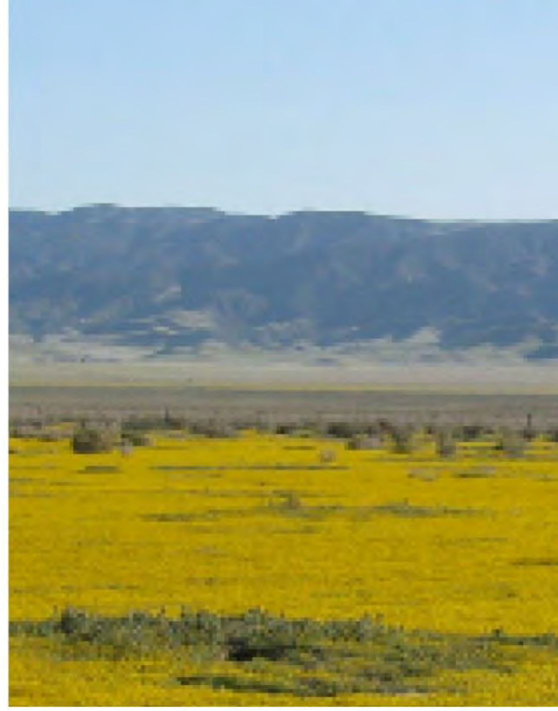
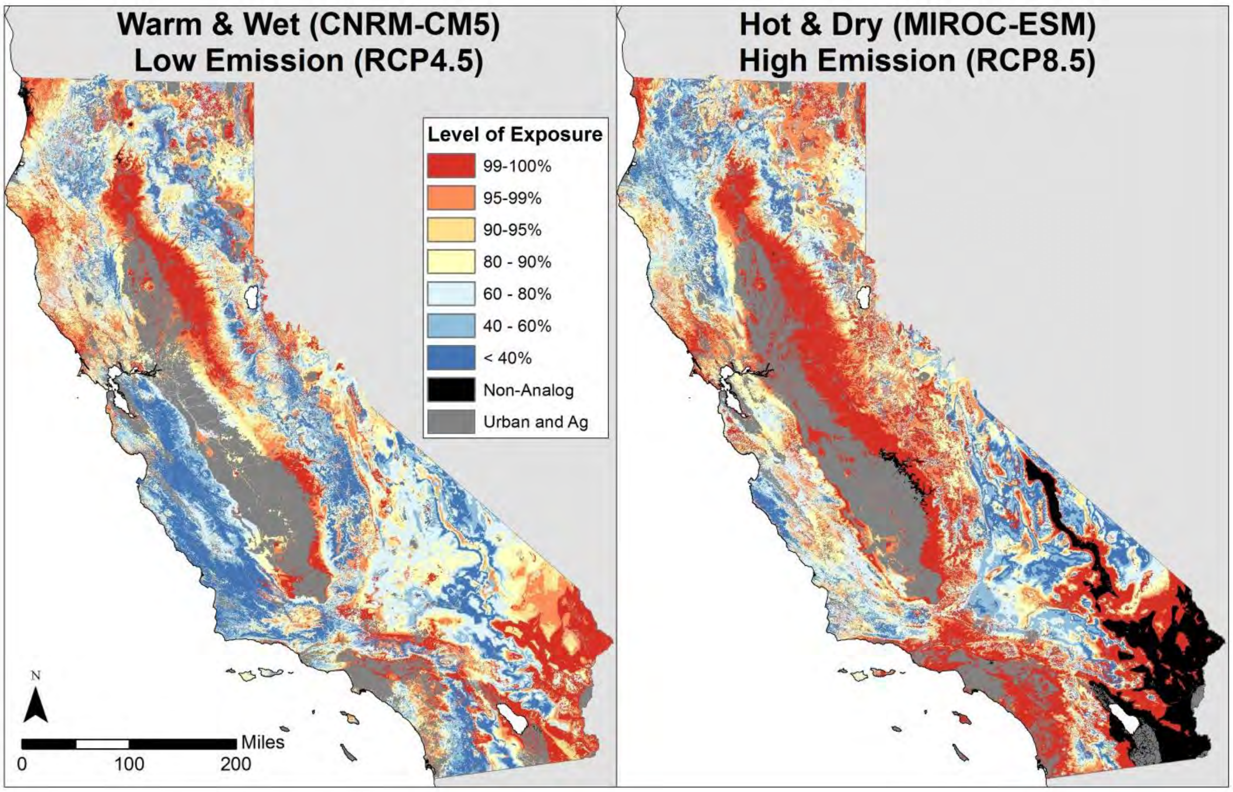


A Climate Change Vulnerability Assessment of California's Terrestrial Vegetation

Prepared for the California Department of Fish and Wildlife by the University of California, Davis

A climate change vulnerability assessment of California's terrestrial vegetation



Final Report to:

California Department of Fish and Wildlife

Prepared by:

James H. Thorne, Ryan M. Boynton, Andrew J. Holguin, Joseph A.E. Stewart and Jacquelyn Bjorkman

Information Center for the Environment

University of California, Davis

January 2016

Suggested Citation:

Thorne, J.H., R.M. Boynton, A.J. Holguin, J.A.E. Stewart, & J. Bjorkman. (2016) A climate change vulnerability assessment of California's terrestrial vegetation. California Department of Fish and Wildlife (CDFW), Sacramento, CA.

Disclaimer: The contents of this document are solely the responsibility of the authors and do not necessarily represent the official views of supporting agencies.

For further inquiries, please contact

James H. Thorne, Ph.D.

jhthorne@ucdavis.edu

Department of Environmental Science and Policy

University of California Davis, CA 95616-8628

Phone: 530-752-4389

or

Whitney Albright

Whitney.Albright@wildlife.ca.gov

Climate Science and Renewable Energy Branch

California Department of Fish and Wildlife

Acknowledgements

This work was funded by the California Department of Fish and Wildlife in association with the State Wildlife Action Plan 2015 update, under agreement number P1382100. We thank the following individuals and agencies: Professor Mark Schwartz, UC Davis; Alan and Lorrie Flint, USGS; Anne Klein, Todd Keeler-Wolf, Armand Gonzales, Steve Schoenig, and Junko Hoshi, California Department of Fish and Wildlife; and Tiffany Meyer, California Department of Forestry and Fire Protection.

Acronyms

AET	Actual Evapotranspiration
BCM	Basin Characterization Model
CDFW	California Department of Fish and Wildlife
CMIP5	Coupled Model Intercomparison Project Phase 5
CNRM CM5	The “Warm and Wet” GCM used in this report
CWD	Climatic Water Deficit
GCM	Global Climate Model (or Global Circulation Model)
MG	Macrogroup
MIROC ESM	The “Hot and Dry” GCM used in this report
NVCS	National Vegetation Classification System
PCA	Principal Component Analysis
PCK	Snowpack, typically summarized as depth of snowpack on April 1st
PET	Potential Evapotranspiration
PPT	Precipitation
RCP	Representative Concentration Pathway
RUN	Runoff
S&A	Sensitivity and Adaptive Capacity
SD	Standard Deviation
SDM	Species Distribution Model
SWAP	State Wildlife Action Plan
TMN	Annual Minimum Temperature (also referred to as Tmin)
TMX	Annual Maximum Temperature (also referred to as Tmax)
WHR	Wildlife Habitat Relationship, a habitat classification scheme specific to California species

Contents

Tables

Figures

EXECUTIVE SUMMARY

Sixteen of 29 natural vegetation community types in California are highly or nearly highly vulnerable to four alternate projected climates by the end of this century. The remaining 13 natural community types have moderate vulnerability. Vulnerability was determined by using a detailed 2015 map of the spatial patterns of California's vegetation community types, and examining how climate conditions will change at those locations. This study also identified biological traits of the dominant plant species that make up the vegetation community types, and found that different types have different levels of sensitivity and adaptive capacity to changing climate. Yet, even the more robust and widespread community types, like California's Foothill and Valley Forests and Woodlands, or Chaparral are moderately vulnerable, with impacts to 28-53% and 12-47% of their current extent, respectively. The variation in the four alternate climate projections had a much larger effect on vulnerability than the biological attributes.

Currently, California and the world are on an emissions trajectory that is closer to the higher level emission scenario used in this study (RCP 8.5), than to the more optimistic scenario used in this report to bracket the results (RCP 4.5). The RCP 8.5 emissions track produces an average of 26% more climate exposure to terrestrial vegetation of the state, and nearly every vegetation type increases a full step in its vulnerability ranking over results from the RCP 4.5 scenario. The use of the vegetation community map permits examination of the rates of transition from climatically suitable to climatically stressed extents for each vegetation type. Of particular importance to resource managers, the predictions in this report can be used to establish monitoring protocols to track the trajectory and rates of change for important biotic resources of the state. Additionally, our use of trait-based sensitivity and adaptive capacity scores provides explicit assumptions about how individual species may respond to climate change. As further information becomes available, these species-specific scores can be adjusted, which may adjust the overall ranking of the vegetation communities they occupy. And, more detailed climate vulnerability work on individual dominant plant species can be developed, to better predict how the species will respond, and to seek adaptation strategies that California's natural resource managers could potentially employ to lower the predicted impacts.

Components of climate change that this study does not explicitly include, but which are currently affecting vegetation in the state, include extreme events such as multi-year droughts or short-duration heavy precipitation events, and secondary impacts such as large wildfires, insect outbreaks and invasive species incursions. These types of impacts will likely interact with the stress or vulnerability of vegetation communities, to compound the effects of climate change. For example, fire may remove a dominant vegetation type from a site and the site may then regenerate to another type of vegetation, because the establishment conditions have changed. The results presented in this report should therefore be treated as conservative estimates of potential future impacts. Finally, the vulnerability scores are best used in concert, to compare relative vulnerability among different vegetation types. For impacts to individual types, review of the components that make up the vulnerability score will be more useful.

OVERVIEW

This report presents the results of a climate vulnerability analysis[1] of the terrestrial vegetation of California. The assessment is based on two global climate models[2] (GCMs) and two emission scenarios that were selected from among 12 considered to represent a range of future conditions for California by the end of the 21st century. The GCMs, CNRM CM5 and Miroc ESM, and emission scenarios used, RCP4.5 and RCP 8.5, represent a range of warming statewide from 1.99 to 4.56°C and between a 24.8% decrease in precipitation and a 22.9% increase, respectively. A 2015 map of the state's natural vegetation compiled from multiple sources[3] was classified to the National Vegetation Classification Standard's mid-level classification, called "Macrogroup". Thirty one natural vegetation macrogroups are identified in the map, covering 99.87% of the state's natural terrestrial vegetation, and occupying 353,271 km^2.

Four analyses were conducted on 29 macrogroups and partial analyses were conducted on the additional two. All results are presented in the main report. The first two analyses use biological traits of the dominant species comprising each macrogroup to estimate the sensitivity to changes in climate, and possible adaptive capacity that the vegetation may exhibit. The third analysis assesses the exposure to changing climate that each vegetation type is projected to experience at the locations it currently occupies. The final analysis estimates the spatial disruption, or movement that will be required to depart areas no longer climatically suitable or to establish in newly suitable areas. The scores were combined to provide a vulnerability ranking that is cross-comparable among the terrestrial vegetation types.

When averaged across the four future climates representing conditions by 2100, no macrogroups have low levels of vulnerability to climate change, 13 macrogroups were found to have moderate vulnerability, 12 have a mid-high level, and four are highly vulnerable (Figure 1, Table 1). Additionally, several of the macrogroups are very close to be being scored into higher vulnerability ranks. We found that while the vegetation types exhibit differing sensitivity and adaptive capabilities, that variation in climate projections had a much larger effect on vulnerability ranking.

Twenty five of 29 vegetation types cross to a higher level of vulnerability under one or both of the more pronounced RCP 8.5 climate emission projections and three others are already at the highest level of vulnerability. These results (Figure 2, Table 2) clearly show the desirability of attaining the lower emission scenario of RCP 4.5, over the higher emission scenario RCP 8.5, which is the track that global emissions are more closely aligning with at the time of this report. Note that the warm and wetter scenario CNRM CM RCP 8.5 produces more non-analog conditions than the drier Miroc ESM RCP 8.5 because California currently does not have places with this extent of heat that also have higher levels of precipitation (the black areas in Figure 3). While the higher level of precipitation could be cause for optimism regarding vegetation conditions, concurrent higher temperatures are expected to require higher levels of plant respiration and therefore water demand is expected increase more rapidly than reduction in water deficit due to the increased precipitation.

Considered from a spatial perspective, the extent of macrogroups in the High vulnerability category by the end of the century varies from 6458 km^2 to 45,094 km^2 depending on the GCM and emission scenario, while no more than 228 km^2 remain in the low vulnerability category under any projection. The extent of macrogroups in the Mid-High vulnerability class ranges from 82,168 to 206,357 km^2, and in the Moderate vulnerability class from 129,811 to 255,536 km^2. Under the higher end of this range (Miroc ESM RCP 8.5), up to 63% of current terrestrial vegetation would be in a Mid-High to High vulnerability condition by end century (Table 3). Our method of calculating future vulnerability does not produce a current condition vulnerability score. However, starting conditions for the climate exposure component class 80% of each

[1] http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch19s19-1-2.html
[2] http://ipcc-data.org/guidelines/pages/gcm_guide.html
[3] http://frap.fire.ca.gov/data/frapgisdata-sw-fveg_download.php

macrogroup's current as climatically suitable. This corresponds to 282,617 km^2 of natural vegetation, almost all of which does not have a future low vulnerability rank under the RCP 8.5 climate projections.[4]

The combining of trait-based scores with climate exposure and spatial disruption scores moderated the results that are produced solely by climate exposure. However, the climate exposure analysis includes the most spatial detail, and contains less assumptions than the sensitivity and adaptive capacity (S&A) and spatial disruption analyses. Climate exposure across the four 2100 projections shows most of the Sierra Nevada, large parts of the interior deserts and steppe and portions of the north coast ranges as having the most changing climate conditions (orange to black in Figure 3).

The use of a 2015 map portraying the current extent of vegetation permitted an assessment of climate exposure based on known locations, rather than on potential locations. This simple approach leverages considerable field effort in ways that species distribution models, which are commonly used as the climate impacts predictors in vulnerability assessments, do not. The use of the vegetation map permits us to also examine the rates of transition from climatically suitable to climatically stressed extents for each vegetation type. This is presented in tabular form for each macrogroup in the main body of the report. However we can compile the types to examine these rates of transition (Figure 4). While climate exposure is typically thought of as the areas that become unsuitable, we can also track the loss of climatically suitable areas. Figure 4 illustrates how the majority of macrogroups transition from 80% climatically suitable and 5% marginal extents in current time, to a mean of 33% in climatically suitable and 46% in highly exposed or marginal climates for the four climate projections used. The range of future levels of exposure among macrogroups varies; 19-47% remains in climatically suitable areas and 30-64% is in climatically stressed areas.

Components of climate change that this report explicitly includes have been made as transparent as possible, in order to allow for future evaluation of results, and potential modification of the parameters to better train the models to portray vegetation dynamics as they progress. In particular, for the S&A analysis, we scored individual species that comprise each macrogroup. This use of trait-based sensitivity and adaptive capacity scores, which are derived from the literature and expert opinion but in most cases have not been quantitatively proven, provides a series of hypotheses about how individual species may respond to climate change. As further information becomes available, these scores can be adjusted, which may adjust the overall ranking of a macrogroup. And, more detailed climate vulnerability work on individual dominant plant species can be developed. The scoring matrix the species occupy could also be expanded to include other important traits, and more species could be scored using the approach. Scores presented here that are particularly based on estimates rather than from study results or substantial field observations, are the species sensitivity to temperature and precipitation changes, which could be better informed through long term monitoring, eddy flux covariance studies, and experimental approaches.

Components of climate change that this study does not explicitly include, but which are currently observed to be affecting vegetation in the state include extreme events such as multi-year droughts or short-duration heavy precipitation events, and secondary impacts such as large wildfires, insect outbreaks and invasive species incursions. These types of impacts will likely interact with the stress or vulnerability of macrogroups, to compound the effects of climate change. For example, fire may remove a dominant vegetation type from a site and the site may then regenerate to another type of vegetation, because the establishment conditions have changed. The results presented in this report should therefore be treated as conservative estimates of potential future impacts.

[4] Thorne, J.H., R.M. Boynton, L.E. Flint, A.L. Flint. 2015. Comparing historic and future climate and hydrology for California's watersheds using the Basin Characterization Model. Ecosphere 6(2). Online http://www.esajournals.org/doi/pdf/10.1890/ES14-00300.

Table 1. Mean Climate Vulnerability Scores for California Macrogroups. The mean climate vulnerability scores for 31 macrogroups in California. The breaks for classing vulnerability scores are: Low = 0.294-1.180; Medium = 1.180 – 2.066; High = 2.066 – 2.952.

