dominated by fine fuels (Westerling et al. 2006).

2.6.4 Water Quality

The potential for new sedimentation through shallow landslides on unstable slopes (Shaw and Johnson 1995), particularly in vulnerable habitats that contain highly erosive soils in the riparian zone or fuels conducive to severe, stand replacing wildfire, is addressed through the Water Quality indicator. Riparian zone erodibility is measured using the average k-value for soils, while wildfire risk is measured using. The Water Quality indicator also looks at the size of standing trees in the riparian zone within the range of anadromous fishes, anticipating that those trees will provide future recruitment of large woody material to streams. Large wood serves to provide shelter and create important instream habitats for aquatic species (Abbe 1996; Roni 2001).

2.6.5 Invasive/Exotic Species

As a final potential future threat, the California Freshwater CSI summarizes the presence of introduced and exotic aquatic species in watersheds. Introduced Species are likely to reduce native aquatic species abundance and diversity through predation, competition, hybridization, and the introduction of non-native parasites and pathogens (Fausch et al. 2006).

Table 5: Indicators and factors within the CSI Future Security Group and their scoring rules and datasources. All subwatersheds receive summaries and scores.

Indicator	Factor	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5	Data Source
Conversion	% vulnerable to urban/ex-urban conversion	80 - 100%	60 - 80%	40 - 60%	20 -40%	0 - 20%	D. Theobald - US Forests on the Edge Spatially Explicit Growth Model v3
	% vulnerable to new vineyard development	80 - 100%	60 - 80%	40 - 60%	20 -40%	0 - 20%	Topographic suitability from USGS National Elevation Dataset 30m; soil suitability from NRCS STATSGO; climate suitability from PRISM Group, Oregon State (1971 - 2000)
Resource extraction	% suitable for solar development	50 - 100%	25 - 50%	10 - 25%	1 - 10%	0 - 1%	BLM Solar Energy Development PEIS; BLM Renewable Energy Project Applications 2013
	% suitable for geothermal development	50 - 100%	25 - 50%	10 - 25%	1 - 10%	0 - 1%	BLM Geothermal potential areas
	% suitable for wind development	50 - 100%	25 - 50%	10 - 25%	1 - 10%	0 - 1%	Wind Powering America and NREL, Wind Resource Potential 2003; excludes USGS Protected Areas Database 1.3 2012
	Count hydro development sites	>= 1 in local sub-watershed	>5 in subbasin	3- 5 in subbasin	1 - 2 in subbasin	0 in subbasin	Idaho National Laboratory, Hydropower Resource Assessment 2004
	% acreage of mining claims	50 - 100%	25 - 50%	10 - 25%	1 - 10%	0 - 1%	BLM LR2000 2003
	% in oil and gas lease areas	50 - 100%	25 - 50%	10 - 25%	1 - 10%	0 - 1%	BLM Geocommunicator 2008; excludes USGS Protected Areas Database 1.3 2012

Indicator	Factor	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5	Data Source
Climate	Winter precipitation regime change risk (2050 current and forecast average winter temp °C)	Current snow (< -1°C) and future rain (>1°C) or mixed (-1 to 1°C)		Current mixed (-1 to 1°C) and future rain (>1°C) or mixed (-1 to 1°C)		Current and future snow (<-1°C) or rain (> 1°C)	E. Maurer et al. "Fine-resolution climate projections enhance regional climate change impact studies", Eos Trans.AGU 88, (2007).
	Summer temperature increase risk, 2050 forecast °C (Salmonids present)	> 24°C	21.5 - 24°C	20 - 21.5°C	18 - 20°C	< 18°C	E. Maurer et al. "Fine-resolution climate projections enhance regional climate change impact studies", Eos Trans.AGU 88, (2007).
	Flow volume change risk I (precipitation forecast)	<90% of current levels		90 - 110% of current levels		>110% of current levels	E. Maurer et al. "Fine-resolution climate projections enhance regional climate change impact studies", Eos Trans.AGU 88, (2007).
	Flow volume change risk II (Base Flow)	0 - 33 (Surface flow regime)		33 - 66		66 - 100 (Groundwater or snowmelt flow regime)	USGS Base Flow Index 2003
	Flow volume change risk III (Heat-related moisture loss)	Upper 1/3 of temp or below average to average temps		1 - 2 st. dev above ave precip or middle 1/3 of temp		> 3 st dev above ave precip or lower 1/3 of temp	E. Maurer et al. "Fine-resolution climate projections enhance regional climate change impact studies", Eos Trans.AGU 88, (2007).
	Altered fire regime risk	W/in 1680 - 2690 m elevation range and fine fuels majority		W/in 1680 - 2690 m elevation range and fine fuels in minority		Outside of 1680 - 2690 m elevation range	USGS National Elevation Dataset 30m; USGS/USFS LANDFIRE Anderson 13 Fuel Models

Indicator	Factor	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5	Data Source
Instream Habitat	% shallow landslide risk area	58 - 100%	28 - 58%	15 - 28%	5 - 15%	0 - 5%	USGS National Elevation Dataset 30m; SMORPH shallow landslide models
	Average fire threat (fire frequency and behavior)	3 - 4		2 - 3		0 - 2	CA Dept. of Forestry FRAP 2006
	Average soil erodibility (k factor) within riparian zone	0.3 – 0.5	0.25 – 0.3	0.2 – 0.25	0.15 – 0.2	0 – 0.15	NRCS SSURGO soil survey; EPA NHD Plus (1:100K) 200m buffer
	% riparian zone in medium/large size class and 40-100% canopy cover (scored for anadromous fish zone only)	80 - 100%	60 - 80%	40 - 60%	20 -40%	0 - 20%	CA Dept. of Forestry FRAP 2006; EPA NHD Plus (1:100K) 200m buffer
Introduced Species	Count of introduced species	>12	8 – 12	4 – 8	2 – 4	0 - 2	Species Database

RESULTS

The following brief summaries describe the broad patterns of the data summary and scoring for the aquatic species status, aquatic systems status, and California Freshwater CSI. These data are available as web maps and best explored online for more detailed information and additional resolution.

3.1 Aquatic Species Status

Aquatic species richness generally aligns with the pattern of perennial streams or larger river systems (Figure 2A) and is greatest in the North Coast and in tributaries to the Central Valley. Listed species richness tracks closely with the largest rivers, with the greatest number of ESA-protected species occurring in the Sacramento and San Joaquin Rivers (Figure 2B). BLM special status species richness follows this pattern, as well, with the addition of important species in the Klamath River system and along the South Coast (Figure 2C).

In watersheds with BLM land holdings, these patterns generally remain – greatest overall species richness (Figure 2D), listed species richness (Figure 2E), and BLM special status species richness (Figure 2F) in watersheds with ample flowing water. Holdings within the Paynes, Dibble, and Battle Creek watersheds (Redding Field Office) and Little Dry Creek watershed (Bakersfield Field Office) have the greatest BLM special status species richness.

3.2 Aquatic Systems Status

Aquatic systems occur throughout the assessment area, with the greatest concentration of perennial streams in the North Coast and higher elevations of the Sierras for both the entire subwatershed and BLM-lands only summaries (Figure 3A and 3D). Waterbodies and springs/seeps are found scattered across the assessment area, with the greatest number of springs/seeps in the vicinity of the Middle Klamath River and Owens Lake (all subwatershed) and throughout the Surprise and Eagle Lake BLM field office areas (Figures 3B, 3C, 3E, 3F).

Figure 2: Patterns of freshwater-dependent species diversity in the assessment area - A) and D) Total species richness; B) and E) ESA-listed species richness; C) and F) BLM special status species richness. Panels D), E), and F) summarize results only on BLM lands in watersheds with at least 10% BLM ownership.