Macro-group Number	Common Name	Macrogroup Name	Area Mapped Km^2	Mean Vulnerability Rank
9	California Foothill and Valley Forests and Woodlands	California Forest and Woodland	49,765	Moderate
20	Subalpine Aspen Forests & Pine Woodlands	Rocky Mountain Subalpine and High Montane Conifer Forest	9,427	High
23	North Coastal Mixed Evergreen and Montane Conifer Forests	Californian-Vancouverian Montane and Foothill Forest	53,427	Moderate
24	Pacific Northwest Conifer Forests	Vancouverian Rainforest	4,512	Mid-High
25	Pacific Northwest Subalpine Forest	Vancouverian Subalpine Forest	1,010	Mid-High
26	Great Basin Pinyon-Juniper Woodland	Intermountain Basins Pinyon-Juniper Woodland	11,148	Mid-High
27	Non-Native Forest and Woodlands	Introduced NA Mediterranean Woodland and Forest	228	Moderate
34	North Coastal Riparian and Montane Riparian Forest and Woodland	Vancouverian flooded and Swamp Forest [Formerly Macrogroup Western Cordilleran Montane–Boreal Riparian Scrub and Forest]	1,204	Moderate
36	American Southwest Riparian Forest and Woodland	Warm Southwest Riparian Forest	1,862	Mid-High
43	Chaparral	California Chaparral	27,259	Moderate
44	Coastal Sage Scrub	California Coastal Scrub	7,868	Mid-High
45	California Grassland and Flowerfields	California Annual and Perennial Grassland	45,229	Mid-High
47	Mountain Riparian Scrub and Wet Meadow	Western North American Montane-Subalpine Wet Shrubland & Wet Meadow	1,277	Mid-High
48	Western Upland Grasslands	Western North American Temperate Grassland and Meadow	181	Mid-High
50	North Coast Deciduous Scrub and Terrace Prairie	Vancouverian Lowland Grassland and Shrubland	1,518	Moderate
52	Montane Chaparral	Cool Interior Chaparral	6,281	Moderate
58	Coastal Dune and Bluff Scrub	Vancouverian Coastal Dune and Bluff	414	Mid-High
73	Freshwater Marsh	Western North American Freshwater Marsh	1,329	High
75	Wet Mountain Meadow	Western North America Wet Meadow and Low Shrub Carr	91	Mid-High
81	Salt Marsh Meadows	North American Pacific Coastal Salt Marsh	441	High
88	Mojave and Sonoran Desert Scrub	Mojavean–Sonoran Desert Scrub	83,268	Moderate
92	Desert Wash Woodland and Scrub	North American Warm-Desert Xero-Riparian	3,794	Moderate
93	Shadscale-Saltbush Scrub	Great Basin Saltbush Scrub Macrogroup	7,776	Moderate
96	Big Sagebrush Scrub	Western North America Tall Sage Shrubland and Steppe	16,181	Mid-High

Macro-group Number	Common Name	Macrogroup Name	Area Mapped Km^2	Mean Vulnerability Rank
97	Great Basin Dwarf Sagebrush Scrub	Western North America Dwarf Sage Shrubland and Steppe	3,014	High
98	Great Basin Upland Scrub	Inter-Mountain Dry Shrubland and Grassland	1,673	High
101	Alpine Vegetation	Vancouverian Alpine Scrub, Forb Meadow, and Grassland	513	High
106	Brackish (Estuarine) Submerged Aquatic Vegetation	Temperate Pacific Intertidal Shore	26	Not scored
110	California Foothill and Coastal Rock Outcrop Vegetation	California Cliff, Scree, and Other Rock Vegetation	6,355	Mid-High
114	Northwest Coast Cliff and Outcrop	Vancouverian Cliff, Scree, and Other Rock Vegetation	590	Not scored
117	Sparsely Vegetated Desert Dune	North American Warm Semi-Desert Cliff, Scree, and Other Rock Vegetation	5,609	Moderate

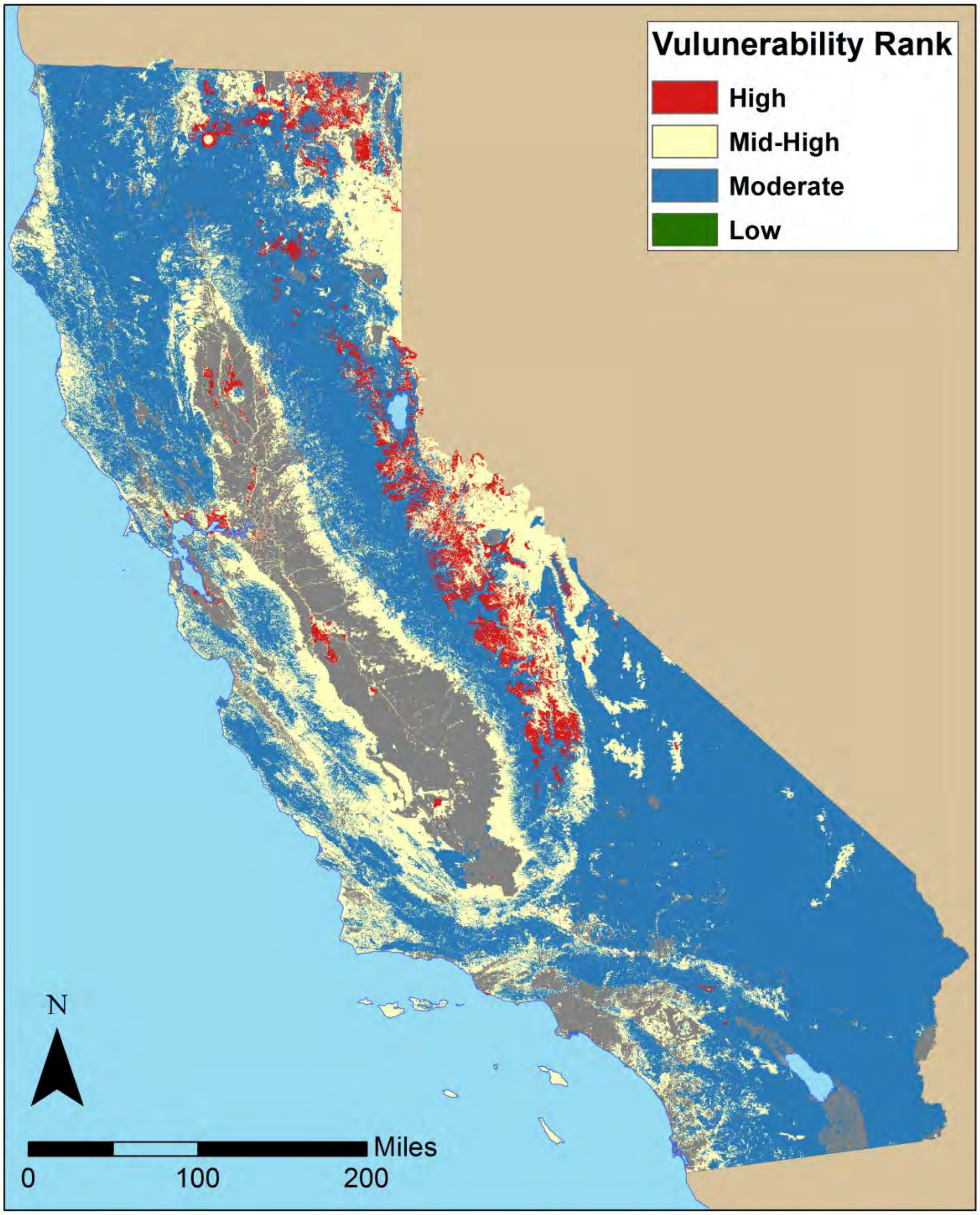


Figure 1. Macrogroup Vulnerability Rankings Averaged Across Climate Projections. The average vulnerability ranking for macrogroups across the four climate projections used. Grey areas on the map represent urban and agricultural areas and were not evaluated.

Table 2. Climate Vulnerability Scores for All Macrogroups and Climate Projections. The climate vulnerability scores for macrogroups scored for four climate projections. The range in values for each macrogroup shows that most transition from one to another level of vulnerability, depending on the climate projection. The breaks vulnerability scores are: Low = 0.294-1.180; Medium = 1.180 – 2.066; High = 2.066 – 2.952. 'S&A' stands for sensitivity and adaptive capacity.

Macrogroup (Common Name)	Climate Scenario	S&A Score	S&A Rank	Climate Exposure (% >95%)	Spatial Disruption (% No Longer Suitable)	Mean Climate Exposure & Spatial Disruption Score	Climate Exposure & Spatial Disruption Rank	Combined Vulnerability Rank	Mean Combined Vulnerability Rank
9. California Foothill and Valley Forests and Woodlands	CNRM CM5 - RCP 4.5	3.12	Moderate	32%	24.50%	28.25%	Moderate	Moderate	Moderate
	CNRM CM5 - RCP 8.5	3.12	Moderate	54%	31.70%	42.85%	Moderate	Moderate	
	MIROC ESM - RCP 4.5	3.12	Moderate	17%	39.80%	28.40%	Moderate	Moderate	
	MIROC ESM - RCP 8.5	3.12	Moderate	47%	59.50%	53.25%	Mid-High	Mid-High	
20. Subalpine Aspen Forests & Pine Woodlands	CNRM CM5 - RCP 4.5	2.50	High	19%	33.80%	26.40%	Moderate	Mid-High	High
	CNRM CM5 - RCP 8.5	2.50	High	53%	66.70%	59.85%	Mid-High	High	
	MIROC ESM - RCP 4.5	2.50	High	33%	72.20%	52.60%	Mid-High	High	
	MIROC ESM - RCP 8.5	2.50	High	84%	94.90%	89.45%	High	High	
23. North Coastal Mixed Evergreen and Montane Conifer Forests	CNRM CM5 - RCP 4.5	2.86	Mid-High	11%	10.90%	10.95%	Low	Moderate	Moderate
	CNRM CM5 - RCP 8.5	2.86	Mid-High	22%	18.80%	20.40%	Low	Moderate	
	MIROC ESM - RCP 4.5	2.86	Mid-High	12%	43.50%	27.75%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.86	Mid-High	34%	69.40%	51.70%	Mid-High	Mid-High	
24. Pacific Northwest Conifer Forests	CNRM CM5 - RCP 4.5	2.89	Moderate	51%	26.80%	38.90%	Moderate	Moderate	Mid-High
	CNRM CM5 - RCP 8.5	2.89	Moderate	89%	48.70%	68.85%	Mid-High	Mid-High	
	MIROC ESM - RCP 4.5	2.89	Moderate	24%	53.00%	38.50%	Moderate	Moderate	
	MIROC ESM - RCP 8.5	2.89	Moderate	53%	81.30%	67.15%	Mid-High	Mid-High	
25. Pacific Northwest Subalpine Forest	CNRM CM5 - RCP 4.5	2.63	Mid-High	1%	60.10%	30.55%	Moderate	Mid-High	Mid-High
	CNRM CM5 - RCP 8.5	2.63	Mid-High	10%	67.50%	38.75%	Moderate	Mid-High	
	MIROC ESM - RCP 4.5	2.63	Mid-High	6%	84.90%	45.45%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.63	Mid-High	44%	93.50%	68.75%	Mid-High	Mid-High	
26. Great Basin Pinyon-Juniper Woodland	CNRM CM5 - RCP 4.5	2.22	High	26%	50.30%	38.15%	Moderate	Mid-High	Mid-High
	CNRM CM5 - RCP 8.5	2.22	High	72%	69.30%	70.65%	Mid-High	High	
	MIROC ESM - RCP 4.5	2.22	High	16%	38.90%	27.45%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.22	High	28%	50.80%	39.40%	Moderate	Mid-High	
27. Non-Native Forest and woodlands	CNRM CM5 - RCP 4.5	3.56	Low	71%	17.40%	44.20%	Moderate	Moderate	Moderate
	CNRM CM5 - RCP 8.5	3.56	Low	97%	10.50%	53.75%	Mid-High	Moderate	
	MIROC ESM - RCP 4.5	3.56	Low	36%	12.00%	24.00%	Low	Low	
	MIROC ESM - RCP 8.5	3.56	Low	74%	6.20%	40.10%	Moderate	Moderate	

Macrogroup (Common Name)	Climate Scenario	S&A Score	S&A Rank	Climate Exposure (% >95%)	Spatial Disruption (% No Longer Suitable)	Mean Climate Exposure & Spatial Disruption Score	Climate Exposure & Spatial Disruption Rank	Combined Vulnerability Rank	Mean Combined Vulnerability Rank
34. North Coastal Riparian and Montane Riparian Forest and Woodland	CNRM CM5 - RCP 4.5	2.89	Moderate	20%	22.50%	21.25%	Low	Moderate	Moderate
	CNRM CM5 - RCP 8.5	2.89	Moderate	26%	25.30%	25.65%	Moderate	Moderate	
	MIROC ESM - RCP 4.5	2.89	Moderate	7%	30.80%	18.90%	Low	Moderate	
	MIROC ESM - RCP 8.5	2.89	Moderate	18%	39.40%	28.70%	Moderate	Moderate	
36. American Southwest Riparian Forest and Woodland	CNRM CM5 - RCP 4.5	3.20	Moderate	57%	24.30%	40.65%	Moderate	Moderate	Mid-High
	CNRM CM5 - RCP 8.5	3.20	Moderate	88%	22.80%	55.40%	Mid-High	Mid-High	
	MIROC ESM - RCP 4.5	3.20	Moderate	43%	15.50%	29.25%	Moderate	Moderate	
	MIROC ESM - RCP 8.5	3.20	Moderate	84%	19.90%	51.95%	Mid-High	Mid-High	
43. Chaparral	CNRM CM5 - RCP 4.5	2.89	Moderate	16%	8.10%	12.05%	Low	Moderate	Moderate
	CNRM CM5 - RCP 8.5	2.89	Moderate	38%	9.10%	23.55%	Low	Moderate	
	MIROC ESM - RCP 4.5	2.89	Moderate	19%	28.00%	23.50%	Low	Moderate	
	MIROC ESM - RCP 8.5	2.89	Moderate	42%	53.90%	47.95%	Moderate	Moderate	
44. Coastal Sage Scrub	CNRM CM5 - RCP 4.5	2.78	Mid-High	25%	13.50%	19.25%	Low	Moderate	Mid-High
	CNRM CM5 - RCP 8.5	2.78	Mid-High	62%	8.70%	35.35%	Moderate	Mid-High	
	MIROC ESM - RCP 4.5	2.78	Mid-High	34%	20.70%	27.35%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.78	Mid-High	59%	27.70%	43.35%	Moderate	Mid-High	
45. California Grassland and Flowerfields	CNRM CM5 - RCP 4.5	2.81	Mid-High	33%	17.70%	25.35%	Moderate	Mid-High	Mid-High
	CNRM CM5 - RCP 8.5	2.81	Mid-High	60%	34.30%	47.15%	Moderate	Mid-High	
	MIROC ESM - RCP 4.5	2.81	Mid-High	24%	16.10%	20.05%	Low	Moderate	
	MIROC ESM - RCP 8.5	2.81	Mid-High	53%	48.30%	50.65%	Mid-High	Mid-High	
47. Mountain Riparian Scrub and Wet Meadow	CNRM CM5 - RCP 4.5	2.97	Moderate	29%	26.70%	27.85%	Moderate	Moderate	Mid-High
	CNRM CM5 - RCP 8.5	2.97	Moderate	85%	69.10%	77.05%	High	Mid-High	
	MIROC ESM - RCP 4.5	2.97	Moderate	16%	36.10%	26.05%	Moderate	Moderate	
	MIROC ESM - RCP 8.5	2.97	Moderate	59%	73.30%	66.15%	Mid-High	Mid-High	
48. Western Upland Grasslands	CNRM CM5 - RCP 4.5	2.58	Mid-High	19%	88.10%	53.55%	Mid-High	Mid-High	Mid-High
	CNRM CM5 - RCP 8.5	2.58	Mid-High	26%	97.60%	61.80%	Mid-High	Mid-High	
	MIROC ESM - RCP 4.5	2.58	Mid-High	2%	89.80%	45.90%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.58	Mid-High	14%	100.00%	57.00%	Mid-High	Mid-High	

Macrogroup (Common Name)	Climate Scenario	S&A Score	S&A Rank	Climate Exposure (% >95%)	Spatial Disruption (% No Longer Suitable)	Mean Climate Exposure & Spatial Disruption Score	Climate Exposure & Spatial Disruption Rank	Combined Vulnerability Rank	Mean Combined Vulnerability Rank
50. North Coast Deciduous Scrub and Terrace Prairie	CNRM CM5 - RCP 4.5	2.97	**Moderate**	16%	26.30%	21.15%	**Low**	**Moderate**	**Moderate**
	CNRM CM5 - RCP 8.5	2.97	**Moderate**	30%	40.20%	35.10%	**Moderate**	**Moderate**	
	MIROC ESM - RCP 4.5	2.97	**Moderate**	13%	29.20%	21.10%	**Low**	**Moderate**	
	MIROC ESM - RCP 8.5	2.97	**Moderate**	50%	57.30%	53.65%	**Mid-High**	**Mid-High**	
52. Montane Chaparral	CNRM CM5 - RCP 4.5	3.00	**Moderate**	6%	20.60%	13.30%	**Low**	**Moderate**	**Moderate**
	CNRM CM5 - RCP 8.5	3.00	**Moderate**	18%	47.30%	32.65%	**Moderate**	**Moderate**	
	MIROC ESM - RCP 4.5	3.00	**Moderate**	3%	38.80%	20.90%	**Low**	**Moderate**	
	MIROC ESM - RCP 8.5	3.00	**Moderate**	13%	68.90%	40.95%	**Moderate**	**Moderate**	
58. Coastal Dune and Bluff Scrub	CNRM CM5 - RCP 4.5	2.41	**High**	51%	12.40%	31.70%	**Moderate**	**Mid-High**	**Mid-High**
	CNRM CM5 - RCP 8.5	2.41	**High**	92%	4.40%	48.20%	**Moderate**	**Mid-High**	
	MIROC ESM - RCP 4.5	2.41	**High**	42%	14.60%	28.30%	**Moderate**	**Mid-High**	
	MIROC ESM - RCP 8.5	2.41	**High**	64%	0.40%	32.20%	**Moderate**	**Mid-High**	
73. Freshwater Marsh	CNRM CM5 - RCP 4.5	3.00	**Moderate**	99%	74.20%	86.60%	**High**	**High**	**High**
	CNRM CM5 - RCP 8.5	3.00	**Moderate**	100%	96.80%	98.40%	**High**	**High**	
	MIROC ESM - RCP 4.5	3.00	**Moderate**	96%	71.30%	83.65%	**High**	**High**	
	MIROC ESM - RCP 8.5	3.00	**Moderate**	100%	93.10%	96.55%	**High**	**High**	
75. Wet Mountain Meadow	CNRM CM5 - RCP 4.5	2.21	**High**	17%	57.40%	37.20%	**Moderate**	**Mid-High**	**Mid-High**
	CNRM CM5 - RCP 8.5	2.21	**High**	58%	78.90%	68.45%	**Mid-High**	**High**	
	MIROC ESM - RCP 4.5	2.21	**High**	11%	55.00%	33.00%	**Moderate**	**Mid-High**	
	MIROC ESM - RCP 8.5	2.21	**High**	29%	75.70%	52.35%	**Mid-High**	**High**	
81. Salt Marsh Meadows	CNRM CM5 - RCP 4.5	3.00	**Moderate**	100%	72.40%	86.20%	**High**	**High**	**High**
	CNRM CM5 - RCP 8.5	3.00	**Moderate**	100%	85.20%	92.60%	**High**	**High**	
	MIROC ESM - RCP 4.5	3.00	**Moderate**	93%	70.80%	81.90%	**High**	**High**	
	MIROC ESM - RCP 8.5	3.00	**Moderate**	100%	92.20%	96.10%	**High**	**High**	
88. Mojave and Sonoran Desert Scrub	CNRM CM5 - RCP 4.5	2.84	**Mid-High**	31%	13.60%	22.30%	**Low**	**Moderate**	**Moderate**
	CNRM CM5 - RCP 8.5	2.84	**Mid-High**	70%	22.30%	46.15%	**Moderate**	**Mid-High**	
	MIROC ESM - RCP 4.5	2.84	**Mid-High**	23%	0.00%	11.50%	**Low**	**Moderate**	
	MIROC ESM - RCP 8.5	2.84	**Mid-High**	47%	0.10%	23.55%	**Low**	**Moderate**	

Macrogroup (Common Name)	Climate Scenario	S&A Score	S&A Rank	Climate Exposure (% >95%)	Spatial Disruption (% No Longer Suitable)	Mean Climate Exposure & Spatial Disruption Score	Climate Exposure & Spatial Disruption Rank	Combined Vulnerability Rank	Mean Combined Vulnerability Rank
92. Desert Wash Woodland and Scrub	CNRM CM5 - RCP 4.5	3.15	Moderate	27%	0.30%	13.65%	Low	Moderate	Moderate
	CNRM CM5 - RCP 8.5	3.15	Moderate	75%	0.40%	37.70%	Moderate	Moderate	
	MIROC ESM - RCP 4.5	3.15	Moderate	33%	0.00%	16.50%	Low	Moderate	
	MIROC ESM - RCP 8.5	3.15	Moderate	65%	0.00%	32.50%	Moderate	Moderate	
93. Shadscale-Saltbush Scrub	CNRM CM5 - RCP 4.5	3.11	Moderate	49%	61.10%	55.05%	Mid-High	Mid-High	Moderate
	CNRM CM5 - RCP 8.5	3.11	Moderate	83%	96.60%	89.80%	High	Mid-High	
	MIROC ESM - RCP 4.5	3.11	Moderate	22%	14.70%	18.35%	Low	Moderate	
	MIROC ESM - RCP 8.5	3.11	Moderate	28%	37.50%	32.75%	Moderate	Moderate	
96. Big Sagebrush Scrub	CNRM CM5 - RCP 4.5	2.67	Mid-High	40%	39.00%	39.50%	Moderate	Mid-High	Mid-High
	CNRM CM5 - RCP 8.5	2.67	Mid-High	86%	84.20%	85.10%	High	High	
	MIROC ESM - RCP 4.5	2.67	Mid-High	12%	14.70%	13.35%	Low	Moderate	
	MIROC ESM - RCP 8.5	2.67	Mid-High	28%	37.70%	32.85%	Moderate	Mid-High	
97. Great Basin Dwarf Sagebrush Scrub	CNRM CM5 - RCP 4.5	2.33	High	97%	99.90%	98.45%	High	High	High
	CNRM CM5 - RCP 8.5	2.33	High	99%	100.00%	99.50%	High	High	
	MIROC ESM - RCP 4.5	2.33	High	93%	100.00%	96.50%	High	High	
	MIROC ESM - RCP 8.5	2.33	High	99%	100.00%	99.50%	High	High	
98. Great Basin Upland Scrub	CNRM CM5 - RCP 4.5	2.44	High	67%	33.80%	50.40%	Mid-High	High	High
	CNRM CM5 - RCP 8.5	2.44	High	95%	74.80%	84.90%	High	High	
	MIROC ESM - RCP 4.5	2.44	High	36%	16.30%	26.15%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.44	High	98%	51.20%	74.60%	Mid-High	High	
101. Alpine Vegetation	CNRM CM5 - RCP 4.5	2.76	Mid-High	33%	47.30%	40.15%	Moderate	Mid-High	High
	CNRM CM5 - RCP 8.5	2.76	Mid-High	94%	76.00%	85.00%	High	High	
	MIROC ESM - RCP 4.5	2.76	Mid-High	77%	90.70%	83.85%	High	High	
	MIROC ESM - RCP 8.5	2.76	Mid-High	97%	98.20%	97.60%	High	High	
106. Brackish (estuarine) Submerged Aquatic Vegetation	CNRM CM5 - RCP 4.5	Not scored		Not scored	100.00%	100.00%			
	CNRM CM5 - RCP 8.5				100.00%	100.00%			
	MIROC ESM - RCP 4.5				100.00%	100.00%			
	MIROC ESM - RCP 8.5				100.00%	100.00%			

Macrogroup (Common Name)	Climate Scenario	S&A Score	S&A Rank	Climate Exposure (% >95%)	Spatial Disruption (% No Longer Suitable)	Mean Climate Exposure & Spatial Disruption Score	Climate Exposure & Spatial Disruption Rank	Combined Vulnerability Rank	Mean Combined Vulnerability Rank
110. California Foothill and Coastal Rock Outcrop Vegetation	CNRM CM5 - RCP 4.5	2.78	Mid-High	13%	13.70%	13.35%	Low	Moderate	Mid-High
	CNRM CM5 - RCP 8.5	2.78	Mid-High	30%	45.70%	37.85%	Moderate	Mid-High	
	MIROC ESM - RCP 4.5	2.78	Mid-High	3%	66.40%	34.70%	Moderate	Mid-High	
	MIROC ESM - RCP 8.5	2.78	Mid-High	8%	93.60%	50.80%	Mid-High	Mid-High	
114. Northwest Coast Cliff and Outcrop	CNRM CM5 - RCP 4.5	Not scored		16%	72.10%	44.05%			
	CNRM CM5 - RCP 8.5			26%	89.20%	57.60%			
	MIROC ESM - RCP 4.5			21%	80.60%	50.80%			
	MIROC ESM - RCP 8.5			26%	95.40%	60.70%			
117. Sparsely Vegetated Desert Dune	CNRM CM5 - RCP 4.5	2.67	Mid-High	16%	6.10%	11.05%	Low	Moderate	Moderate
	CNRM CM5 - RCP 8.5	2.67	Mid-High	70%	12.50%	41.25%	Moderate	Mid-High	
	MIROC ESM - RCP 4.5	2.67	Mid-High	23%	0.90%	11.95%	Low	Moderate	
	MIROC ESM - RCP 8.5	2.67	Mid-High	60%	0.90%	30.45%	Moderate	Mid-High	

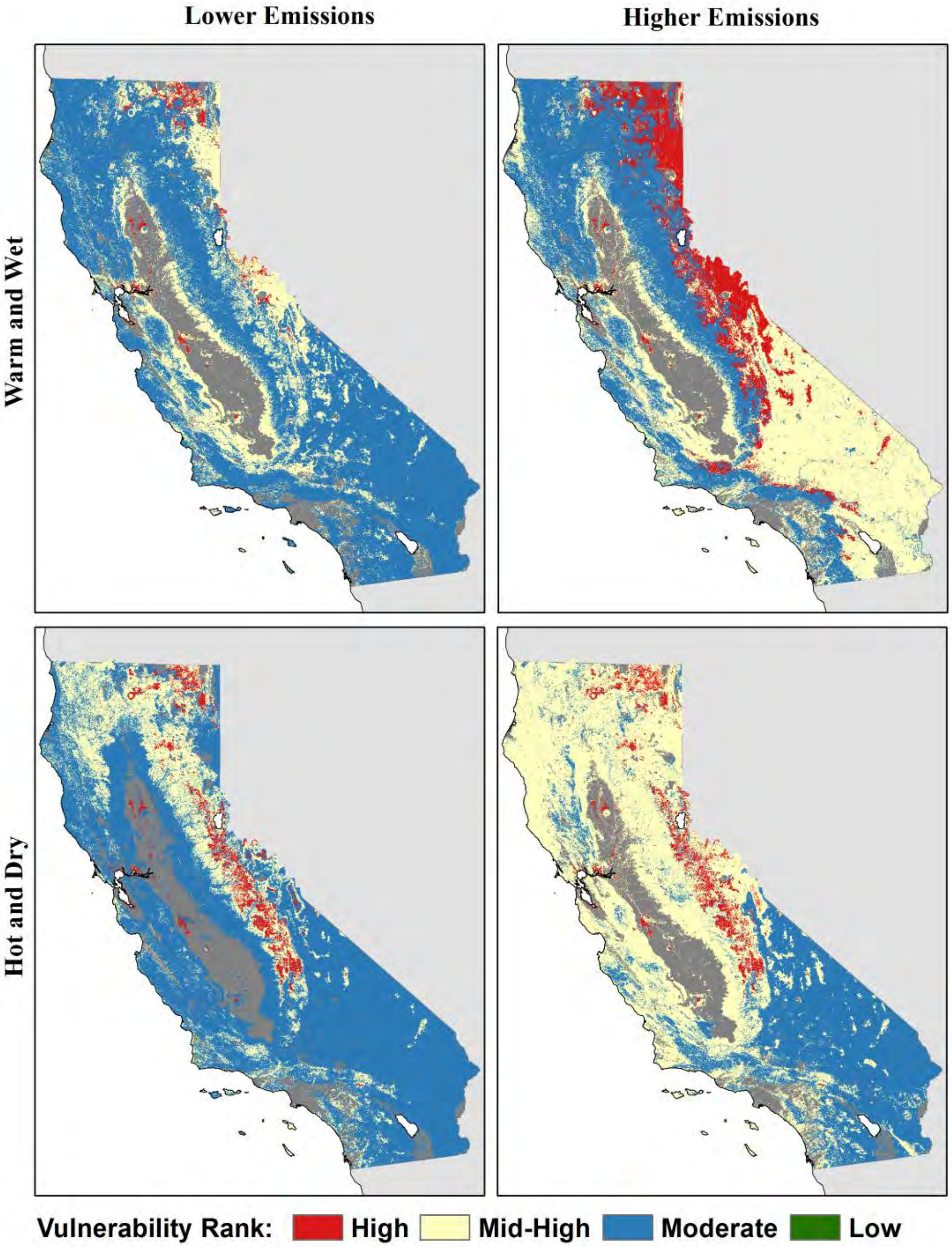


Figure 2. Mapped End-of-Century Vulnerability Rankings Under Four Climate Projections. A map of the end century vulnerability rankings for macrogroups under the four climate projections. "Warm and Wet" = CNRM CM5, "Hot and Dry" = MIROC ESM, Lower Emissions = RCP 4.5, and Higher Emissions = RCP 8.5. Grey areas on the map represent urban and agricultural areas and were not evaluated.

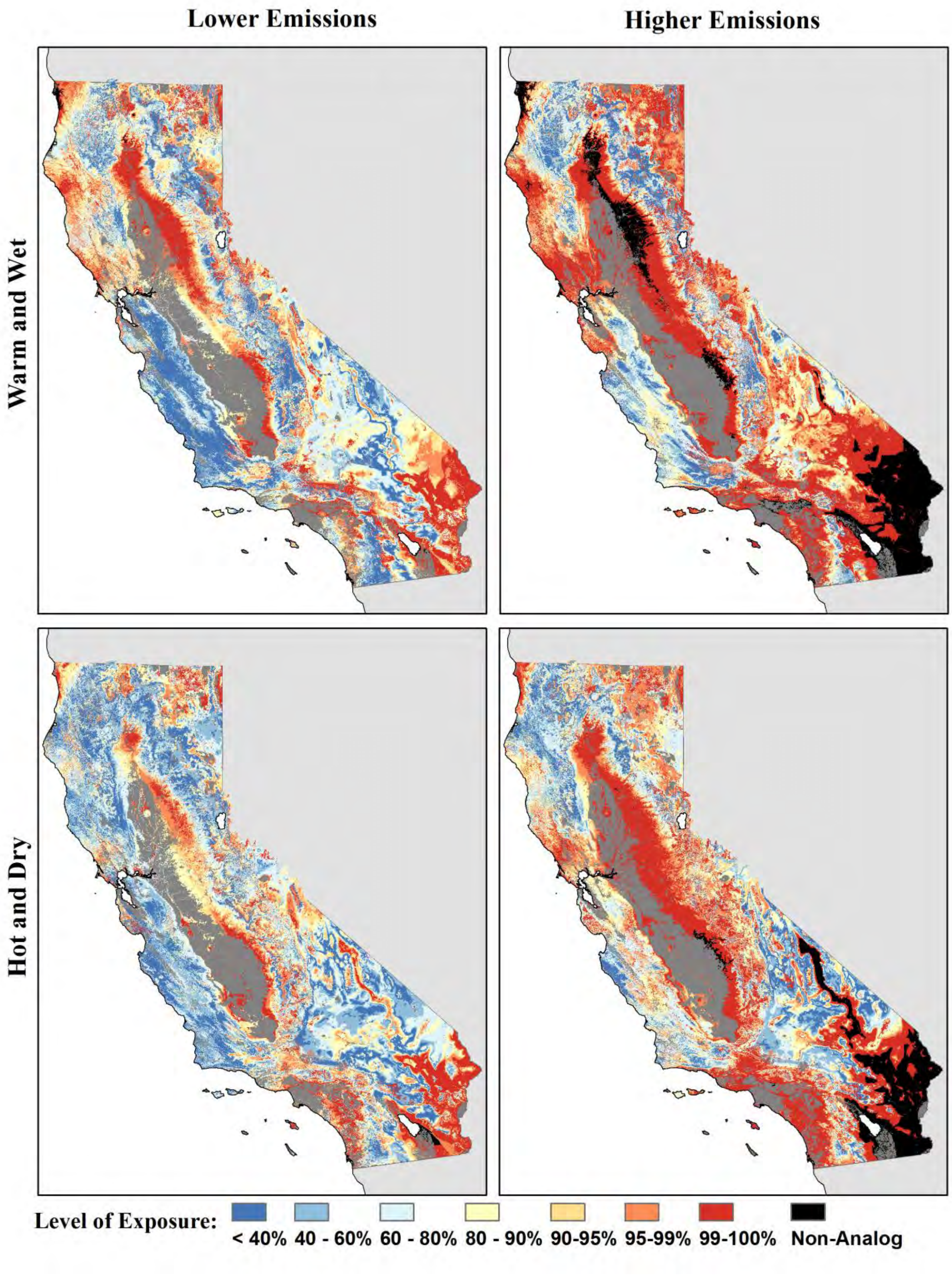


Figure 3. Mapped Climate Exposure Under Four Climate Projections. This image shows the climate exposure of macrogroups under the four climate projections. Areas considered to be highly stressed are in the 95-99%, 99-100% and Non-Analog categories. Areas with values <80% are considered to be in climatically suitable conditions for the vegetation that currently occupies them. “Warm and Wet” = CNRM CM5, “Hot and Dry” = MIROC ESM, Lower Emissions = RCP 4.5, and Higher Emissions = RCP 8.5. Grey areas on the map represent urban and agricultural areas and were not evaluated

Table 3. Extent of Vegetation in Each Vulnerability Class. The extent of vegetation in each vulnerability class by the end century under four climate projections.

Vulnerability Class	CNRM CM5 4.5 (km^2)	Miroc ESM 4.5 (km^2)	CNRM CM5 8.5 (km^2)	Miroc ESM 8.5 (km^2)
Low	0	0	228	0
Moderate	254,228	143,476	255,536	129,811
Mid-High	91,971	164,086	82,168	206,357
High	6,458	45,094	14,724	16,488
Not Analyzed	615	615	615	615
Total	353,271	353,271	353,271	353,271

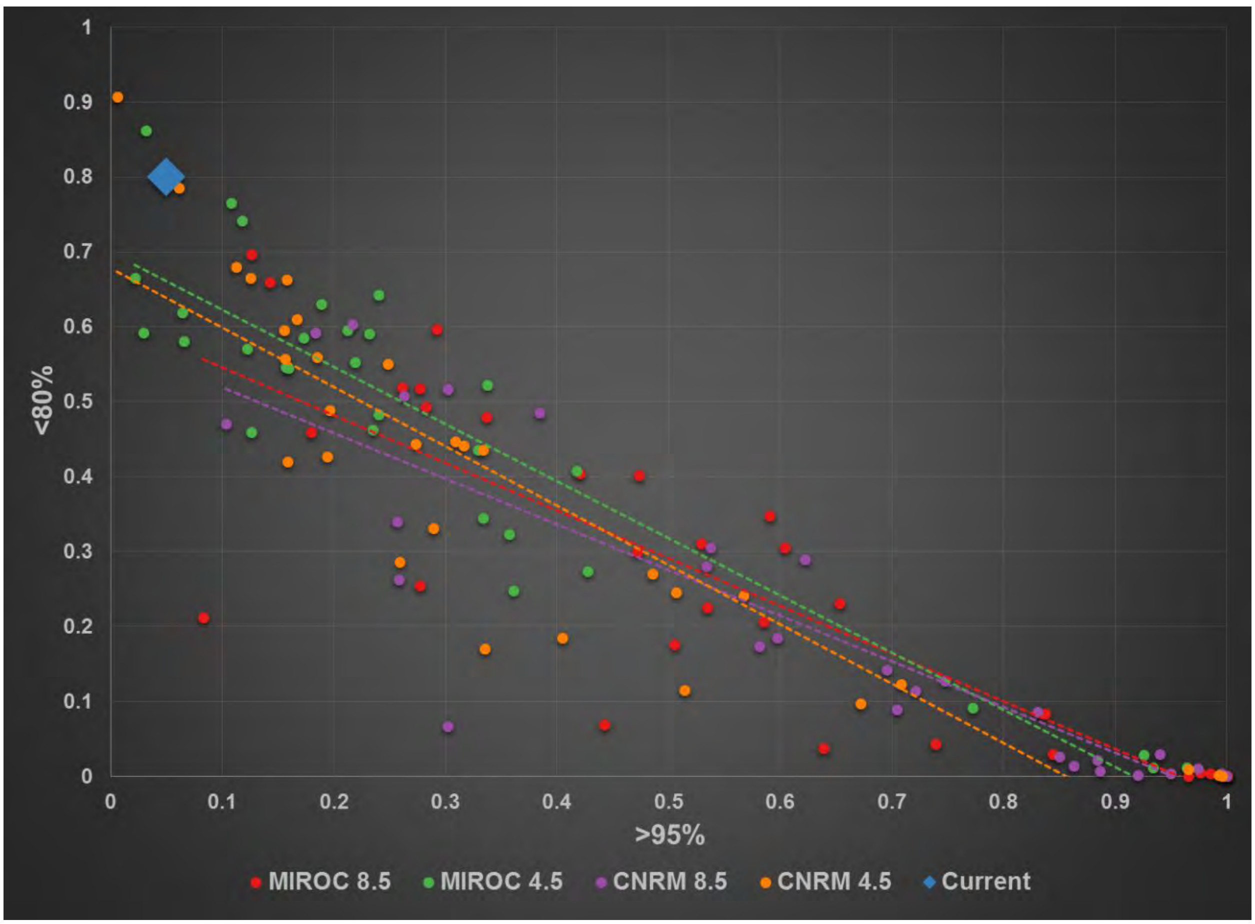


Figure 4. Percentage of Each Macrogroup Under Climatically Suitable and Stressed Conditions. The percent of each macrogroup under suitable (<80%) and stressed (>95%) conditions for each climate projection. Current-time classification is shown as the blue diamond, which sets 80% of the area of each type as climatically suitable and 5% as already marginal. The colored dots represent the macrogroups in each of the four future climates modeled. The dots further to the right are macrogroups with higher proportions of their extent in highly climatically exposed conditions by 2100. Note that the proportions do not sum to 100% because the mid-level climate conditions (80-95%) are not shown.