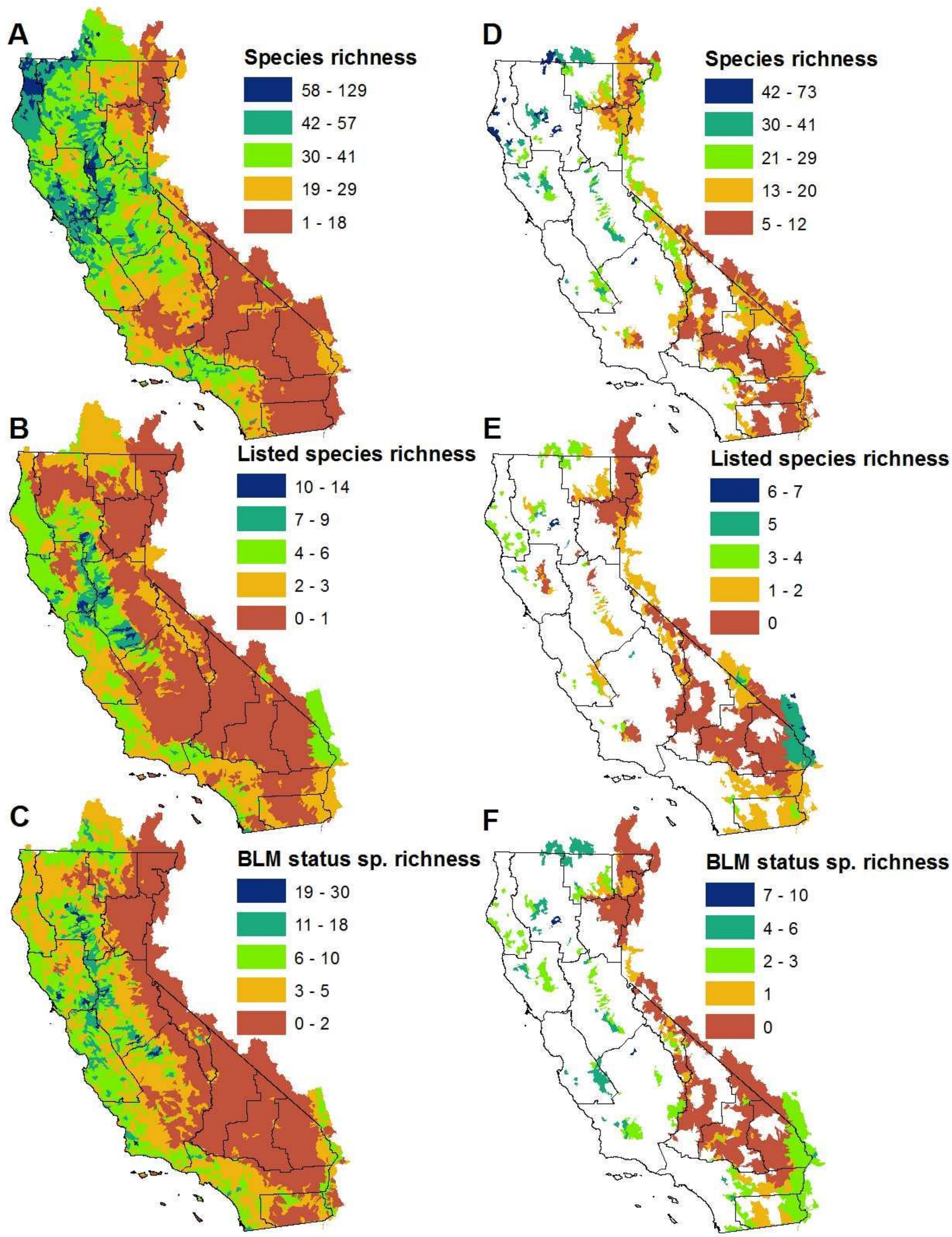
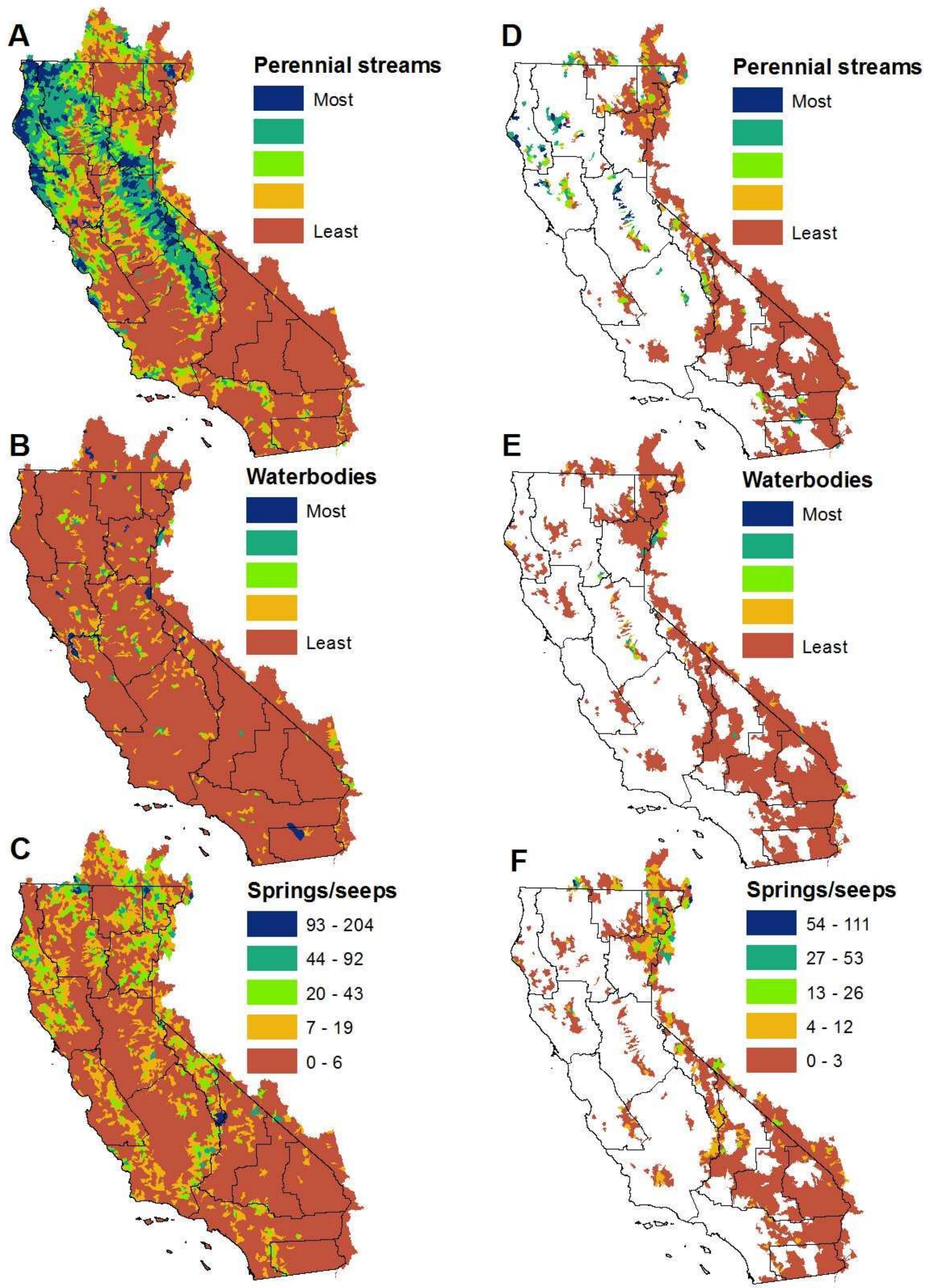


Figure 3: Patterns of aquatic systems occurrence in the assessment area – A) and D) perennial stream miles from NHD Plus normalized by subwatershed area; B) and E) waterbody area normalized by subwatershed area; C) and F) count of spring/seep systems. Panels D), E), and F) summarize results only on BLM lands in watersheds with at least 10% BLM ownership.



3.3 CSI Results – Habitat Integrity

Watershed condition scores, which assess road densities, roads in the riparian zone, and sedimentation of in-stream habitats, are lowest in coastal regions with the most productive forests, reflecting the current and historical impacts of industrial forestry, and surrounding the major urban areas in the state (Figure 4A). Highest watershed condition scores are associated with montane and desert regions. For BLM-land only summaries, watershed condition scores maintain the pattern of low scores for coastal watersheds, but a less defined pattern within montane and desert watersheds (Figure 4E). Temperature scores, which are lowest where riparian vegetation is limited and watershed average summer temperatures exceed 24°C, are oriented along two gradients: a cool-warm-cool gradient as elevations shift from sea level to mid-elevations to high elevations and a warm-cool gradient from the deserts of southeastern California to the more montane north (Figure 4B). On BLM lands, temperature scores are highest in the highest elevation watersheds (Figure 4E). Connectivity scores, an interpretation of local and downstream barrier counts and the accessibility of habitats from the ocean (within the range of anadromous fishes) or within connected habitat patches (for inland regions), are broadly lowest in the Central Valley tributaries which historically supported populations of anadromous salmonids (Figure 4C). Low water quality scores reflect a large footprint of urban areas, agriculture, mines, and oil and gas development in the Central Valley and south in California (Figure 5A). For BLM lands, low grazing intensity and distribution scores make the greatest contribution to the overall pattern of low scores (Figure 5D). Flow regime scores track the amount of water storage and delivery infrastructure in watersheds; these scores are lowest in the urban centers around San Francisco Bay and Los Angeles, and in agricultural centers in the Upper Klamath, Central Valley, and Russian River areas. Land Stewardship scores, which rate public, BLM, specially designated land management status, are highest in the designated BLM wilderness areas in the eastern portion of the assessment area (Figure 5C).