INTRODUCTION

Purpose of study

Climate change is a major challenge to the conservation of California's natural resources. Climatic changes are already occurring in the state and have resulted in observed changes in natural systems. For example, migrating butterflies have been appearing earlier in the year, some mammal species population distributions have shifted, and some forest species are gradually moving to higher elevations[5]. Projected changes in climate, including extreme events such as fire, drought, flood, extreme temperatures, and storm events, are likely to have significant impacts on habitats, species, and human communities in the near future[6].

California is ranked as a global biodiversity hotspot, both biologically diverse and highly threatened. As stewards of the state's diverse fish, wildlife, and plant species, and the habitats they depend on, the California Department of Fish and Wildlife (CDFW) needs to better understand and plan for these environmental changes. The CDFW has taken a lead role in climate adaptation planning for biodiversity conservation. For example, the 2015 revision of the State Wildlife Action Plan (SWAP 2015)[7], presents an opportunity to review climate risks from the perspective of developing a state-wide framework for conservation.

The CDFW requested the University of California, Davis to produce a California-wide, climate change vulnerability analysis at the macro-habitat scale for aggregated terrestrial vegetation types. Climate vulnerability is defined as a species' or system's exposure to and sensitivity to climatic changes and its ability to adapt to or cope with these changes.

The vegetation classification used in this study and in the SWAP report is a mid-level step in the National Vegetation Classification System (NVCS) called Macrogroups[8], which represent the 4th level up of generalization from the most detailed descriptions (Association) and the 5th level down from the most general. Macrogroups were chosen as the reporting unit for this analysis as these vegetation types serve as terrestrial conservation targets in the SWAP, and conservation strategies have been developed for them as part of the SWAP 2015 update. This report does not include a detailed analysis for all macrogroups presented in the SWAP 2015 update, as only 31 macrogroups are mapped in the 2015 vegetation map of the state that we used. See the 'Vegetation Data' section for more detail.

Use of Study Results
The detailed results of the macrogroup vulnerability assessment presented here can contribute to the development of climate adaptation strategies that complement and provide context for conservation strategies for California's major vegetation types. The study results could also be used in climate change scenario planning exercises, and may be especially informative when combined with the results of taxa or species-specific climate vulnerability assessments that have been completed in previous years by CDFW and partners.

The scores provided in this study are general estimates of vulnerability, and are best used in concert with one another to evaluate the relative vulnerability of California's plant communities to climate change; they should not be viewed as local predictions or declarations of vulnerability at an individual site. Reviewing the components that comprise the overall vulnerability score (the climate exposure, sensitivity, adaptive capacity, and spatial disruption) will be more useful than the overall score, when examining impacts to an individual vegetative community. It should be noted that these components incorporate explicit assumptions about how individual species will respond to climate change, often relying in part on expert opinion and published literature. Because current knowledge about each vegetation type and associated physiological responses to climate varies, these assumptions introduce some uncertainty into the component scores that are incorporated into the overall vulnerability score of an individual macrogroup. As more information about individual plant species becomes available, component scores can be updated and new categories of rankings added (e.g. plant species rooting depth), and the overall vulnerability score of a macrogroup adjusted accordingly. The approach presented here is designed to accommodate the addition of new information and future modifications with relative ease.

[5] http://www.oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicatorsReport2013.pdf
[6] http://www.energy.ca.gov/2012publications/CEC-500-2012-007/CEC-500-2012-007.pdf
[7] http://www.dfg.ca.gov/swap/
[8] http://usnvc.org/data-standard/natural-vegetation-classification/

All data products related to this report were provided to the CDFW. It is the intention of CDFW to make the data available to the public via a website called the California Climate Commons (http://climate.calcommons.org/). The date of posting of the data has not yet been determined, and is beyond the scope of this report.

Organization of the report

This introduction presents the approaches used for the vulnerability assessment, an overview of the data used, and spatial representation of the statewide results. A summary of key results is presented in the Executive Summary at the top of this report. Results for each of the macrogroups analyzed are presented in separate profile sections hereafter.

The report addresses all of California's lands that are occupied by native vegetation, and excludes the agricultural and urban regions. The report details 31 macrogroups, covering 99.87% of the state's natural terrestrial vegetation, which were analyzed across their full mapped extent. The results were also produced as geographic information system (GIS) data, which can be combined with various spatial representations of California such as counties or ecoregions for more regional analyses. In the interests of brevity, ecoregional summaries are not included in the report.

APPROACH USED

The objectives of this report are to assess the climatic vulnerability of California's terrestrial macrogroups, and to create a ranking system that is transparent and updateable. To do this, we compiled four types of information as components of an overall vulnerability score. Each macrogroup's overall score is a combination of estimates of its sensitivity, adaptive capacity, climate exposure and expected shifts in extent. This section presents a summary of the methods used. More detailed information on how the individual estimates were derived is presented in the Analysis Approach section below.

First, each Macrogroup (MG) was analyzed to determine which California habitats and associated dominant plant species make up its definition. California habitats are defined by the California Department of Fish and Wildlife (CDFW) through their California Wildlife Habitat Relationship (WHR) models[9]. WHR types are made up of plant species, such as the dominant trees, shrubs, and smaller plants. CDFW experts determined which WHR types correspond to each individual macrogroup; this cross-walk was used to develop a list of the dominant plant species that comprise each macrogroup.

We then scored each dominant species for its sensitivity to, and ability to adapt (adaptive capacity) to climate change. Sensitivity refers to the degree to which changes in climate are thought to directly impact different species. Adaptive capacity refers to estimates of the degree to which different species can use their life history characteristics to moderate impacts from changing climate. These two sets of scores represent the biological attributes of the dominant species in each macrogroup. We scored each of the dominant species comprising each macrogroup, according to life history characteristics defined in attribute tables of the California Manual of Vegetation (Keeler Wolf et al. 2009[10]), and supplemented by information found in the USDA plants database[11] and the Jepson Interchange[12], a web portal for California plant taxonomy. The scores were combined to generate a single sensitivity and adaptive capacity (S&A) score. More detail is provided in the "Analysis Approach" section below.

Climate exposure is the level of climate change expected in the areas where each macrogroup is dominating. This report uses the term "vegetation climate exposure analysis" to describe the following analysis which was conducted on each macrogroup. The vegetation climate exposure analysis is calculated using the mapped extent of each macrogroup. Every grid cell of each macrogroup was ranked as to its level of exposure, relative to the entire area of that macrogroup. This was done for the current time, and used to define the common climate found for each macrogroup. Once each type's "climate envelope" was defined, we then assessed how much every grid cell changed under various future climate projections. This allowed a measure of the vegetation stress, or climate exposure. The area extent of each macrogroup that will be lost from the most commonly occurring climate conditions (≤80%) and the area that will fall into current marginal,

---

[9] https://www.dfg.ca.gov/biogeodata/cwhr/wildlife_habitats.asp
[10] http://www.cnps.org/cnps/vegetation/manual.php
[11] http://www.plants.usda.gov
[12] http://ucjeps.berkeley.edu/interchange/

or stressed, climate conditions (>95%) or outside the current climate conditions was calculated. This approach is particularly useful for resource managers, who often are constrained to work in specified areas, and need estimates of what areas within their jurisdiction are likely to be highly stressed, and what areas are likely to be less stressed, in effect climate refuge areas. A more detailed description of the climate exposure analysis can be found in the Analysis Approach section below. Detailed information on climate data is presented under 'Climate Model Selection and Data' in the "Data Used" section below.

The fourth measure is an estimate of the spatial disruption that could be expected for each macrogroup. To evaluate spatial disruption, expected shifts in the area occupied by each macrogroup were modeled using the species distribution model Maxent[13], a software program used to predict the range of a species, given a series of known locations, and environmental predictor variables such as temperature and precipitation. We randomly sampled the map of each macrogroup for 300 presence locations. These were used to develop current and future ranges, or expected extents of each macrogroup. The difference in current and future extent represents the amount of spatial disruption that can be expected for a given type. We measured this as the percent of predicted currently suitable range lost. We show the potential future suitable range gained under climate projections, but do not include it in the vulnerability scoring due to assumptions regarding the ability of the vegetation type as a whole to disperse to the new area and the concurrent required vacating of space by other occupying vegetation to accommodate vegetation transition. A more detailed description of the spatial disruption analysis can be found in the section below titled "Analysis Approach".

The four measures were then combined into an index of vulnerability for each macrogroup, allowing for a relative cross-comparison of macrogroups. Vulnerability scores were calculated, and are portrayed in tabular, graphical, and map-based forms in the profile for each type, with a summary of expected vulnerability for all types in the Executive Summary. The tables in each profile include numeric and categorical vulnerability scores, made up from the component scores for sensitivity and adaptive capacity, exposure and turnover. We tested several ways to calculate a combined vulnerability score, which all produced similar results. This report uses a simple classification table. The vertical axis of the table classes the S&A scores into four 25% categories, from the minimum score of 2.21 to the maximum score of 3.56. The horizontal axis of the table classes the mean of the climate exposure and spatial disruption scores into four 25% categories as well. The categories in each case are termed 'Low', 'Moderate', Mid-High' and 'High'. Final rankings for each macrogroup are determined from Table 4 as follows:

[13] https://www.cs.princeton.edu/~schapire/maxent/

Table 4. Vulnerability Ranking Rules. This matrix was used to assign vulnerability ranks to macrogroups. The sensitivity and adaptive capacity (S&A scores) represent the mean of nine measures for the dominant plant species analyzed for each macrogroup. Each measure was scored from 1-5, and the overall mean S&A scores were then partitioned into four categories. The mean climate exposure and spatial disruption scores are derived from mapped-based analyses that assess the proportion of current macrogroup extent that becomes climatically stressed, and the proportion of the current modeled range of the macrogroup projected to be lost, respectively. The mean of these two percentages for all macrogroups were portioned into four classes.

		Mean Climate Exposure & Spatial Disruption Score			
		75-100%	**50-75%**	**25-50%**	**0-25%**
		Climate Exposure & Spatial Disruption Rank			
S&A Score	**S&A Rank**	**High**	**Mid-High**	**Moderate**	**Low**
2.210 - 2.5475	**High**	High	High	Mid-High	Mid-High
2.5475 - 2.885	**Mid-High**	High	Mid-High	Mid-High	Moderate
2.885 - 3.225	**Moderate**	High	Mid-High	Moderate	Moderate
3.225 - 3.560	**Low**	Mid-High	Moderate	Moderate	Low

These values were calculated for each of the two GCMs and two emission scenarios. As a final rollup, the mean of the four GCM/emission vulnerability scores was taken, to provide a single cross-comparable vulnerability score for each macrogroup. In the event that there were even numbers of vulnerability ranks within a macrogroup for the four future projections, the mean of the combined climate exposure and spatial disruption score was considered as well as the mean of only the two GCM projections from the RCP 8.5 emission scenario, which is the emissions track that most closely aligns with the 2015 actual emissions globally.

DATA USED

This section describes the two key types of data used in the analysis, climate data and vegetation data.

Climate Model Selection and Data

This report uses projections of future climate using two global climate models (GCMs) that respectively are hotter and drier, and warmer and wetter than current conditions. For each GCM we used two emission scenarios that represent lower and higher levels of greenhouse gas concentration. All analyses were conducted on projections for the end century (2070-2099), which allow the furthest assessment of future trends. Additional climate exposure analyses were conducted for (2010-2039 and 2040-2069).

These modeled projections were selected in a two-part process. First, we wanted to coordinate with the upcoming California Energy Commission climate vulnerability assessment. The lead climate scientists from that effort identified a draft short list of 10 GCMs for California, that meet various criteria based on replicability of current and historical climate conditions, and the ability to predict extreme events. We added two GCMs to the collection and assessed 12 GCMs for a moderate and a high emission scenario (RCP 4.5 and 8.5). These were assessed using 12 km grids of California to quantify the level of difference between current (1981-2010) and future conditions for the state (Figures 5 and 6).

We then statistically downscaled eight of the GCMs to 270m grid scale[14]. At this level, 410,000 km^2 California contains about 5.6 million grid cells, which could be analyzed for projected changes in climate. We reviewed the various climate projections in GIS, and found that they do not represent uniform trends for precipitation and

[14] Flint, L. E., and A. L. Flint. 2012a. Downscaling future climate scenarios to fine scales for hydrologic and ecological modeling and analysis. Ecological Processes 1:1.

temperature across all of California. To select the futures to be reported in this report, we selected two that are relatively much drier or wetter than most of the models, in order to both capture a range of future conditions, and also to minimize the areas within the state that seem to be trending in opposite directions from the overall direction of a given model. The two GCMs selected are MIROC ESM and CNRM CM. The California mean change in annual precipitation (PPT) and annual minimum (TMN) and maximum temperatures (TMX) for these two GCMs and the RCP 4.5 and 8.5 are shown in Table 5. The emission scenarios were selected to represent a more hopeful level of climate change (the lower emissions RCP 4.5) and emissions levels that are closer to the current trend in emissions (the RCP 8.5).

Table 5. Projected Changes in Temperature and Precipitation in California by Climate Scenario. The mean change in annual minimum and maximum temperature, and in precipitation from a current 30-year average, derived from maps representing all of California in 1981-2010, and 2070-2099.

GCM	RCP	Change In Annual Minimum Temperature °C	Tmin SD	Change In Annual Maximum Temperature °C	Tmax SD	Percent Change In Precipitation	PPT SD
CNRM CM5	rcp4.5	1.994	1.773	2.671	1.363	23.0%	23.4%
CNRM CM5	rcp8.5	3.890	1.863	4.284	1.459	38.1%	27.2%
MIROC ESM	rcp4.5	2.534	1.720	3.667	1.418	-18.9%	15.7%
MIROC ESM	rcp8.5	4.557	1.790	5.863	1.657	-24.9%	15.0%

We ran the downscaled CNRM CM5 and MIROC ESM climate models under the RCP 4.5 and 8.5 emission scenarios through the hydroclimatic model called the Basin Characterization Model[15] (Figure 7) (BCM) to obtain a series of landscape hydrology values that could be what vegetation is more directly responding to, including potential evapotranspiration (PET), actual evapotranspiration (AET), climatic water deficit (CWD) (Figure 8), snowpack (PCK) on April 1st, runoff (RUN) and recharge. In sum, 13 climate and hydrological variables were developed for every grid cell.

15 Flint, L.E., A.L. Flint, J.H. Thorne, R.M. Boynton. 2013. Fine-scale hydrological modeling for regional landscape applications: Model development and performance. *Ecological Processes*. 2:25. http://www.ecologicalprocesses.com/content/2/1/25; Thorne, J.H., R.M. Boynton, L.E. Flint, A.L. Flint. 2015. Comparing historic and future climate and hydrology for California's watersheds using the Basin Characterization Model. *Ecosphere* 6(2). Online http://www.esajournals.org/doi/pdf/10.1890/ES14-00300.1; Flint, L. E., and A. L. Flint. 2012a. Downscaling future climate scenarios to fine scales for hydrologic and ecological modeling and analysis. Ecological Processes 1:1.