3.4 CSI Results – Future Security

The CSI Land Conversion indicator summarizes a prediction of where currently undeveloped lands will likely be converted to urban and ex-urban land uses in 2030 or to vineyard land uses in the near term. Urban and ex-urban development areas in California primarily occur in the vicinity of existing developments that are unconstrained by topography or public land ownership, especially in the foothills of the Central Valley (Figure 6A), while vineyard development is concentrated in Sonoma, Napa, San Luis Obispo, and Santa Barbara counties. The threat of new resource extraction and development is scattered throughout the assessment area (Figure 6B), with finer-grained patterns emerging through the separate analyses by development type. Solar development areas are concentrated in the Mohave Desert, wind development is concentrated along ridgelines in the far southern Sierra, and potential dam sites are found in the mid elevations of much of the state.

Figure 4: CSI Habitat Integrity indicator scores, Panel 1 - A) and D) Watershed Condition; B) and E) Temperature; and C) Connectivity. Panels D) and E) provide scores only for BLM lands in watersheds with at least 10% BLM ownership.

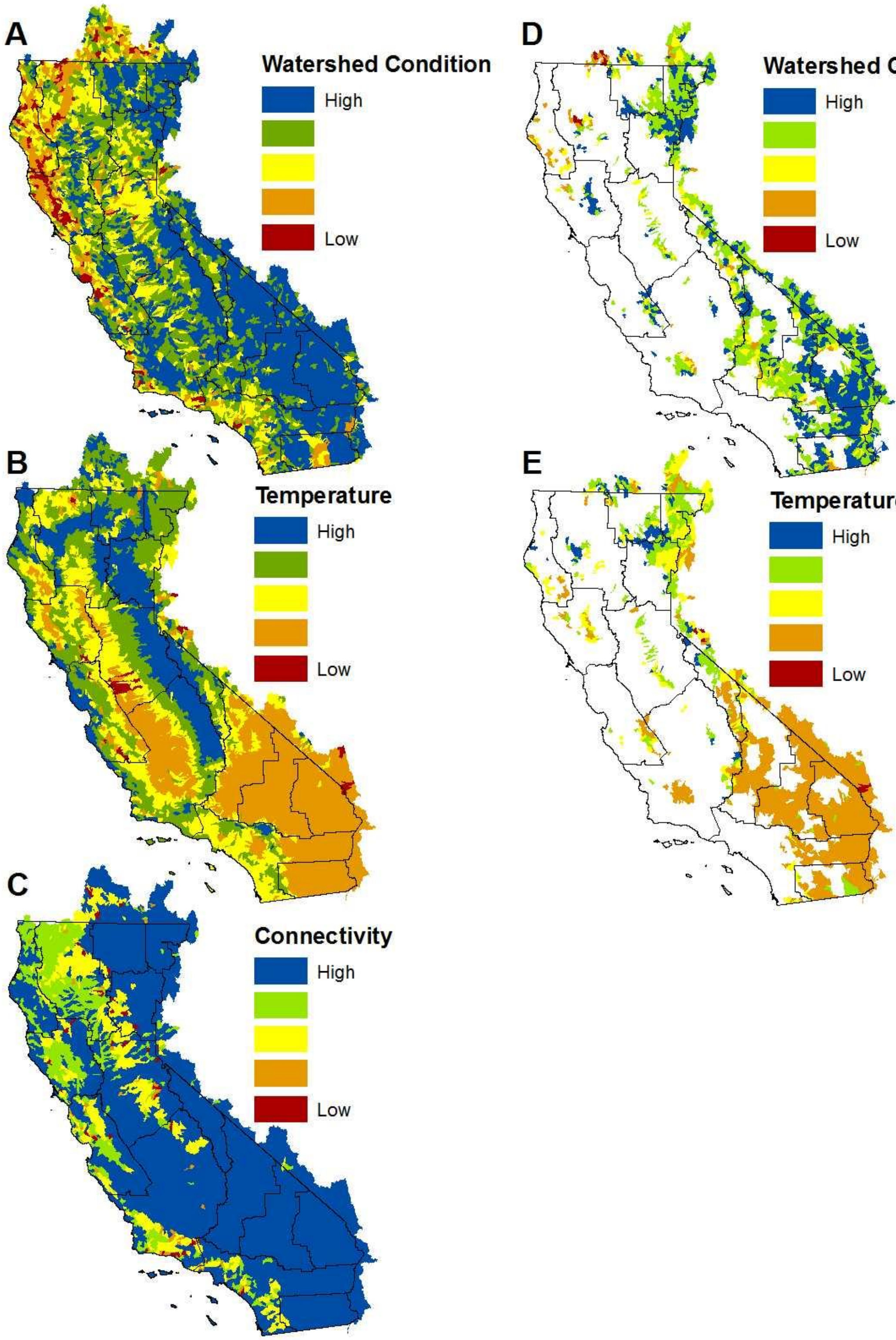
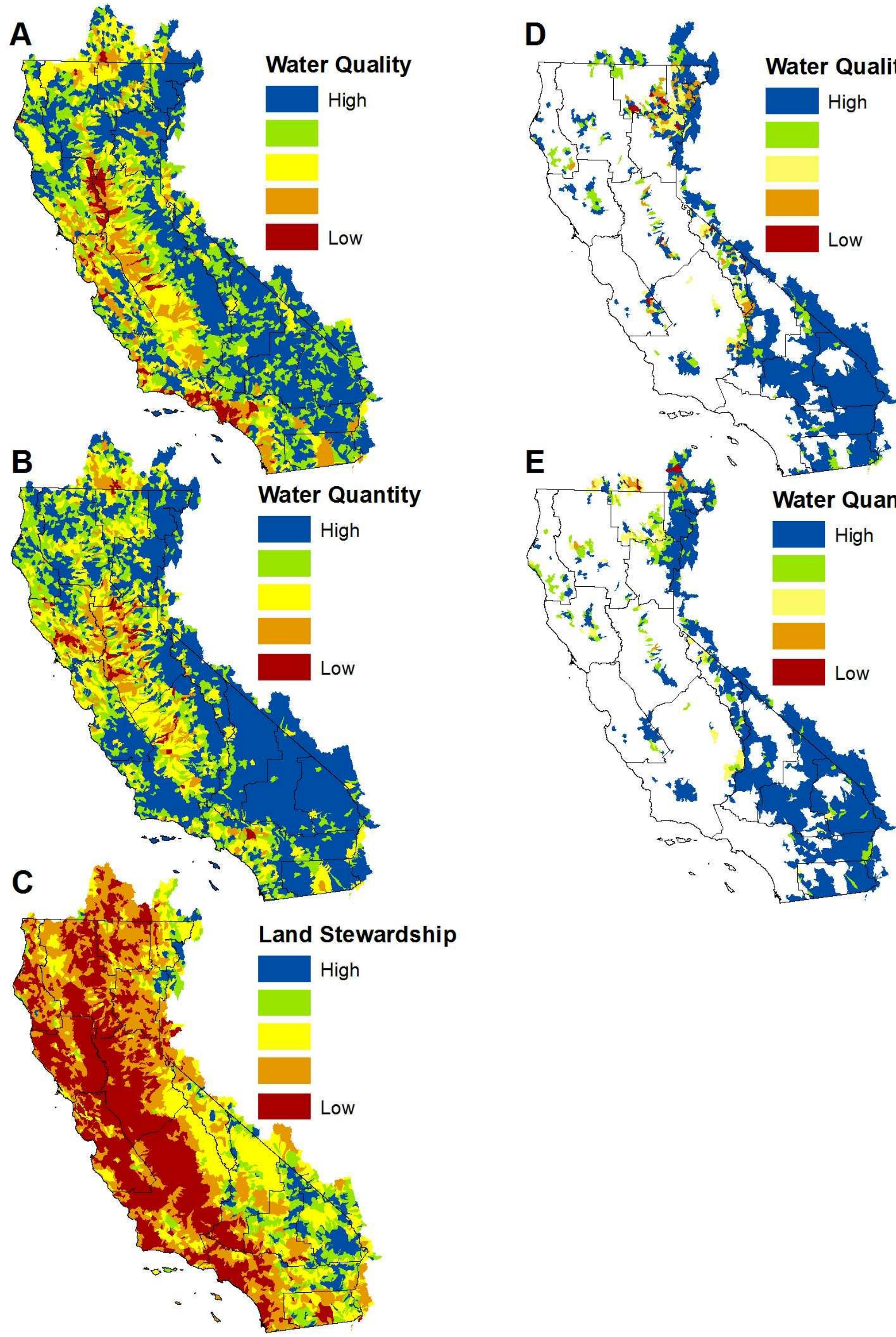