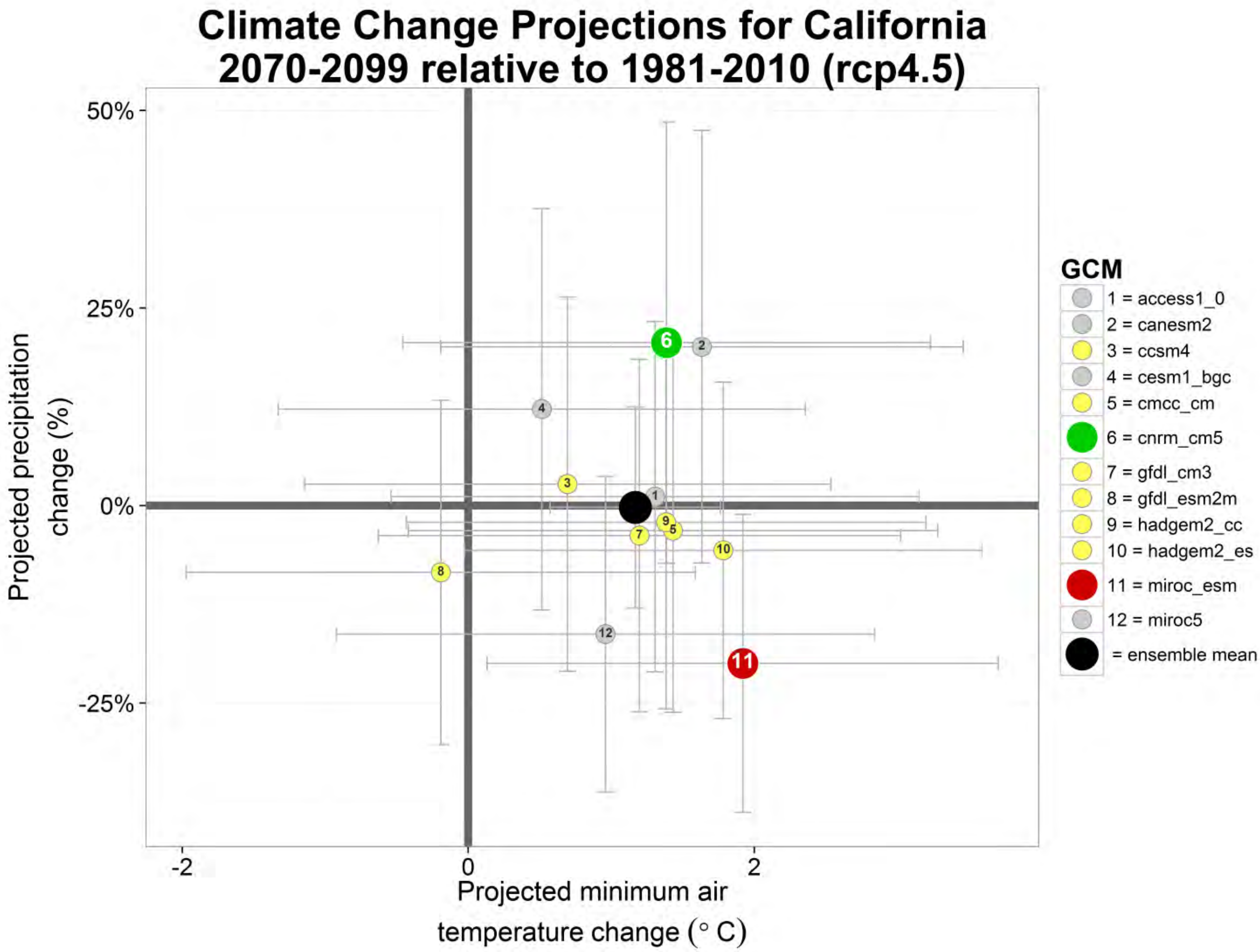


Figure 5. Projected and Historical Climate Comparison for California Under the RCP 4.5 Emissions Scenario. The difference between the 1981-2010 mean annual minimum temperatures and precipitation for California, and the 2070-2099 projections for 12 CMIP5 GCM projections and the RCP 4.5 emission scenario. The origin of the axes represents mean California conditions for the 1981-2010 timeframe, used as the baseline. The x axis refers to changes in temperature, and the y axis to changes from the % of current precipitation.

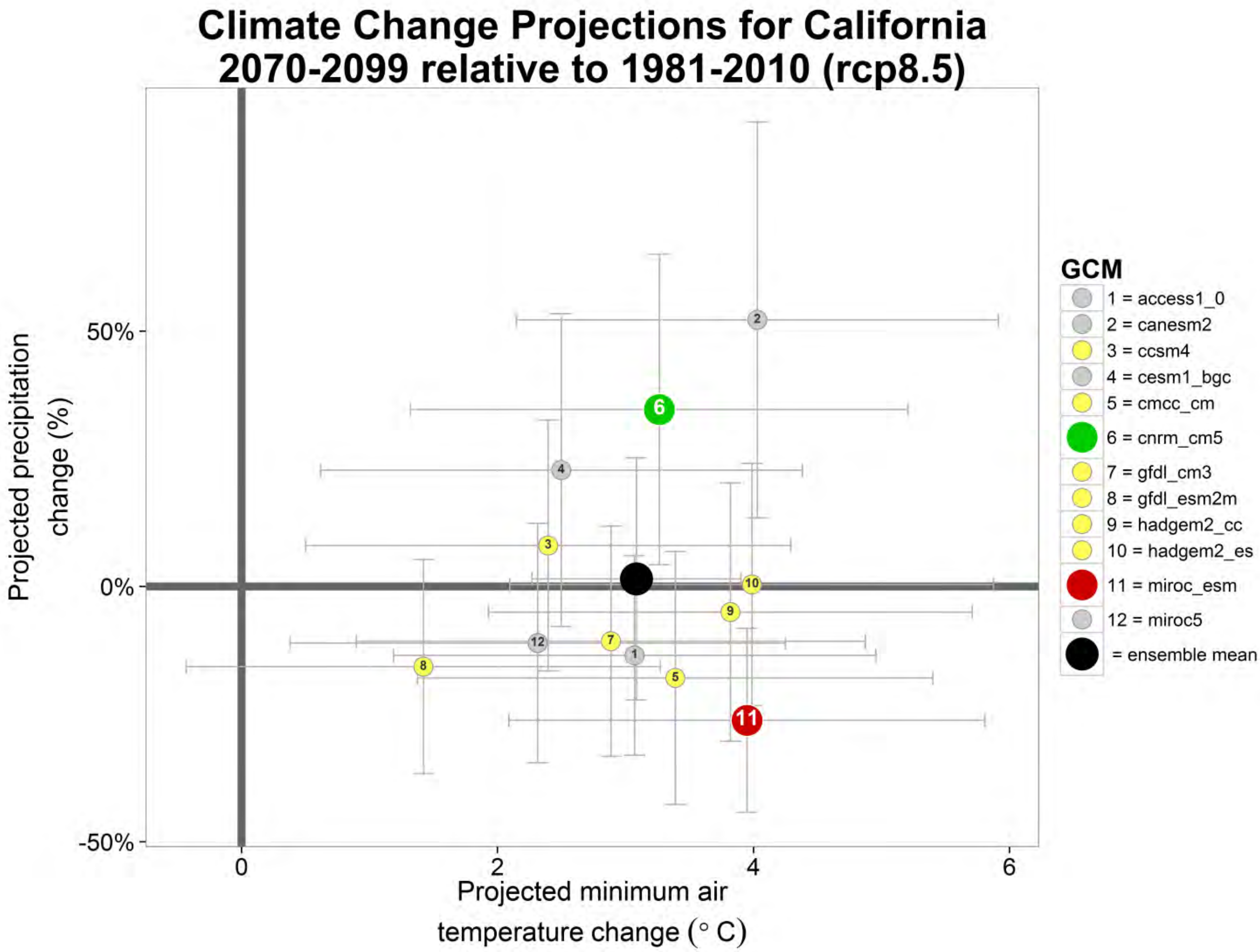


Figure 6. Projected and Historical Climate Comparison for California Under the RCP 8.5 Emissions Scenario. The difference between the 1981-2010 mean annual minimum temperatures and precipitation for California, and the 2070-2099 projections for 12 CMIP5 GCM projections and the RCP 8.5 emission scenario. The origin of the axes represents mean California conditions for the 1981-2010 timeframe, used as the baseline. The x axis refers to changes in temperature, and the y axis to changes from the % of current precipitation.

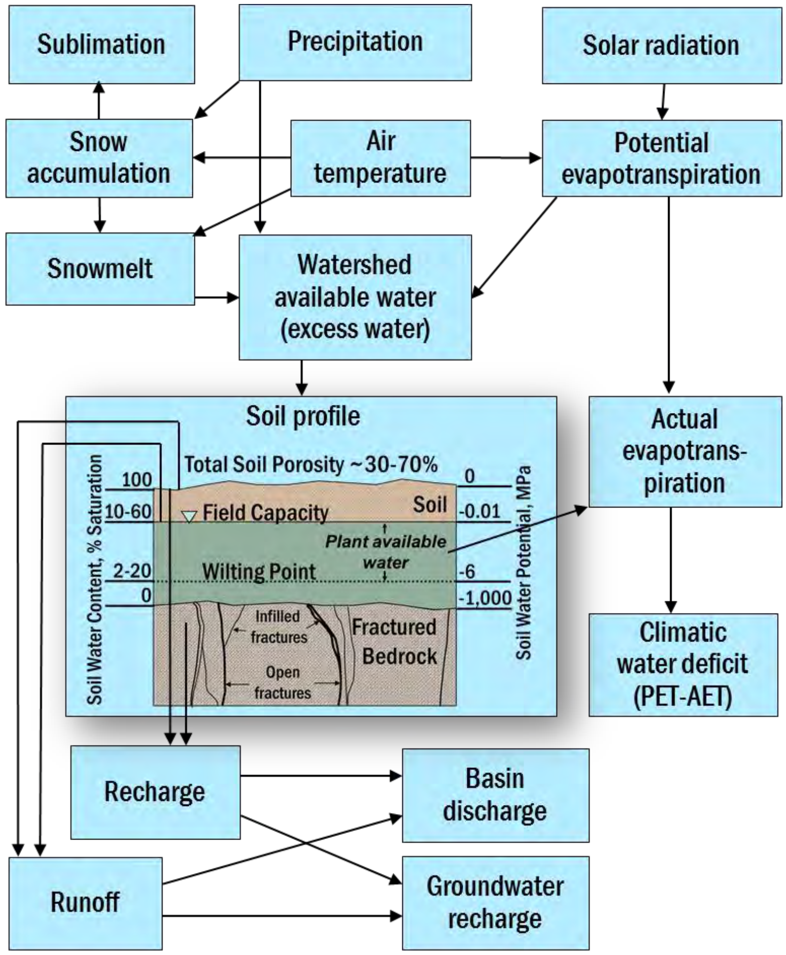


Figure 7. Basin Characterization Model Variables. The variables calculated by the Basin Characterization Model (BCM). The model runs on a grid cell basis[16].

[16] Thorne, J.H., R.M. Boynton, L.E. Flint, A.L. Flint. 2015. Comparing historic and future climate and hydrology for California's watersheds using the Basin Characterization Model. *Ecosphere* 6(2). Online http://www.esajournals.org/doi/pdf/10.1890/ES14-00300.1.

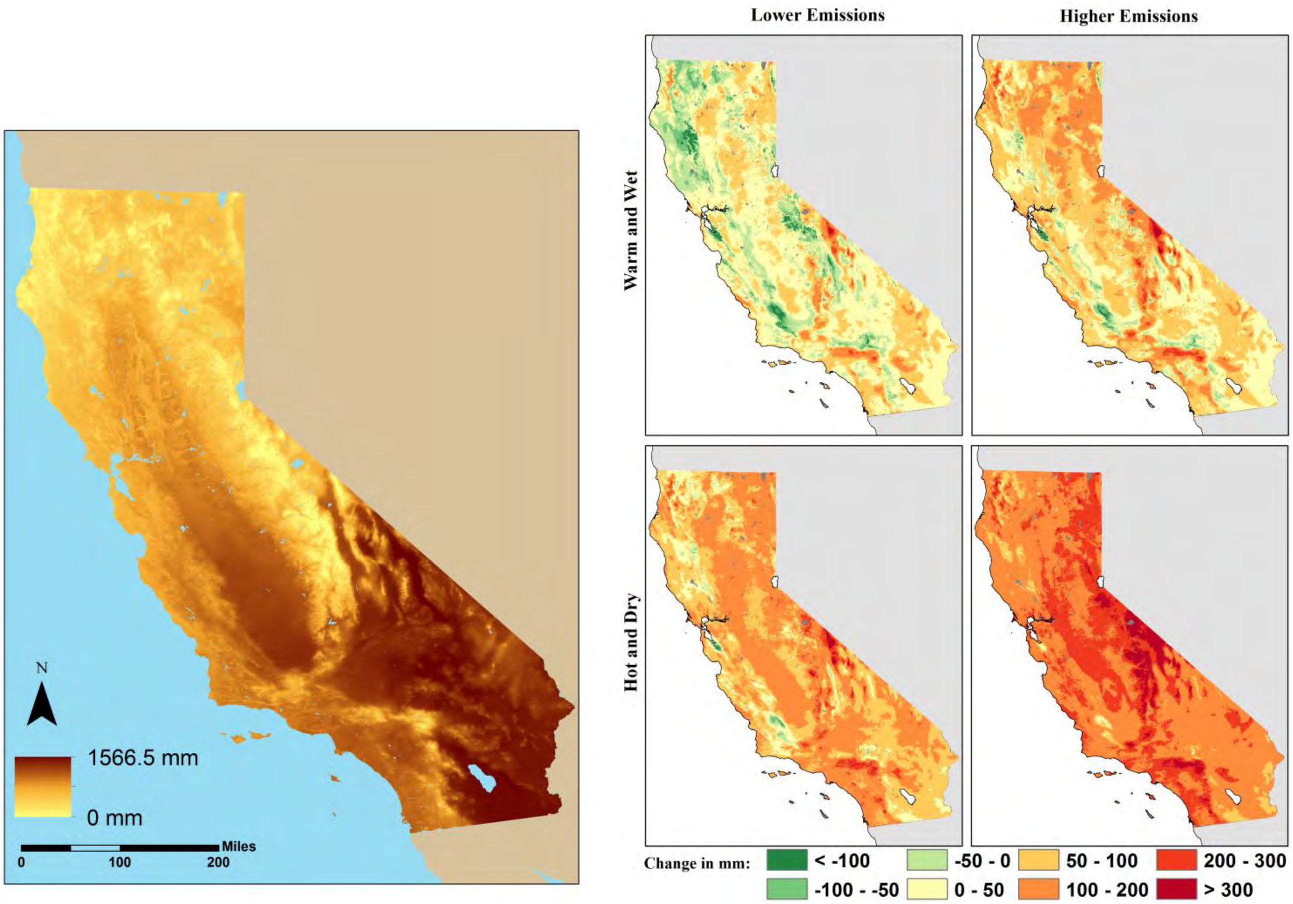


Figure 8. Map of Projected Change in Climate Water Deficit Under Four Climate Scenarios. The left panel shows one of the BCM model outputs, annual climatic water deficit (CWD) values, for the current baseline 30 year period. The right hand panel shows the difference in climatic water deficit from the current time to the four future climate projections. The change is in annual values in mm. These maps represent one of the climate and hydrology variables used in the development of the climate envelopes for each macrogroup, in this case CWD represents an estimate of plant stress due to unmet physiological demand for water.

Vegetation Data

This study takes advantage of a statewide vegetation map that can be portrayed using the macrogroup classification. The use of a map permits site-specific climate impact assessments and development of the vegetation climate exposure analysis, which compares each location occupied by a macrogroup to all the other locations occupied by the same type. A general description of each macrogroup is provided in the Result sections.

The California State Department of Forestry and Fire Protection (CalFire) Fire and Resource Assessment Program (FRAP) has produced a statewide vegetation map (Figures 9 and 10), which is a compilation of the most recent and most accurate maps produced for various parts of the state[17]. This most recent edition uses maps produced between 1990 and 2014, and is portrayed as a 30m grid. The vegetation in the map can be portrayed as either the WHR classes used by the California Department of Fish and Wildlife, or by the macrogroup classification that is part of the national vegetation classification system and has been adopted for use in the SWAP 2015 update to select conservation targets. We used the macrogroup vegetation classification, for which there are 31 in vegetation map, and conducted the climate exposure analysis and spatial disruption analysis using this map. The map was resampled to a 270m grid before analysis, to reduce computing time, and to align the patterns of vegetation distribution with climate data used. The sampling selected the most prevalent vegetation type found in the 81 30m grids within each 270m pixel. The resulting vegetation map used for analysis contains approximately 5.6 million pixels, and retains the 31 macrogroups. The SWAP 2015 update identifies 38 macrogroups as occurring in California. However, seven macrogroups listed in the SWAP document do not appear in the

[17] http://frap.fire.ca.gov/data/frapgisdata-sw-fveg_download.php

statewide vegetation map: Western Cordilleran Montane Shrubland and Grassland, Warm Interior Chaparral, Western North American Montane/Boreal Peatland, Western North American Vernal Pool, Warm Semi-Desert/Mediterranean Alkali-saline Wetland, Cool Semi-Desert Wash and Disturbance Shrub, and Western North American Freshwater Aquatic Vegetation. These types were excluded from analysis in this report because a spatial footprint of the type is needed for two of the analyses presented here.

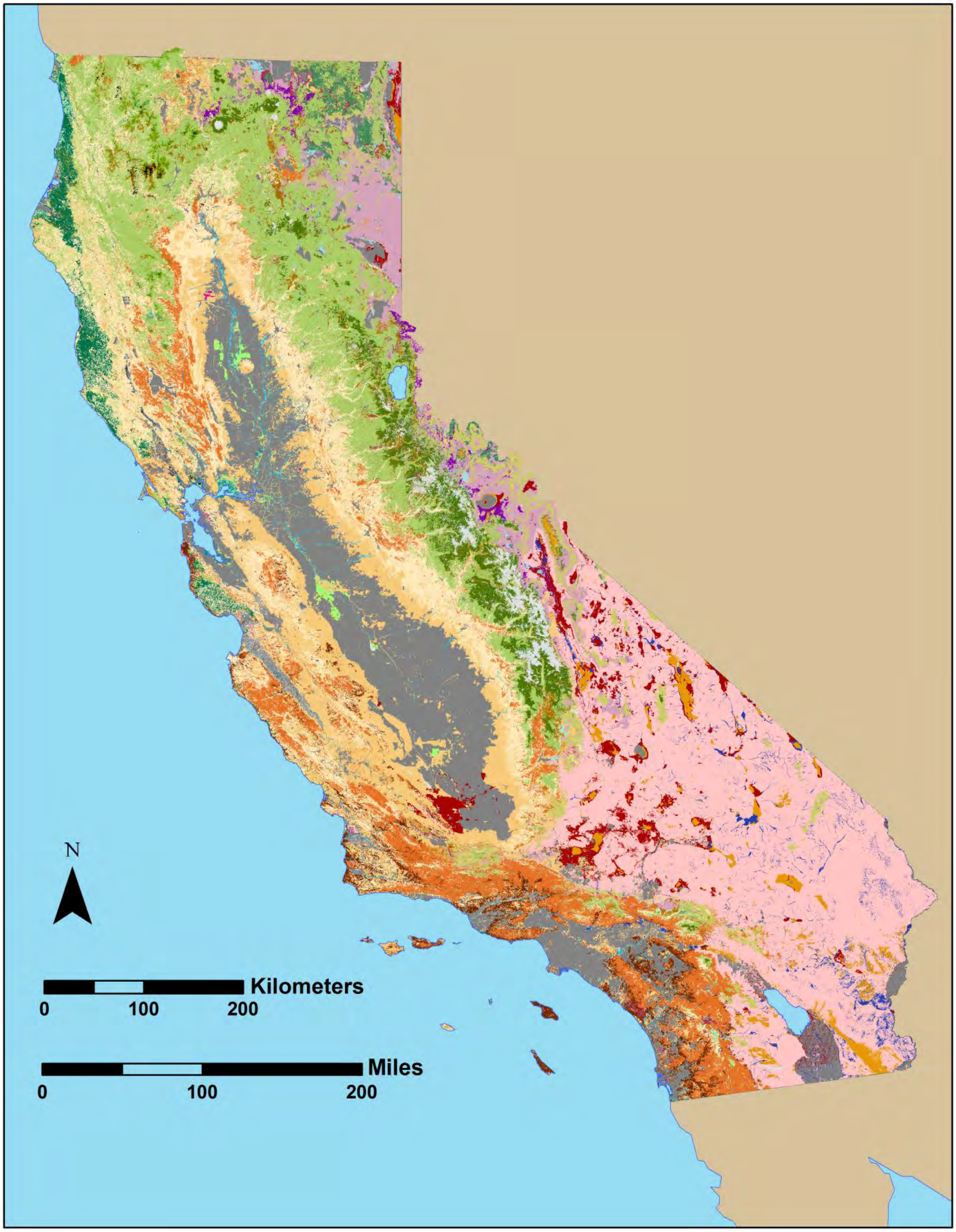


Figure 9. Statewide Vegetation (Macrogroup) Map. The statewide vegetation map used for the climate exposure analysis in this report. This image portrays the distribution of macrogroups which are analyzed. Note that some areas in the central valley and urban centers are in grey, indicating zones that were excluded from this analysis. The natural vegetation in the central valley that is mapped is visible as small extents of vegetation.

Figure 10. Macrogroup Map Legend. The legend for the macrogroup map.

ANALYSIS APPROACH

This section briefly reviews the sensitivity and adaptive capacity analysis, the vegetation climate exposure analysis, and the spatial disruption analysis, which are used to generate the final vulnerability scores, as detailed above.

Sensitivity and Adaptive Capacity

Sensitivity and adaptive capacity scores were developed for the dominant plant species found within each macrogroup; scores were generated based on the life history characteristics defined in attribute tables of the California Manual of Vegetation (Keeler Wolf et al. 2009[18]), and supplemented by information found in the USDA plants database[19] and the Jepson Interchange[20], a web portal for California plant taxonomy

Six scores were developed for sensitivity:

Sensitivity to Temperature
Sensitivity to Precipitation
Fire Sensitivity
Germination Agents
Mode(s) of dispersal
and, Reproductive lifespan

We also scored each species for three adaptive capacity traits:

Adaptive capacity to fire
Mode and level of recruitment
and, Seed longevity

Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or least adaptive, and 5 representing the least sensitive or highest level of adaptive capacity. The reasoning and scoring rules as applied to the Keeler Wolf et al. (2009) life history tables are presented in the appendix. If a species' condition was neutral for a category or was not known, it was given a value of 3 for that entry.

The sensitivity and adaptive capacity scores (S&A scores) for all component dominant plants were then averaged for each macrogroup, to come up with composite scores representing the macrogroup's ecological attributes. The mean of the two sets of scores were further developed, resulting in a comparable ranking of the each macrogroup's ecological attributes.

Vegetation Climate Exposure Analysis

The vegetation climate exposure analysis takes advantage of the 2015 vegetation map compiled for California, which is described above. The vegetation climate exposure model is implemented in the R programming language, and takes the vegetation and climate raster files as the primary input data. The values of the climate raster files were randomly sampled at 100,000 points on the landscape, which were used to fit a statistical model characterizing the relationship between the variables both in the current time and for the modeled future data.

At each of these 100,000 points, 9 hydro-climatic variables were sampled to characterize the range and variation of conditions in the study region. These variables were: annual mean minimum temperature (Tmin), annual mean maximum temperature (Tmax), annual precipitation (PPT), actual evapotranspiration (AET), potential evapotranspiration (PET), climatic water deficit (CWD), snowpack depth on April 1st, runoff, and recharge. The variation between these variables was modeled using a principal component analysis[21] (PCA) to identify the dominant components of variation. The top-

[18] http://www.cnps.org/cnps/vegetation/manual.php
[19] http://www.plants.usda.gov
[20] http://ucjeps.berkeley.edu/interchange/
[21] McCune and Grace. 2002. Analysis of ecological communities. MJM Software design, Gleneden Beach, Oregon.

two principal components axes, representing about 79% of the variability across the four climate projections, were extracted as a two-dimensional space, and are portrayed as the axes for the PCA plots shown in each macrogroup chapter below. This was done to simplify the representation of the climate space, while maintaining the most important information on the variables to be associated with the observed vegetation distributions.

Next, the climate space occupied by each distinct macrogroup from the current time period was identified. This was done by using the points for each type and applying a kernel density estimator on a 2-d surface composed of the first two principal components of the climate conditions, shown below in each macrogroup chapter (e.g. Figure 11). The result is a smoothed continuous point density surface, showing the prevalence of each vegetation type across the range of sampled climatic conditions. This surface was partitioned by fitting contour lines so that they enclose a proportion of the original points from the current time period. Contours were calculated at 5% increments. For example the innermost 5% contour line encloses the 5% of pixels for the given vegetation type which are at the core of the climate space for that type, as determined by its density in the climate space. Cells further away from the dense central core, are considered to be more marginal in the vegetation type's distribution. The outer contours are fit to enclose the 95-99% of climatically marginal points, with the last 1% of cells (beyond the 99% contour) being the most marginal. In addition, if a cell lies outside the space defined by the 99% contour of **any** vegetation type, it is considered to be "non-analog," which means that it experiences climatic conditions outside of the conditions where we have a good sample in the initial time period. As a result, the status of that point is uncertain. There are occasionally a few extreme points which appear to be far outside the general distribution for the type. These may be due to misclassified vegetation types in the source data, microclimatic conditions not captured by the climate data, historic anomalies in long-lived species, etc.

Macrogroup 106 (Temperate Pacific Intertidal Shore) was excluded from the exposure analysis due to its limited distribution within the study areas (351 270 m pixels in the macrogroup raster). The small sample size made it difficult to accurately fit contour lines representing its climate space. Also excluded from this assessment are non-vegetated types such as snow, open water, and ice; and non-natural landcover types mapped as vineyards, tilled earth, orchards and Urban.

Once the climate space contours were developed for each vegetation type, the outermost (99%) contours of all macrogroups were unioned together to define the domain of the sampled climate space for the state, which appears as a pale polygon on the images of the PCA charts below (e.g. Figure 11).

With the current climate space defined for each vegetation type, each pixel from every time period was then classified into an exposure category based on where it falls relative to the density contours of its historic distribution. In the initial time period, 1981-2010, the pixels by definition follow a uniform distribution across the classes. However, in the future time periods climate conditions shift, resulting in the vegetation becoming exposed to different conditions (Figure 12, left panel). Over time, they tend to experience increasingly marginal conditions relative to their observed distribution in the recent past. The raster cells in these marginal conditions are considered to be highly exposed to stress and type conversion. The most highly exposed cells fall completely outside the range of recent historic conditions for its type. There is also the possibility that a location is exposed to a combination of climatic conditions which are outside the range of the sampled historic conditions for the whole state. In this case, the conditions are considered "non-analog", and no explicit exposure ranking is made.

To visualize the values on the landscape, the exposure scores are projected back into spatial raster files, which can be portrayed either in the original 5% intervals, or in fewer aggregated classes on a map (Figure 12, right panel). The classes used in this report are: 0-20; 20-40; 40-60; 60-80; 80-90; 90-95; 95-99; 99-100; and >100, including non-analog space, shown in black. For cartographic purposes, some classes were collapsed. We term all grid cells within 80% of the current climate distribution to be in climatically suitable areas, and all grid cells in the >95% classes, including non-analog, to be in the climatically stressed or marginal classes. The proportion of the entire range of each macrogroup that becomes climatically stressed was used as the metric for climate exposure described above.

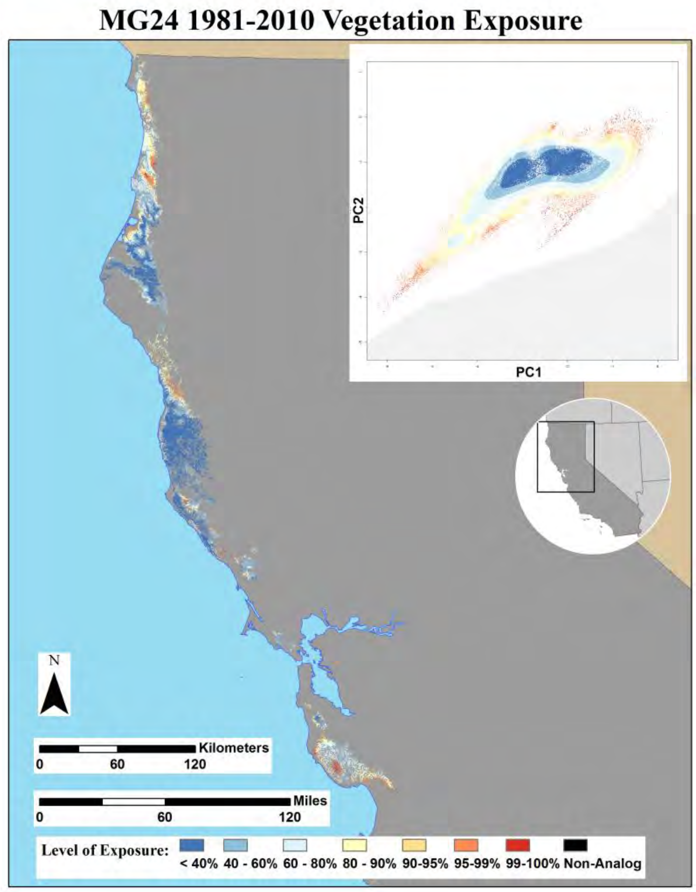


Figure 11. Example of Vegetation Exposure for an Individual Macrogroup. An example of a macrogroup , sampled for points to which hydroclimatic data were attached to render the current time PCA chart (inset), and classed by frequency of vegetation occurrence across climate space. The map is classed to the same colors as the contour lines in the PCA diagram.

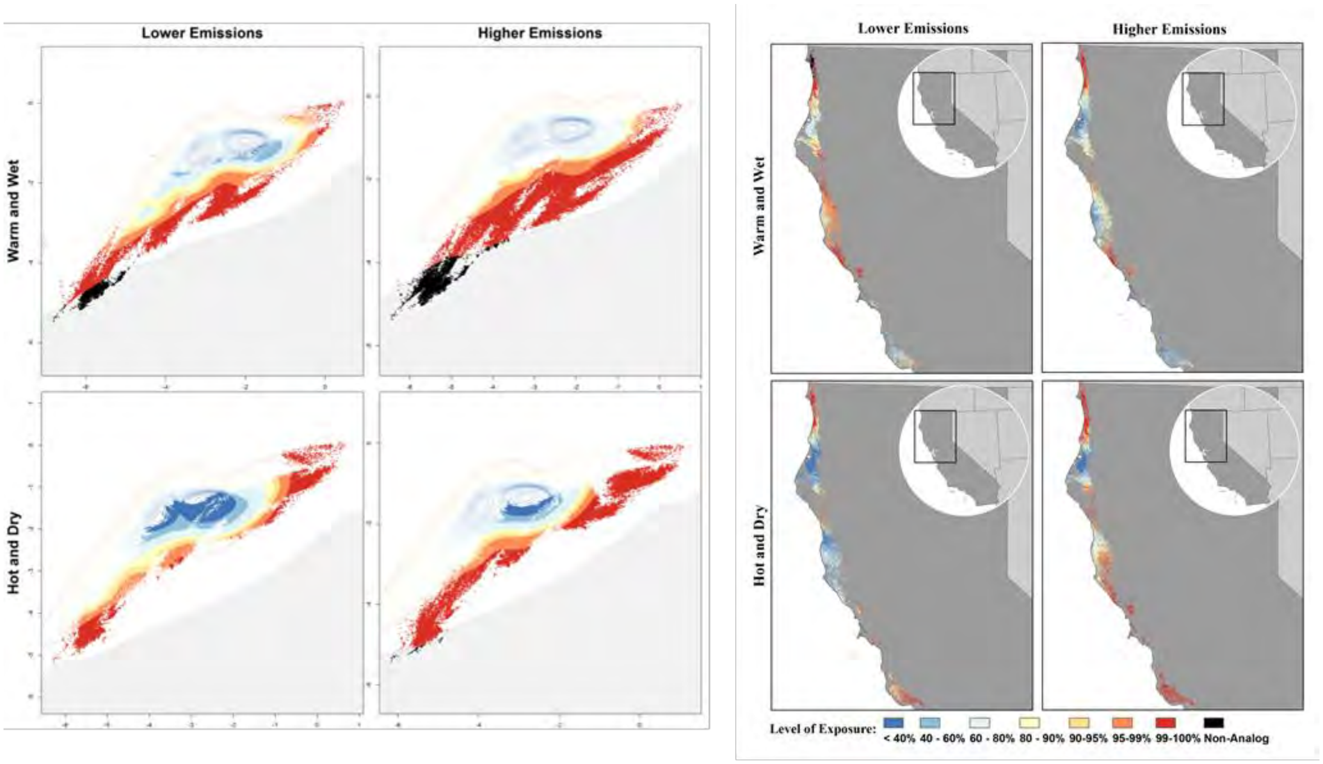


Figure 12. Example of a Macrogroup's Progression Across its Climate Space. The transition of each grid cell for macrogroup 24 across its climate space by the end century, portrayed in the PCA space (left) and reprojected to the map to illustrate areas expected to be climatically stressed (in orange, red, and black).

Spatial Disruption

The spatial disruption analysis also takes advantage of the 2015 vegetation map compiled for California. The vegetation map was randomly sub-sampled for 300 points for each macrogroup, which were used to generate the following analysis (Figure 13). We selected each macrogroup's points, and sampled the current and future climate conditions for 6 variables to characterize the range of hydro-climatic conditions in the study region: mean annual actual evapotranspiration (AET), mean annual snowpack (PCK), mean annual runoff (RUN), mean annual minimum temperature (Tmin), mean annual maximum temperature (Tmax), and mean annual precipitation (PPT).

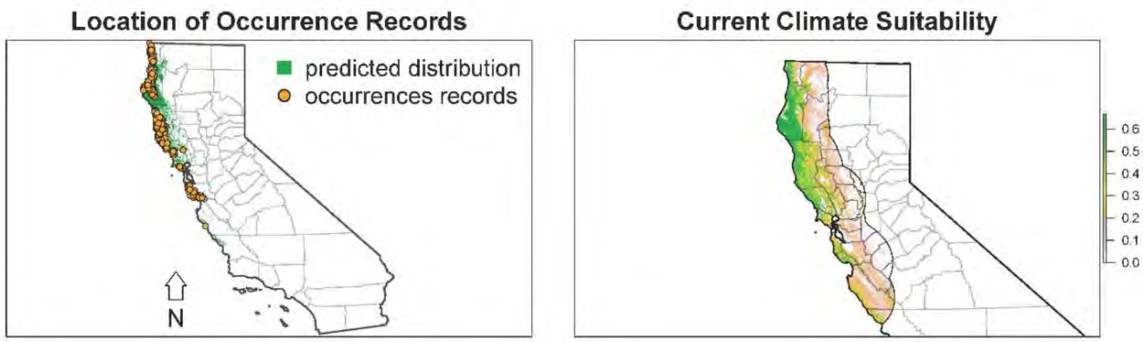


Figure 13. Example of Mapped Climate Suitability for an Individual Macrogroup. An example of a macrogroup sampled for points to which hydroclimatic data were attached to parameterize the Maxent species distribution model. Sampled points and thresholded current climatically suitable habitat are depicted in the left panel. Continuous probability surfaces within 100 km of occurrence locations are depicted in the right panel.

The vegetation Species Distribution Models (SDMs) were implemented in the R programming language, and used the Dismo[22] library and Maxent version 3.3.3k (Elith et al., 2011[23]) for model parameterization. The following measures were implemented to maximize model performance and temporal transferability and to reduce spurious relationships and model complexity. For each macrogroup we used AIC_c model selection[24] to evaluate models produced from 33 possible predictor variable combinations with Pearson's correlation coefficients less than 0.64 and up to four predictor variables per model (Table 6). Maxent threshold and hinge features were turned off. Continuous climate suitability surfaces for each macrogroup (Figure 13, right panel) were converted into binary surfaces representing the range of each species (the green in Figure 13, left panel) using the threshold that maximized the sum of sensitivity and specificity. Background points, representing pseudo absences needed to run Maxent were sampled from within 100 km of presence points.

We used the best performing (lowest AIC_c) Maxent model parameterization to spatially project the current (1981-2010) and modeled future (2070-2099) climatically suitable range for each macrogroup. For each type we present summaries of projected change in suitable climate space over time, including area remaining suitable, area no longer suitable, and area newly suitable (Figure 14). For the vulnerability analysis described above, we used the loss of current suitable range as the metric. However, in the individual macrogroup reports below, we include greater detail about the changes projected using this approach, including the expected gain in climatically suitable range.

[22] Robert J. Hijmans, Steven Phillips, John Leathwick and Jane Elith (2015). dismo: Species Distribution Modeling. R package version 1.0-12. http://CRAN.R-project.org/package=dismo

[23] Elith J., Phillips S., Hastie T., Dudík M., Chee Y., & Yates C. (2011) A statistical explanation of MaxEnt for ecologists. Diversity and Distributions, 17, 4357.

[24] Warren D. & Seifert S. (2011) Ecological niche modeling in Maxent: the importance of model complexity and the performance of model selection criteria. Ecological Applications, 21, 335–42.