Figure 5: CSI Habitat Integrity indicator scores, Panel 2 - A) and D) Water Quality; B) and E) Water Quantity; and C) Land Stewardship. Panels D) and E) provide scores only for BLM lands in watersheds with at least 10% BLM ownership



Composite climate change risk is greatest in the lower elevation portions of the Mohave Desert and in the eastern Modoc Plateau (Figure 6C). The lowest risk portions of the assessment area occur in the highest elevations of the Sierra. Portions of California currently dominated by winter rains and the highest portions of the Sierra will likely experience the least effects of changes in winter precipitation regime, while a band of middle elevation watersheds in the Sierra, on the Modoc Plateau, and upper Klamath will like experience the greatest effects as their winter precipitation switches from snow to rain (Figure 7A). Elevation and maritime influence will be the primary factors mitigating the broad pattern of summer temperature increases across the study area (Figure 7B). The majority of the analysis area is forecast to have maintained or slightly increasing annual precipitation in 2050, resulting in only moderate risks for overall precipitation volume changes (Figure 7C). The exception is much of the Mohave ecoregion, which is forecast to see precipitation volumes decrease by greater than 10%. Base flows in California in the eastern Sierra in the northern Sierra from Mt. Lassen north to Mt. Shasta and the Klamath River headwaters where late snowpacks contribute to groundwater outputs (Figure 7D). Lowest base flows are found in the lower elevation portions of the coastal and Mohave regions. Drought risk is greatest in the portions of the study area that receive the lowest amounts of rainfall (Figure 7E). The risk from altered fire regimes is greatest in a mid-elevation band along the foothills of the Sierra and scattered throughout the Modoc Plateau (Figure7E).

Future Security Water Quality scores are lowest in the steeper chaparral ecosystems of southern coastal California, where unstable slopes and extreme fire risks co-occur (Figure 6D). The North Coast receives moderate scores due to moderate landslide risk scores, moderate riparian zone soil erodibility, and the general lack of any watersheds with significant stand of mature trees in the riparian zone. Finally, the risks associated with the direct and indirect threats of introduced species on aquatic species and habitats is likely greatest in proximity to urban areas and larger watercourses (Figure 6E), especially near the San Francisco Bay delta and the Colorado River.

Figure 6: CSI Future Security indicator scores - A) Conversion Risk; B) Resource Development Risk; C) Climate Change Risk; D) Water Quality Risk; and E) Introduced Species

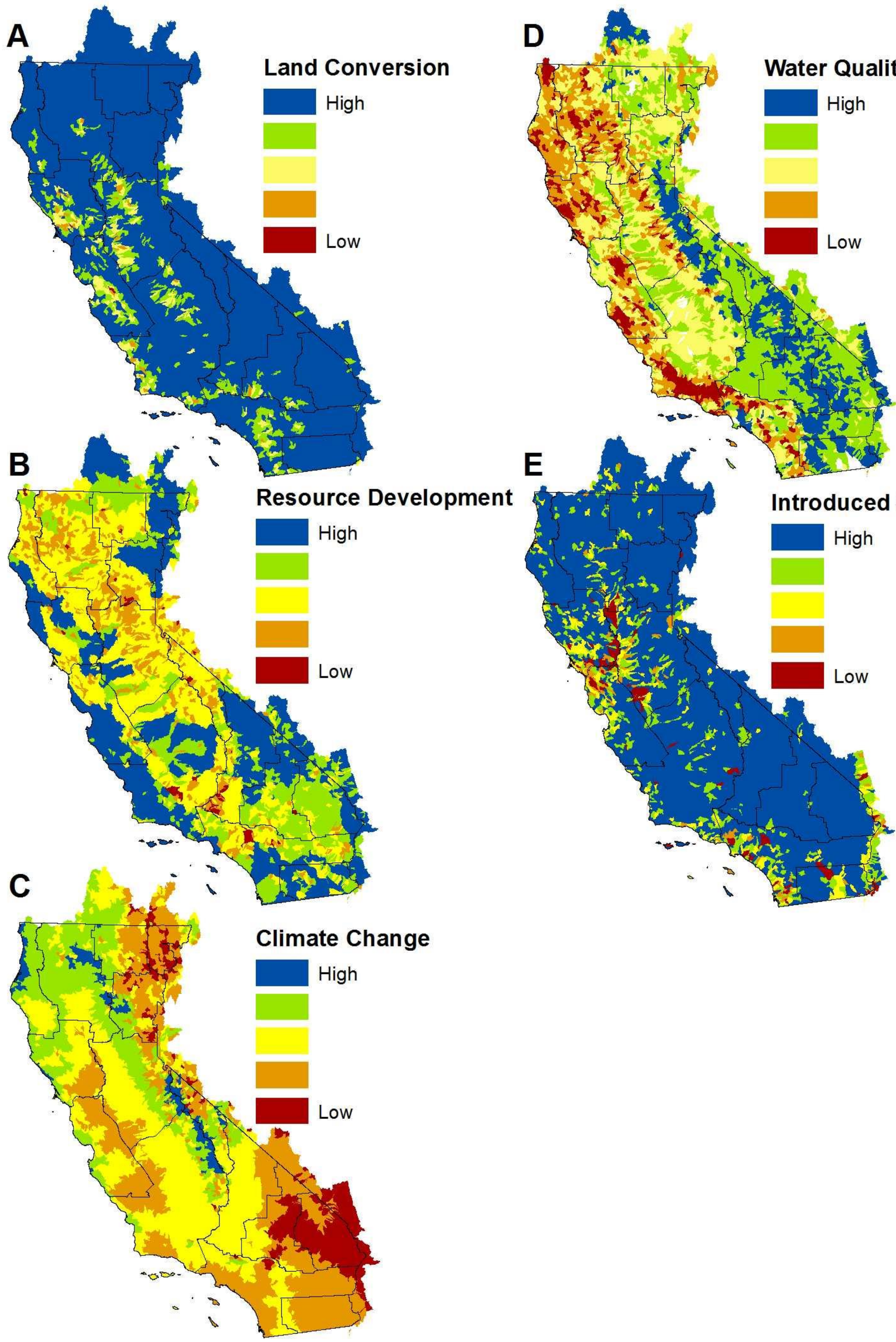
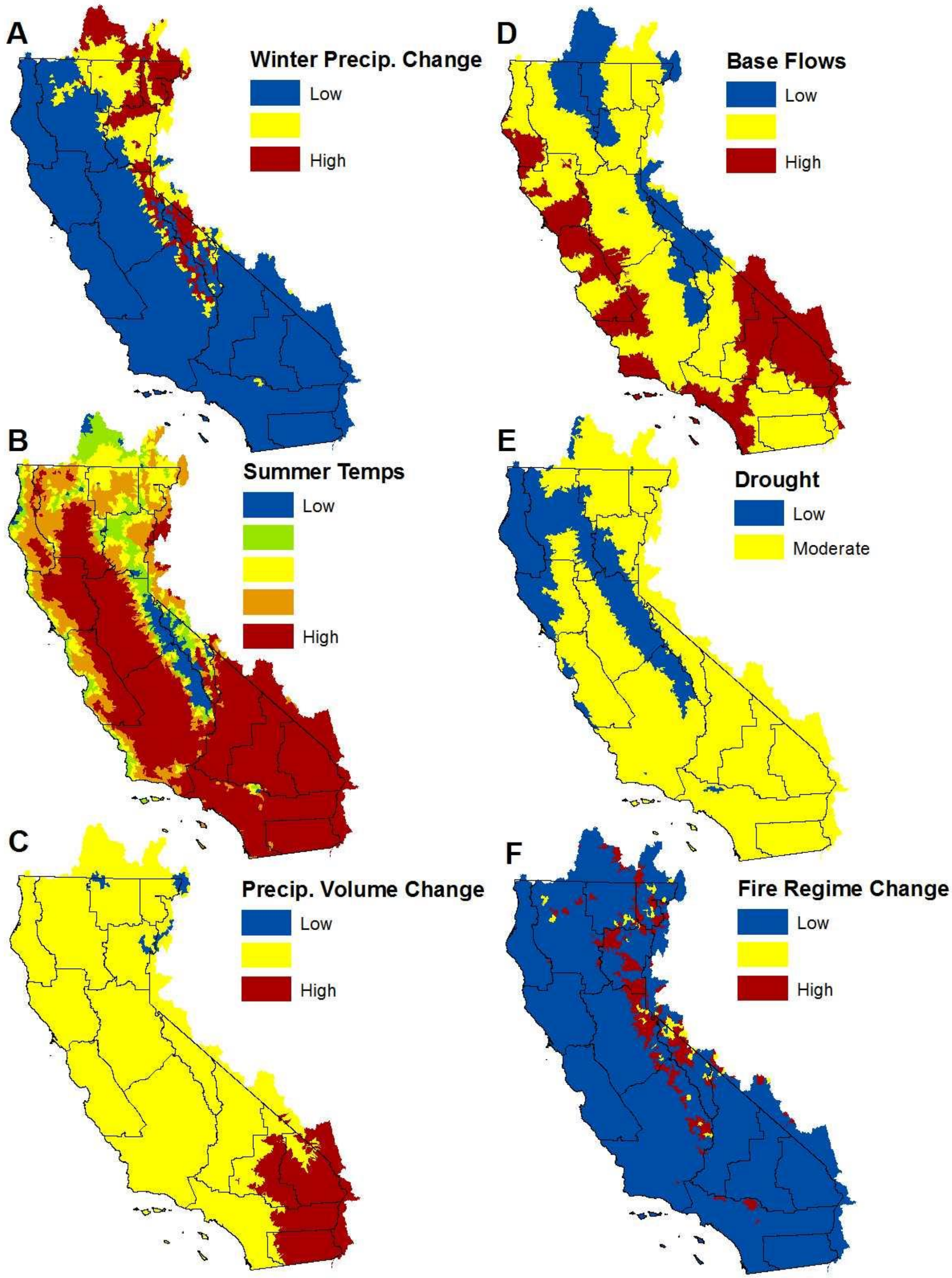