Table 6. Candidate Variable Combinations for Macrogroup Range Modelling Using Species Distribution Model Techniques. Table of 33 candidate variable combinations for the modeling of macrogroup ranges using species distribution model techniques.

aet_ave	**pck_ave + ppt_ave**
aet_ave + pck_ave	pck_ave + ppt_ave + tmn_ave
aet_ave + pck_ave + run_ave	pck_ave + ppt_ave + tmx_ave
aet_ave + pck_ave + run_ave + tmn_ave	pck_ave + run_ave
aet_ave + pck_ave + run_ave + tmx_ave	pck_ave + run_ave + tmn_ave
aet_ave + pck_ave + tmn_ave	pck_ave + run_ave + tmx_ave
aet_ave + pck_ave + tmx_ave	pck_ave + tmn_ave
aet_ave + run_ave	pck_ave + tmx_ave
aet_ave + run_ave + tmn_ave	ppt_ave
aet_ave + run_ave + tmx_ave	ppt_ave + tmn_ave
aet_ave + tmn_ave	ppt_ave + tmx_ave
aet_ave + tmx_ave	run_ave
cwd_ave	run_ave + tmn_ave
cwd_ave + pck_ave	run_ave + tmx_ave
cwd_ave + pck_ave + run_ave	tmn_ave
cwd_ave + run_ave	tmx_ave
pck_ave	

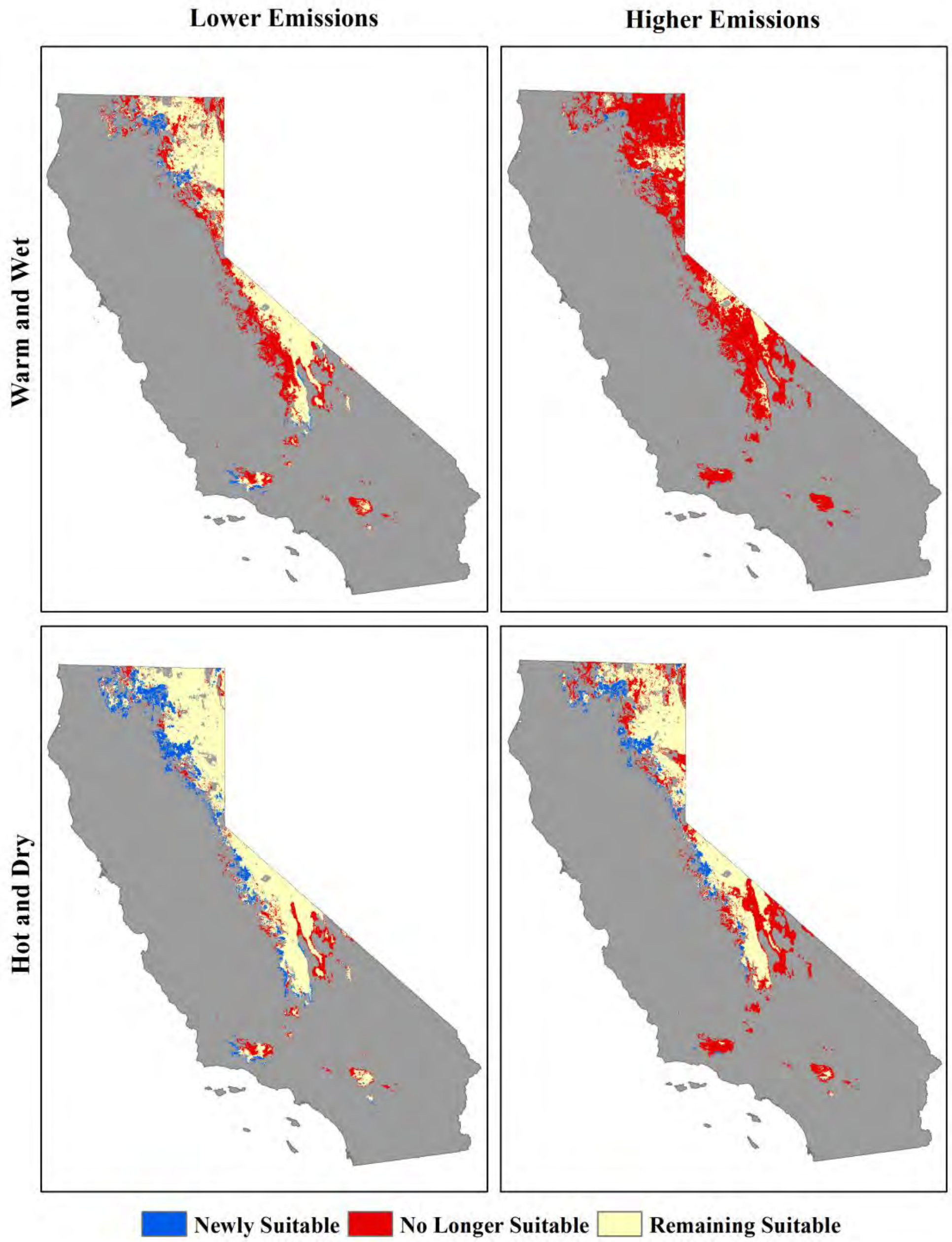


Figure 14. Example of the Projected Changes in Suitable Climate Space for an Individual Macrogroup. An example of projected changes in suitable climate space for macrogroup 96, as predicted by the best performing species distribution model for vegetation using Maxent.

RESULTS

Overall results are presented in the Executive Summary. This section provides detail on each macrogroup.

MG009: Macrogroup California Forest and Woodland
Common Name: California Foothill and Valley Forests and Woodlands

This type includes all Mediterranean climate woodlands and forests in California from sea level to the point where snow and frost in combination with high winter precipitation enables cool temperate species of trees to dominate the overstory layer. This macrogroup ranges throughout the state west of the deserts and below the higher mountains where snow is the main form of precipitation. This includes the central and south coast ranges, the Northern California Interior coast ranges, The Sierra Foothills, Central Valley, and lower elevations of the west slope of the Sierra, the Southern Cascades, the Southern Klamath Mountains, and the Transverse and Peninsular Ranges.

These forests and woodlands are composed of tree species largely adapted and endemic to the warm, dry summers, and cool rainy winters of California's Mediterranean climate. They may be open woodlands to denser forests, and may be dominated by broadleaf evergreen or deciduous hardwoods, co-dominated by hardwoods and conifers, or dominated entirely by conifers. The understory can be grassy, shrubby, or mixed with both. This macrogroup contains two groups, one dominated by broad leaf trees and the other dominated by conifers. The fire ecology is varied depending on the spacing of trees and the herbaceous or woody understory characteristics.

For the broad-leaf component covered within the Group - Californian broadleaf forest and woodland, the macrogroup is more general than any single WHR type. It includes the following WHR types, or components of WHR types: 1) coastal oak woodland (COW) = stands dominated by coast live oak (*Quercus agrifolia*) and/or California bay, and/or Shreve oak, and/or Engelmann oak (*Quercus englemannii*); 2) blue oak woodland (BOW) = stands dominated by blue oak (*Quercus douglasii*) and or California buckeye; 3) blue oak –foothill pine (BOP) = stands dominated or co-dominated by blue oak or foothill pine (*Pinus sabiniana*); 4) montane hardwood (MHW) = stands dominated by interior live oak (*Quercus wislizeni*); and that with canyon oak (*Quercus chrysolepis*) and or black oak (*Quercus kelloggii*), co- dominant with Douglas-fir (*Pseudotsuga menziesii*) or ponderosa pine (*Pinus ponderosa*)); 5) part of valley foothill riparian (VRI) (that part with the valley oak (*Quercus lobata*) dominant) and montane hardwood conifer; and 6) valley oak woodland (VOW). For the Coniferous component covered under this macrogroup, the WHR types include: closed-cone pine/cypress = stands dominated by Bishop (*Pinus muricata*), knobcone (*Pinus attenuata*), or Monterey pine (*Pinus radiata*), and/or any native cypress species; 7) juniper (JUN) = non-desert stands dominated by California juniper (*Juniperus californica*). Some mixed stands of this group with Coulter pine (*Pinus coulteri*) and black oak may be considered as part of the Sierran mixed conifer (SMC) habitat (8).

Macrogroup 9 is comprised of approximately eight WHR types for which we scored 13 representative dominant species. The statewide extent for the current time period cover 49,530 km^2, here shown classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 15). Using the current climate conditions for the extent of Macrogroup 9, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

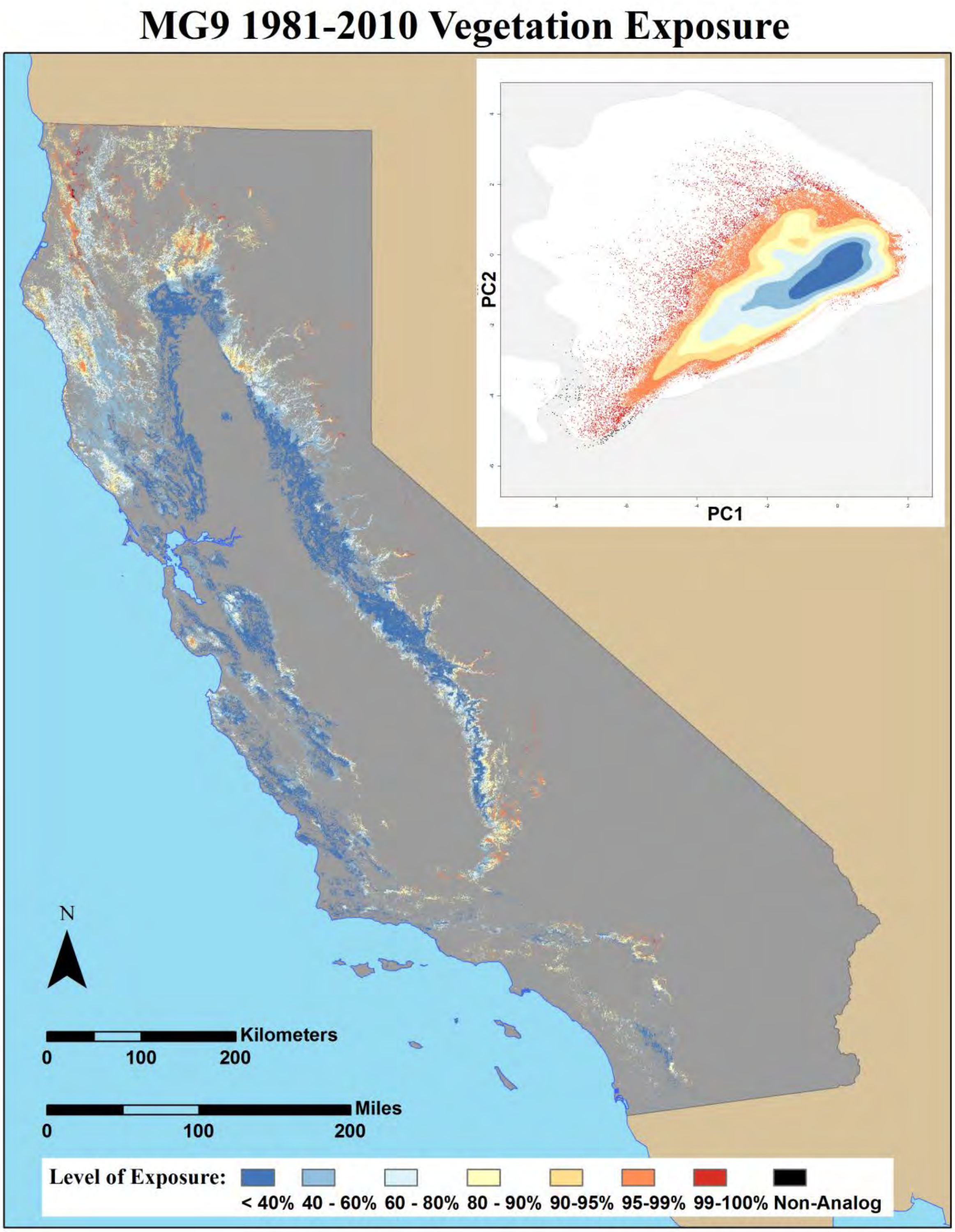


Figure 15. Map of Current Climate Suitability for Macrogroup 9. The 2015 mapped extent of macrogroup 9, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

The dominant plant species for macrogroup 9 are assessed for their sensitivity to and ability to adapt to climate change, and given a set of scores to indicate how each species will be impacted by climate change. The sensitivity score measures the sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The adaptive capacity score measures how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or least adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity. The plant species within macrogroup 9 include both hardwoods and conifers, which have slightly different sensitivity and adaptive capacity means (Table 7). The overall or grand mean for macrogroup 9 was found to be 3.12 for sensitivity and adaptive capacity.

Table 7. Sensitivity and Adaptive Capacity Rankings for Magrocroup 9. Sensitivity and Adaptive Capacity rankings for the dominant species comprising macrogroup 9. Two species, *Pinus sabiniana* and *Pinus attenuate*, are known to sprout after a fire, so sensitivity in germination is not as low as general scoring for the agents listed.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Hardwoods										
Quercus agrifolia	3	3	5	3	2	4	5	3	1	**3.2**
Quercus englemannii	3	3	4	3	2	3	5	1	1	**2.8**
Quercus douglasii	4	4	3	3	2	4	3	1	1	**2.8**
*Pinus sabiniana**	4	3	2	4	5	3	1	4	4	**3.3**
Quercus chrysolepis	3	3	4	3	2	5	5	3	1	**3.2**
Quercus lobata	3	3	5	3	2	5	5	1	1	**3.1**
Quercus wislizeni	4	3	4	3	2	3	5	4	1	**3.2**
Mean	**3.43**	**3.14**	**3.86**	**3.14**	**2.43**	**3.86**	**4.14**	**2.43**	**1.43**	
					Mean	**3.31**		**Mean**	**2.67**	
Conifers										
Pinus radiata	3	3	1	4	3	3	5	4	5	**3.4**
Juniperus californica	3	3	1	2	2	3	5	2	2	**2.6**
Pinus attenuata	4	3	1	4	5	2	5	4	5	**3.7**
Pinus ponderosa	3	3	5	2	4	5	4	4	1	**3.4**
Calocedrus decurrens	3	3	5	2	3	5	1	5	1	**3.1**
Abies concolor	2	2	2	2	4	5	1	5	1	**2.7**
Mean	**3.00**	**2.83**	**2.50**	**2.67**	**3.50**	**3.83**	**3.50**	**4.00**	**2.50**	
					Mean	**3.06**		**Mean**	**3.33**	
Grand Mean	**3.12**									

Projected Climate Exposure

The future climate exposure for macrogroup 9 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 16).

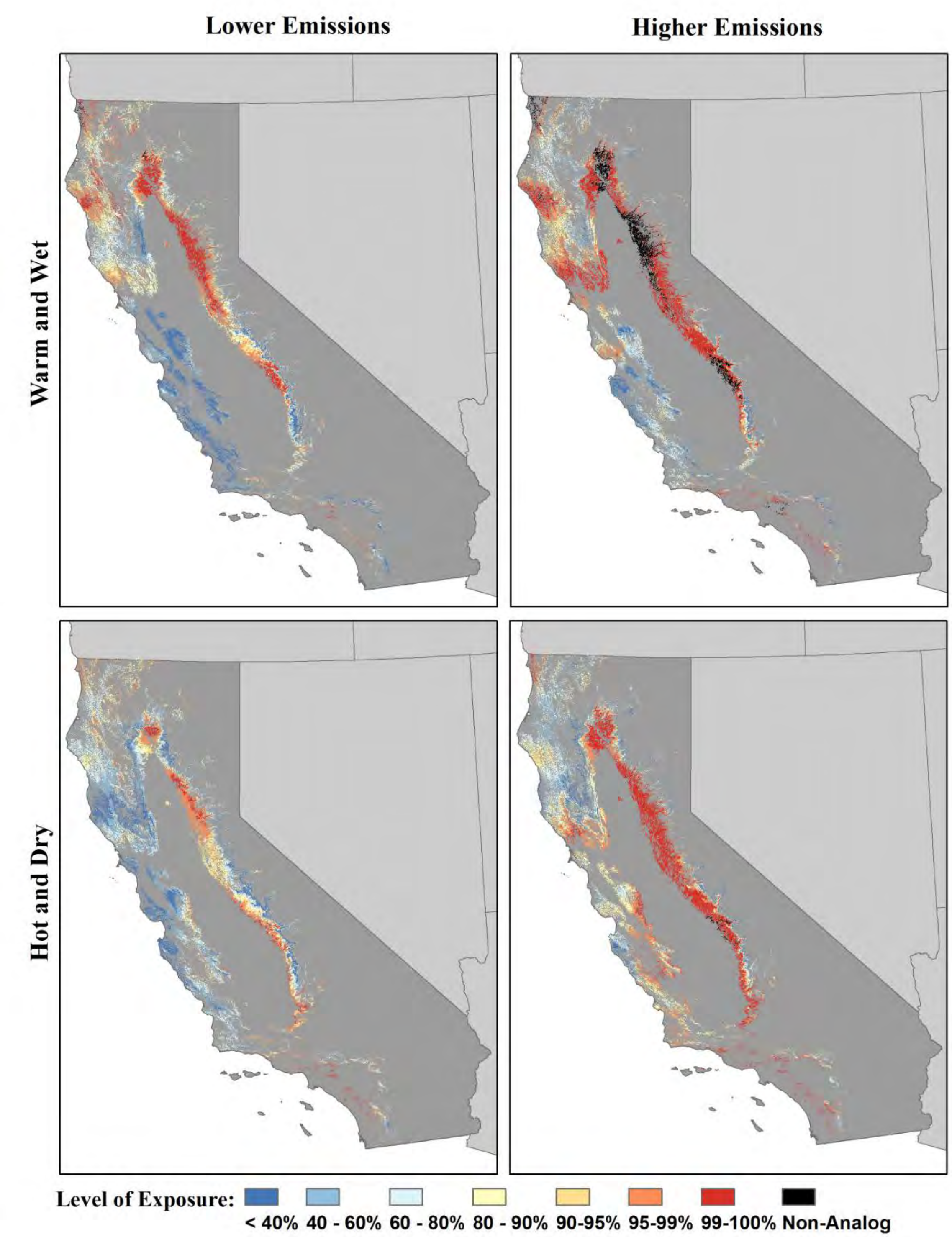


Figure 16. Maps of Projected Climate Exposure for Macrogroup 9. The climate exposure level for macrogroup 9 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 16 is derived from the PCA charts (Figure 17), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