Figure 7: CSI Climate Change factor scores - A) Winter Precipitation Regime Change Risk; B) Summer Temperature Increase Risk; C) Precipitation Volume Change Risk; D) Base Flow Risk; E) Drought Risk; and F) Fire Regime Change Risk



3.4 CSI Results – Conservation Strategies

Taken together, the aquatic species and systems databases and California Freshwater CSI provide an assessment of species, habitat, and threat data from multiple data sources summarized at a consistent scale and interpreted using transparent scoring rules. By comparing factors from the combined products across administrative boundaries, we can categorize watersheds according to generalized conservation strategies:

- *Protection strategies* occur in subwatersheds with best habitat conditions, as indicated by the highest CSI Habitat Integrity scores, on BLM lands and within the surrounding mosaic of other public or private ownership. Examples of protection strategies that fall within the purview of BLM land management include land status designations (e.g. Areas of Critical Environmental Concern), limiting or mitigating development, or land ownership consolidation.
- *Restoration strategies* are appropriate in watersheds where the BLM lands have lower relative habitat condition than the surrounding mosaic of public or private lands, as reflected in CSI Habitat Integrity scores. Restoration strategies may need to address single factors that lower the CSI scores (e.g. addressing a water quantity factor on BLM lands through a forest thinning project) or a broader suite of factors.
- *Partnership strategies* occur when relative habitat condition is high on BLM lands, but relatively low within the surrounding private or public lands. Partnership opportunities include multi-agency species work groups, conservation easements with private landowners, or cooperative restoration projects (e.g. Challenge Cost Share projects) on private lands.

High CSI future security scores and the presence of at least one BLM special status species provide useful overlays for further prioritization within these areas, reflecting the likelihood of success of conservation actions or additional priority driven by BLM species or habitat objectives. Figures 8-12 provide one example of how the species and systems database along with the CSI results can be used to map conservation strategies for BLM lands by field office.

We present these opportunities at the subwatershed scale, given recent evidence of the importance of concentrating restoration efforts in limited areas in order to produce measurable changes in aquatic species abundance (Roni et al. 2010). Recovery plans and local knowledge will provide important information on fine-scale condition and opportunities within watersheds identified based on their relative condition across the analysis landscape. For example, restoration opportunities likely exist on local scales within watersheds with a protection priority.

Figure 8: Conservation Strategies for subwatersheds in the Alturas Field Office with at least 10% BLM land within the California Freshwater CSI area, with overlays of high future security watersheds and watersheds with at least 1 BLM special status species present.

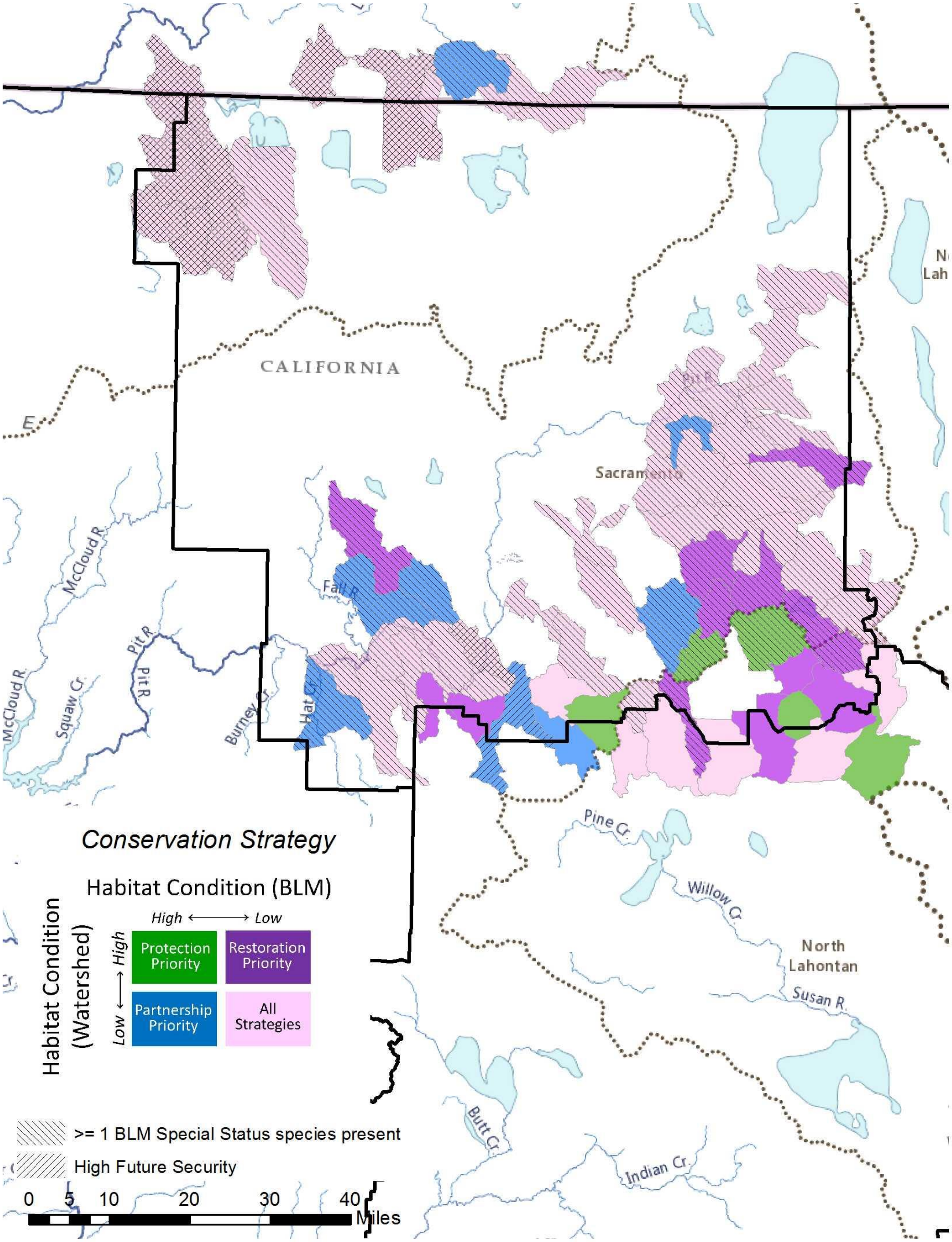


Figure 9: Conservation Strategies for subwatersheds in the Arcata Field Office with at least 10% BLM land within the California Freshwater CSI area, with overlays of high future security watersheds and watersheds with at least 1 BLM special status species present.

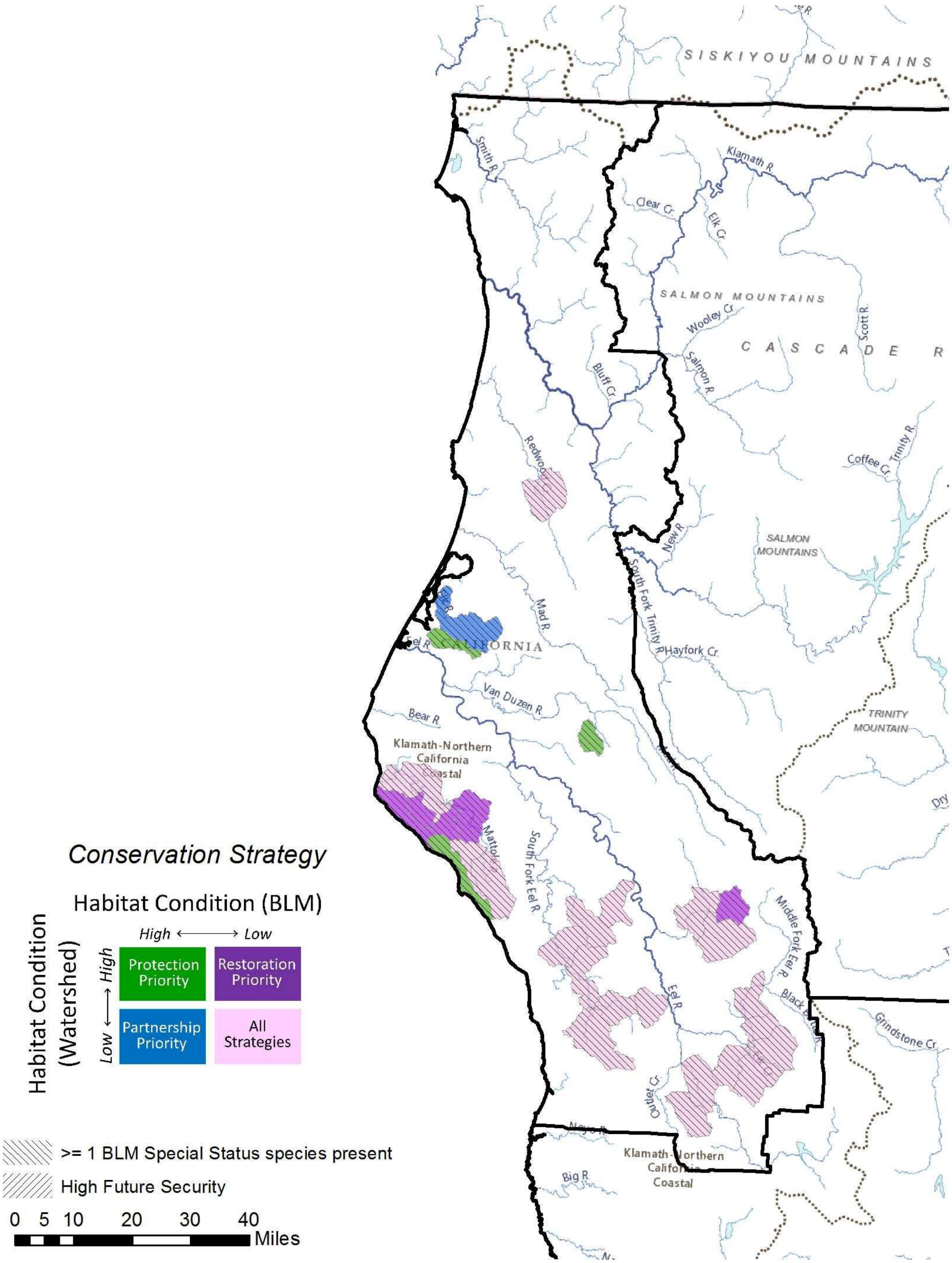


Figure 10: Conservation Strategies for subwatersheds in the Eagle Lake Field Office with at least 10% BLM land within the California Freshwater CSI area, with overlays of high future security watersheds and watersheds with at least 1 BLM special status species present.

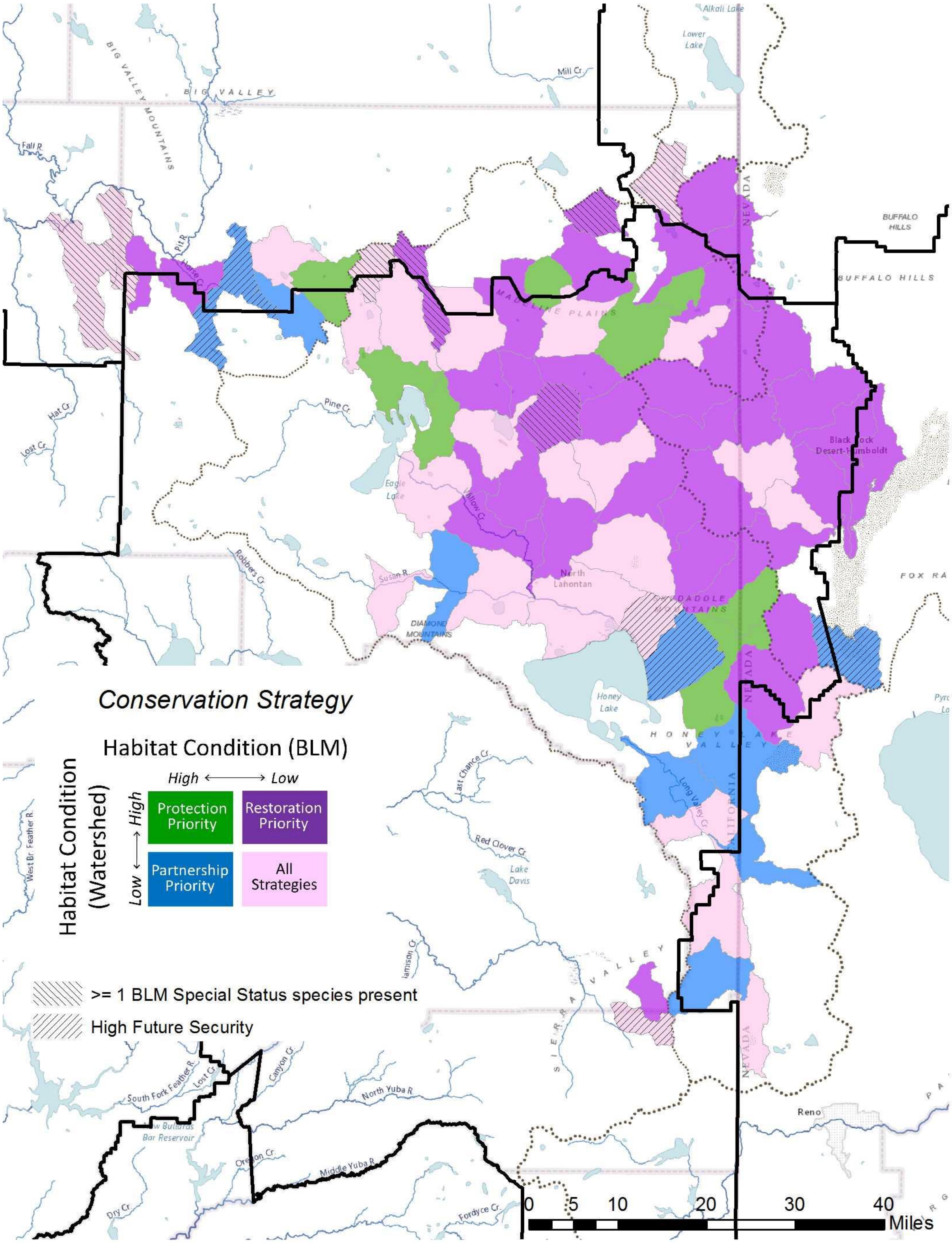


Figure 11: Conservation Strategies for subwatersheds in the Redding Field Office with at least 10% BLM land within the California Freshwater CSI area, with overlays of high future security watersheds and watersheds with at least 1 BLM special status species present.

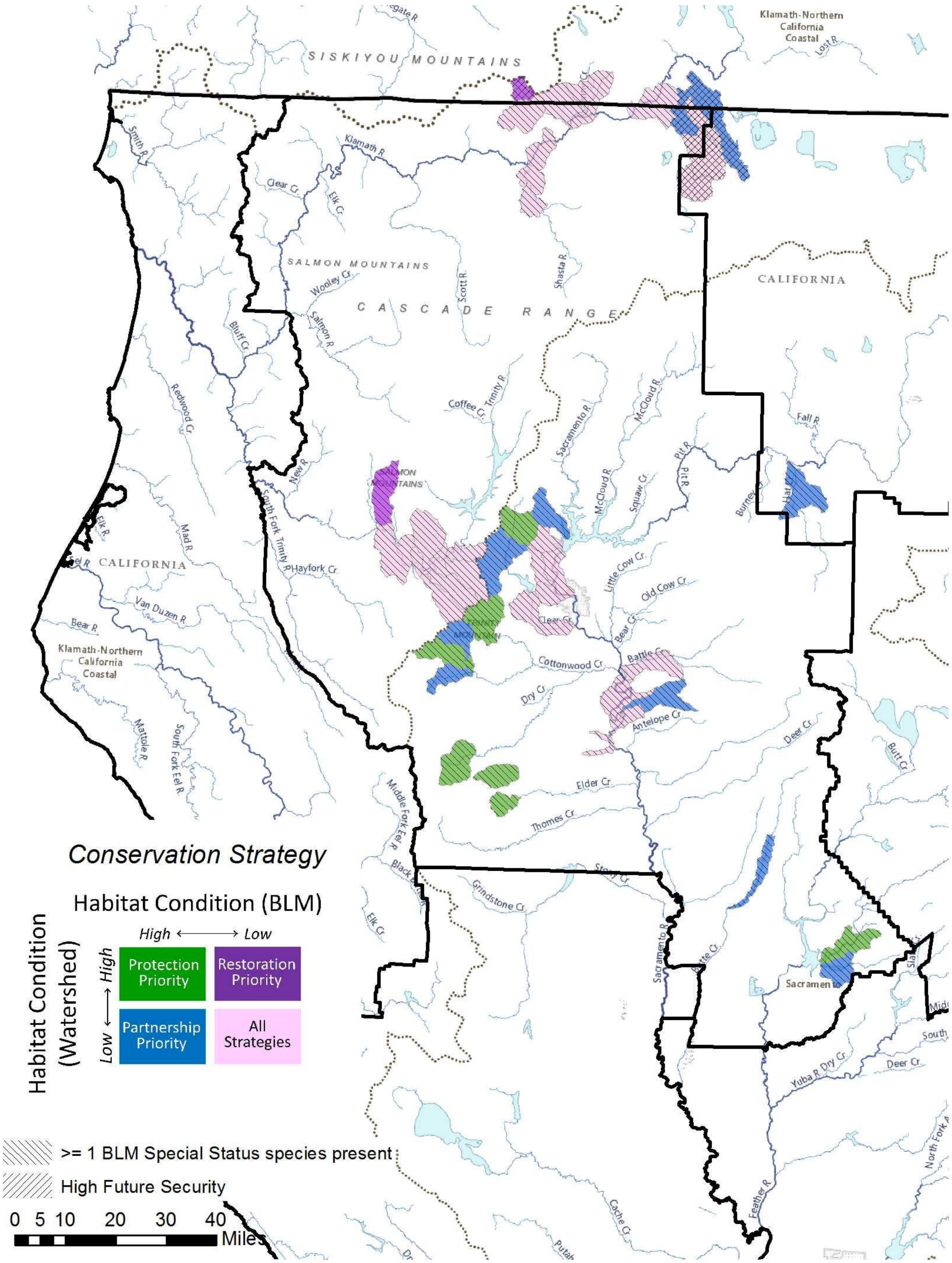
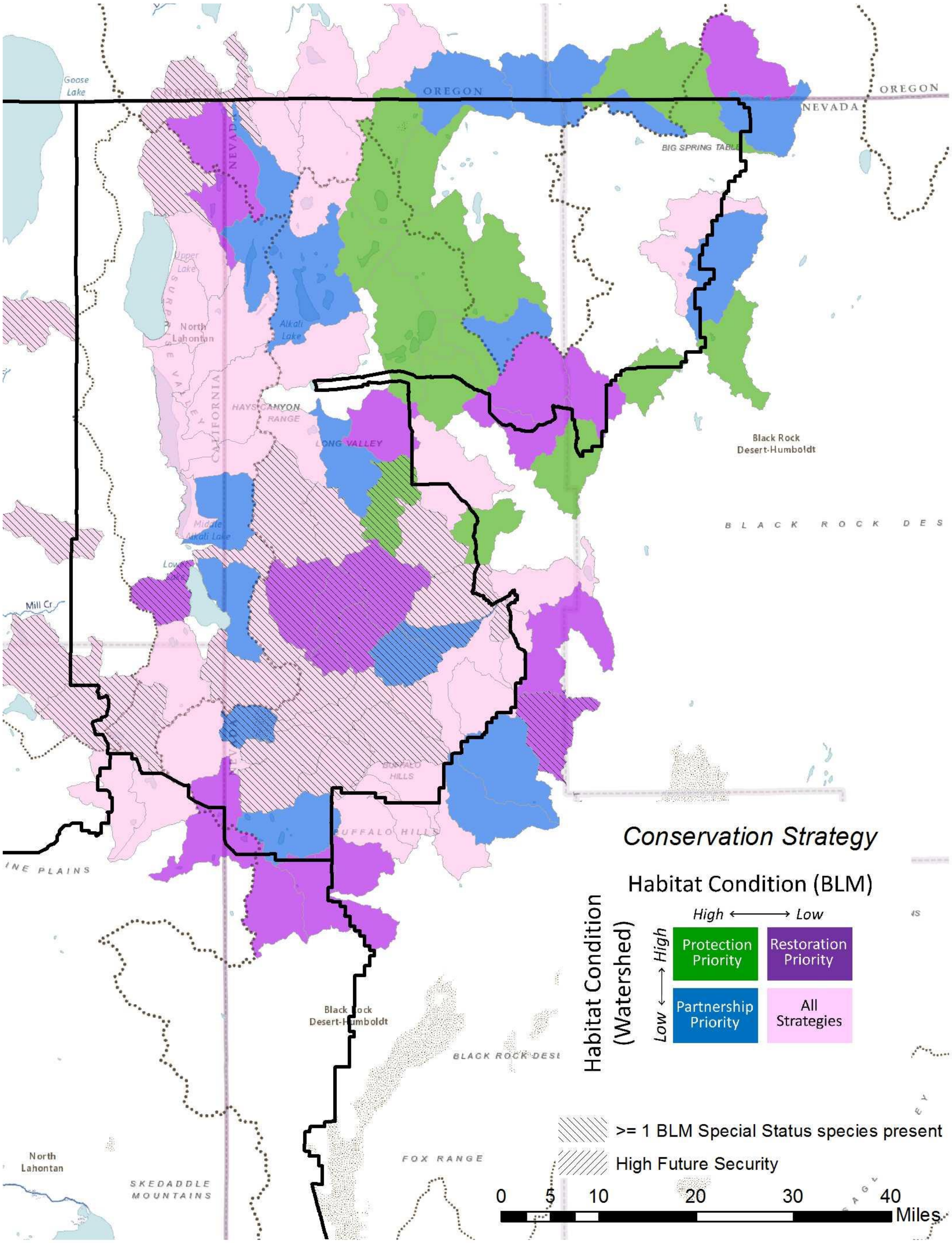


Figure 12: Conservation Strategies for subwatersheds in the Surprise Field Office with at least 10% BLM land within the California Freshwater CSI area, with overlays of high future security watersheds and watersheds with at least 1 BLM special status species present.



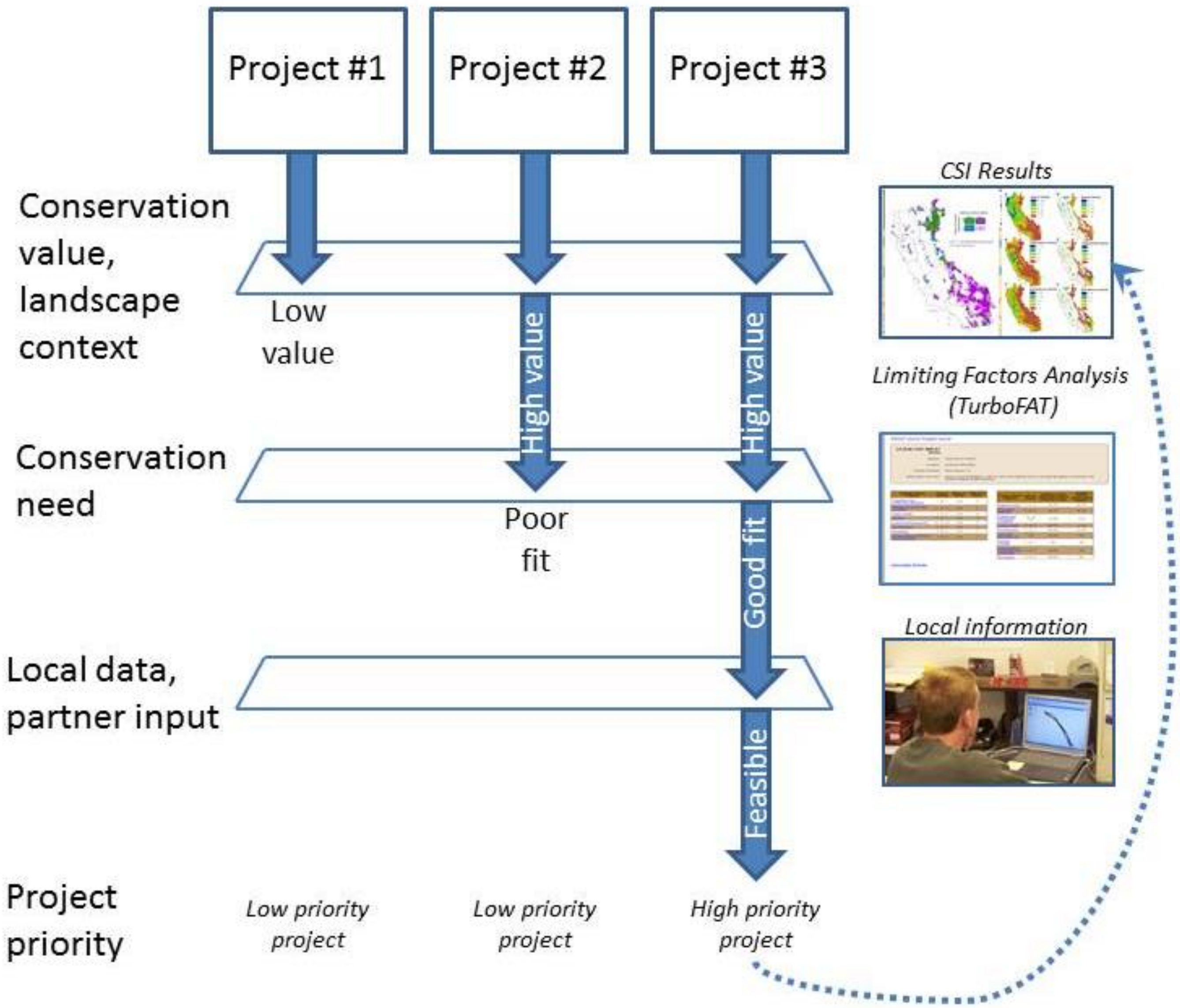
DISCUSSION

The California Freshwater CSI assessment described here provides a consistent and transparent structure for assembling diverse data and interpreting those data to describe broad patterns of aquatic species and habitats, the likely condition of those habitats, and the threats those habitats and species are likely to face in the future. The results outlined in this document are one of a multitude of interpretations of the original data based on a suggested set of scoring rules and the organizing structure of the indicators and factors (e.g. conservation strategies). However, the primary utility of this effort and other watershed conservation planning tools is to provide a single product for filtering and querying a large set of disparate but important data with *user-defined questions about landscape scale patterns* (see Game et al 2013). These questions can be general or specific: Where in northern California are the greatest number of aquatic species found? Then: Which of those watersheds have roads in the riparian zone on BLM lands? And: Which of those watersheds are vulnerable to floods as a result of changing winter precipitation regimes that may threaten those roads and the aquatic species? These questions can be asked at the level of districts, field offices, and in comparison between BLM lands and the watershed within which those lands are nested.

An equally useful approach is to *start instead with a specific location and pose questions about its local condition and features or its context within the landscape*. An example question may be: How large is the proportion of young, dense stands in this watershed relative to other watersheds in the vicinity? This approach is especially useful for evaluating projects. As proposals or alternatives come together, the California Freshwater CSI becomes one criterion in the project evaluation phase. Additional considerations can be gained from a limiting factors analysis, such as the TurboFAT tool developed for BLM, or local data sources, such as species recovery plans. Figure 13 provides a conceptual model of this project evaluation process, in which different tools are used to identify priorities.

Transparency is a main strength of the summary and scoring approach in the CSI. The CSI scoring is based on the best understanding from scientific literature of how a particular metric affects aquatic habitat. In the absence of a well-described relationship, we use natural breaks or patterns within the data summaries (i.e. quantiles, even percentage breaks) that warrant consideration by the end users. If the results of the scoring or strategies don't make sense to you, look back at the individual indicators and factors and their scoring – these may not all be pertinent to your area or species of interest, and CSI results can be reconfigured, weighted, and rescored accordingly within a GIS. Even small changes in scoring decisions can influence the scores – for example, changing indictor aggregated scores from average of the factor scores to the minimum of the factor scores.

Figure 13: Conceptual model of how information within the California Freshwater CSI can be used with other tools, such as the TurboFAT limiting factors analysis, and local knowledge to help screen and prioritize conservation actions. In some cases, post-project effects can be used to update the metrics and scoring within the CSI. Adapted from Dauwalter et al. 2013.



When interpreting CSI results, there are two important considerations related to the input data – data quality and missing data. The data we use represent the best available datasets for representing a particular feature. Most data are from the period from 2000-2010, and may not be the most up to date: the CSI provides a snapshot – not trend – for features and conditions for that period. Additionally, there may be variability within a particular factor not captured by the broad data. For example, we use road densities to approximate sedimentation effects from road networks, but roads will vary greatly in their delivery of sediment to streams based on their quality of construction, position in the watershed, and bedrock geology (Black et al. 2010). Likewise, there may be local spatial datasets overlooked during the data gathering of broader, more general datasets that may provide additional resolution for considering conditions or resources on the ground.

A second consideration is what important factors are missing from the CSI. For the species dataset, observational data are biased to a certain degree towards large, readily observable species, public lands due to a mandate for resource management, and locations with easy access, so species and locales outside those categories (i.e. private lands with rare invertebrates) may be underrepresented. We are also only providing a broad look at current distributions for species and do not anticipate how those distributions may shift in response to changes in climate.

For Habitat Integrity results, several factors lack any spatial data for approximating or measuring impact, including indirect measures of grazing, direct measures of instream temperature, and accurate maps depicting seasonality of stream flows. In particular, the lack of measures of grazing impacts will likely overestimate instream habitat quality in the eastern portion of the study area, where grazing is often the only land use or anthropogenic disturbance on large blocks of public land. For Future Security, we lack overlays on the resilience of aquatic systems to change or the interactive effects of natural disturbances like fire and floods that may compound existing or future threats.

One opportunity the CSI serves is providing baseline information that can be updated as new data are available – thus establishing trends – or as projects are completed that address factors in the CSI. For example, a single instream barrier may dramatically influence habitat connectivity measured in the CSI. Removing that one barrier may switch a watershed score from the worst (1) to best (5), effectively changing the color on the CSI results map with a single restoration action.

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