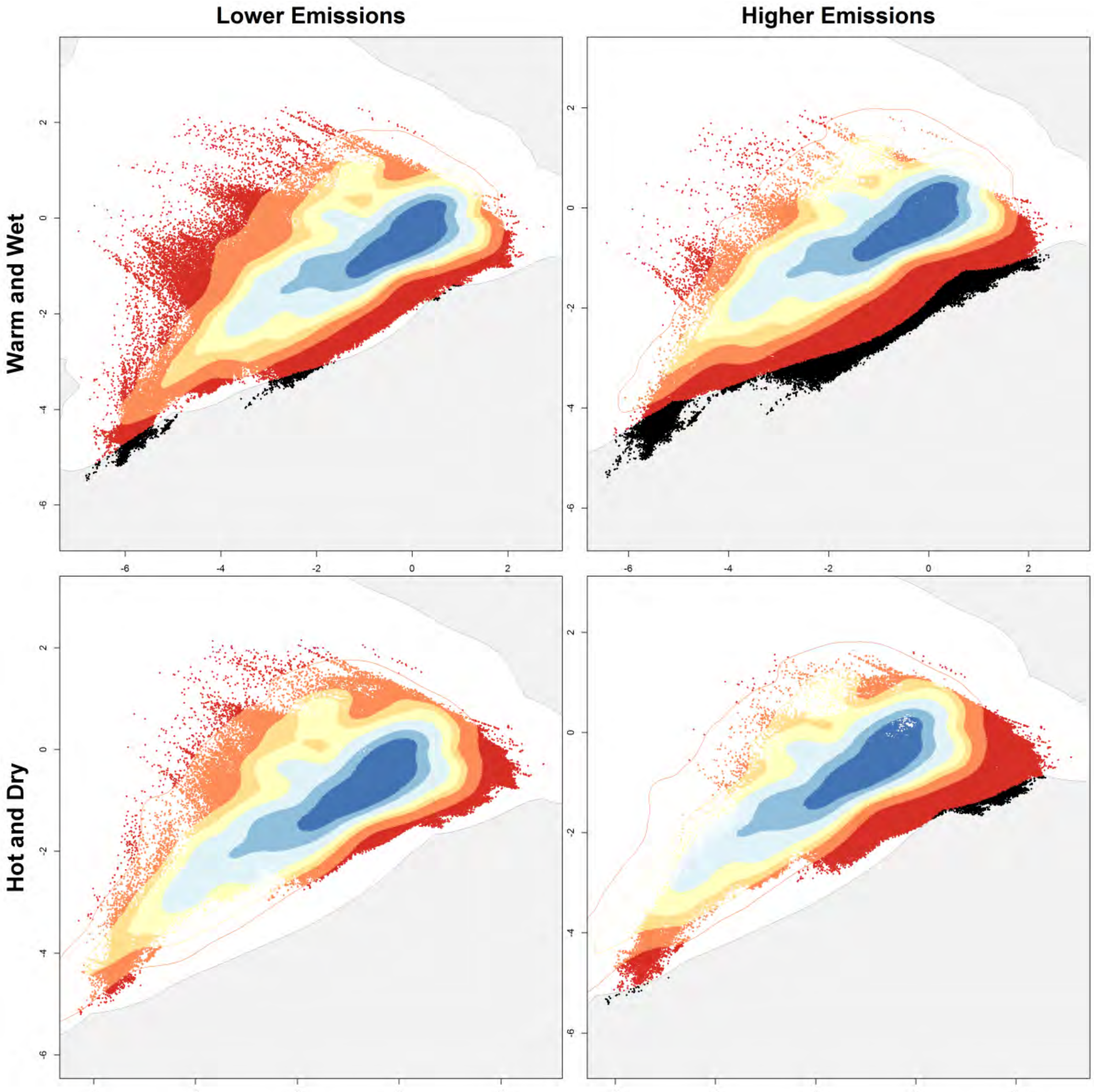


Figure 17. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 9. The PCA charts are two dimensional representations of climate exposure for macrogroup 9 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 8). In the current time period, macrogroup 9 occupies 49,530 km^2. By the end of the century, there will be between 14,826 km^2 (30%) and 29,010 km^2 (69%) of the total area that will remain suitable or become refugia for the vegetation in macrogroup 9, depending on the future climate conditions. Between 8,578 km^2 (17%) and 26,643 km^2 (54%) will be climatically exposed by the end of century.

Table 8. Percentage of the Current Extent of Macrogoup 9 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	9,904	9,908	9,906	9,902	4,958	2,472	1,981	487	11
1980-2010 (%)	20.00	20.00	20.00	19.99	10.01	4.99	4.00	0.98	0.02
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	13.02	15.63	16.22	19.99	12.64	7.12	10.80	4.57	0.00
2040-2069 (%)	11.78	12.84	13.35	21.45	13.37	7.98	13.18	6.05	0.00
2070-2099 (%)	9.33	10.14	8.86	15.76	13.93	10.31	14.83	16.56	0.28
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	12.11	15.22	14.28	20.61	12.52	8.23	11.99	5.04	0.00
2040-2069 (%)	9.43	10.60	10.39	19.46	14.19	8.99	13.93	12.92	0.09
2070-2099 (%)	2.79	3.83	7.36	16.57	8.65	7.01	11.21	31.50	11.07
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	13.16	20.28	20.76	20.29	9.18	4.46	8.98	2.89	NA
2040-2069 (%)	9.49	15.13	19.10	24.59	13.68	8.13	8.40	1.49	NA
2070-2099 (%)	5.65	11.75	16.65	24.52	13.96	10.15	12.35	4.97	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	13.49	21.32	21.87	17.79	8.20	4.45	9.49	3.39	NA
2040-2069 (%)	6.83	12.54	16.51	23.03	15.86	9.86	12.17	3.20	0.00
2070-2099 (%)	1.99	3.22	8.82	15.91	13.95	8.96	16.04	30.59	0.53

Spatial Disruption

To determine how the vegetation types present in macrogroup 9 would be distributed under future climate scenarios, the current extent was first mapped along with 300 randomly selected points within the extent to be used in the species distribution model Maxent (Figure 18). From this, a current climate suitability model could be developed showing areas with climate suitability for the macrogroup 9 vegetation types.

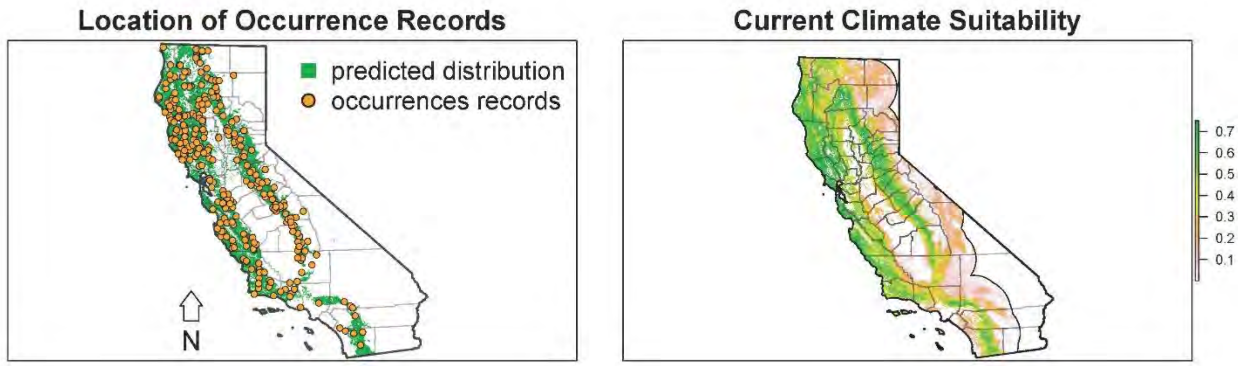


Figure 18. Map of Points Selected from the Extent of Macrogroup 9 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 9. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability model and the future climate scenarios, the future extents for areas can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for the vegetation types in macrogroup 9 (Figure 19). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for vegetation types to shift their location, will be required in areas that are newly suitable or no longer suitable. By the end of the century for macrogroup 9, between 31,301 km^2 (24%) and 76,037 km^2 (59%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 51,796 km^2 (41%) and 96,532 km^2 (76%) will remain climatically suitable, and between 14,087 km^2 (11%) and 43,382 km^2 (34%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 9.

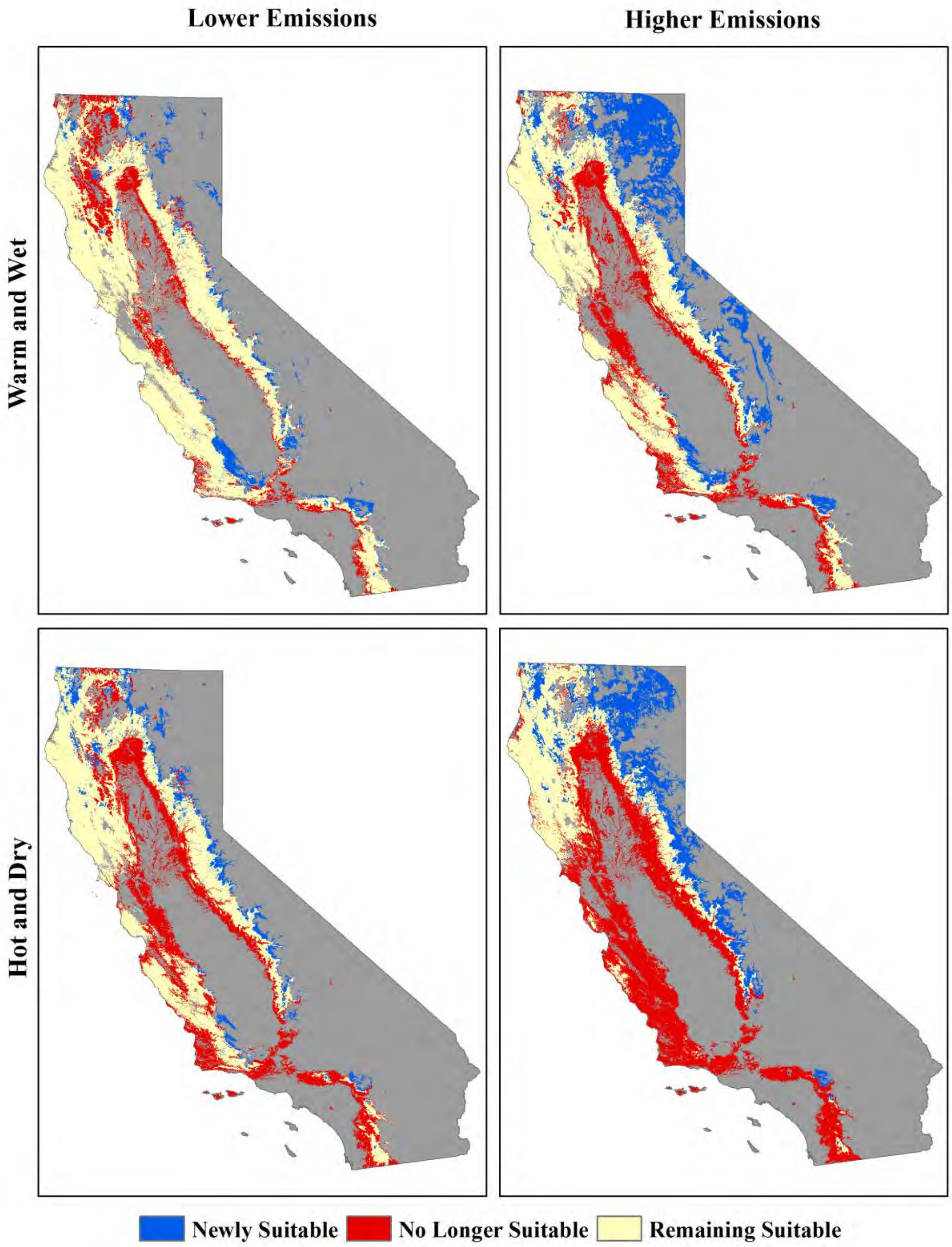


Figure 19. Maps of the Projected Climatically Suitable Range for Macrogroup 9. Maps showing the modeled climatically suitable range for macrogroup 9 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 9. Area of Projected Climatic Suitability for Macrogroup 9. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 9, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	31,301	96,532	14,252	24%	76%	11%
CNRM CM5 - RCP 8.5	40,551	87,282	43,382	32%	68%	34%
MIROC ESM - RCP 4.5	50,886	76,947	14,087	40%	60%	11%
MIROC ESM - RCP 8.5	76,037	51,796	35,008	59%	41%	27%

MG020: Macrogroup Rocky Mountain Subalpine and High Montane Conifer Forest
Common Name: Subalpine Aspen Forests and Pine Woodlands

This macrogroup represents the cold but less snowy subalpine to high montane forests of the Sierra, Cascades, Klamaths, Transverse, and Peninsular Ranges of California. It is a wide ranging macrogroup, including similar forests and woodlands in the Rocky Mountains, and the high mountains of the Great Basin.

The subalpine forests of the California mountains can be divided into shady concave stands, which tend to accumulate large winter snow loads or drier, more exposed woodlands, which tend to occupy south-facing or high exposed ridges. This macrogroup describes the latter situation. In California, it is represented by two groups, one characterized by the subalpine pine species (Foxtail (*Pinus balfouriana*), white-bark (*Pinus albicaulis*), limber (*Pinus flexilis*), bristlecone (*Pinus longaeva*), and Sierra lodgepole pine (*Pinus contorta murrayana*)), and the other by aspen (*Populus tremuloides*), which tends to form expansive non-riparian stands, widespread inland in the high mountains and on mid-slopes bordering the Great Basin, but limited to cooler riparian drainages on the west side of the mountains.

The Aspen Group matches well with the Aspen (ASP) WHR habitat. The other group within this macrogroup is the drier subalpine forests included within the subalpine conifer (SCN) habitat, which include lodgepole, foxtail, whitebark pine, limber, or bristle-cone pine forests; this also includes the lodgepole pine (LPN) WHR, but not red fir, mountain hemlock, etc.

Macrogroup 20 is comprised of approximately three WHR types for which we scored four representative dominant species. The statewide extent for the current time period cover 9,390 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 20). Using the current climate conditions for the extent of Macrogroup 20, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

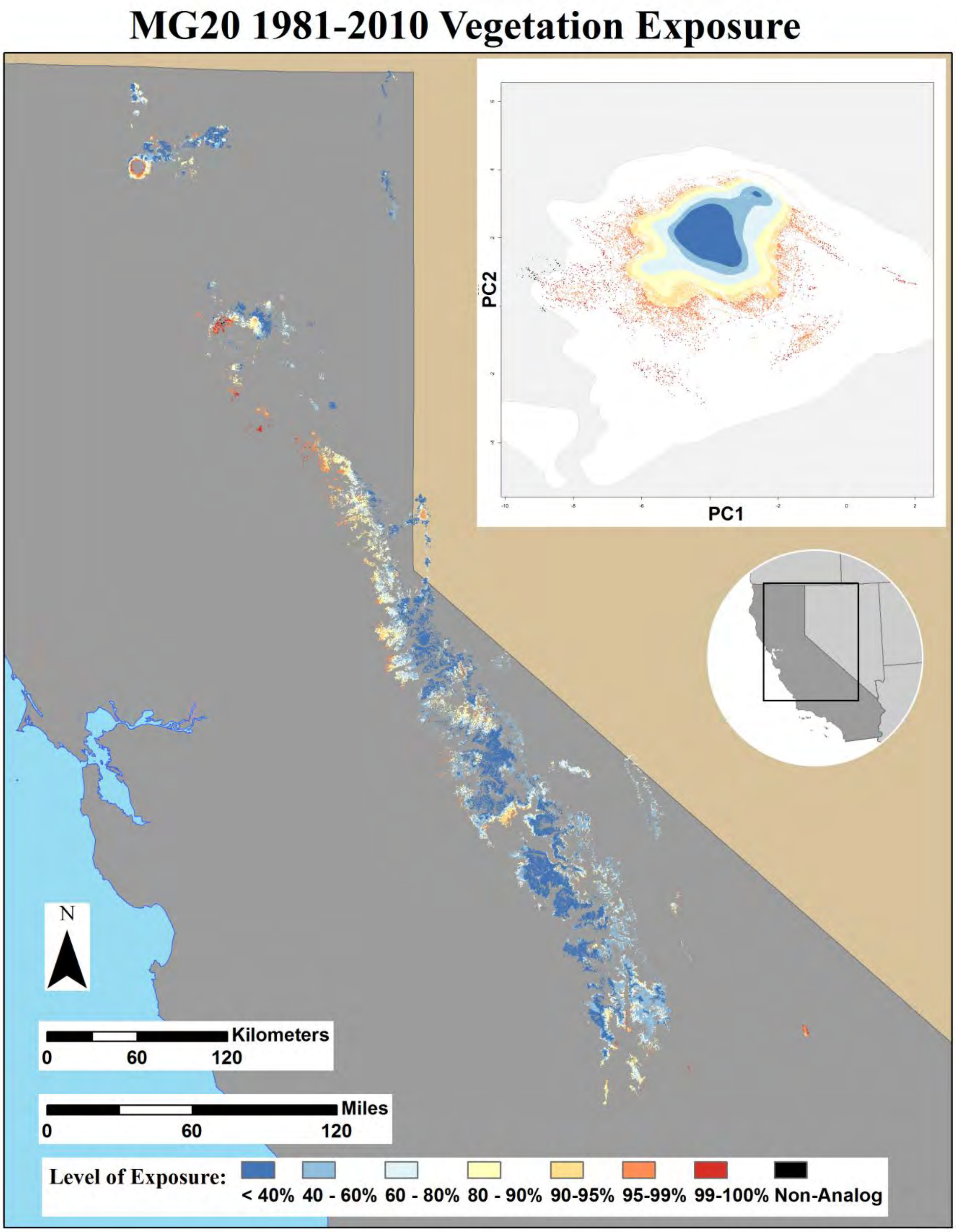


Figure 20. Map of Current Climate Suitability for Macrogroup 20. The 2015 mapped extent of macrogroup 20, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 20 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 10). The overall or grand mean for macrogroup 20 was found to be 2.50 for sensitivity and adaptive capacity, among the lowest scores for macrogroups analyzed.

Table 10. Sensitivity and Adaptive Capacity Rankings for Macrogroup 20. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 20. The species *Pinus contorta* combines two subspecies with different lifespans, and serotinous cones.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Populus tremuloides	1	2	4	3	3	3	4	1	1	**2.4**
Pinus flexilis	1	3	2	2	1	5	1	3	3	**2.3**
Pinus albicaulis	1	3	1	2	1	5	1	4	3	**2.3**
Pinus contorta	2	3	2	3	3	4	5	3	1	**2.9**
Mean	**1.25**	**2.75**	**2.25**	**2.50**	**2.00**	**4.25**	**2.75**	**2.75**	**2.00**	
Grand Mean	**2.50**				**Mean**	**2.50**		**Mean**	**2.50**	

Projected Climate Exposure

The future climate exposure for macrogroup 20 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 21).

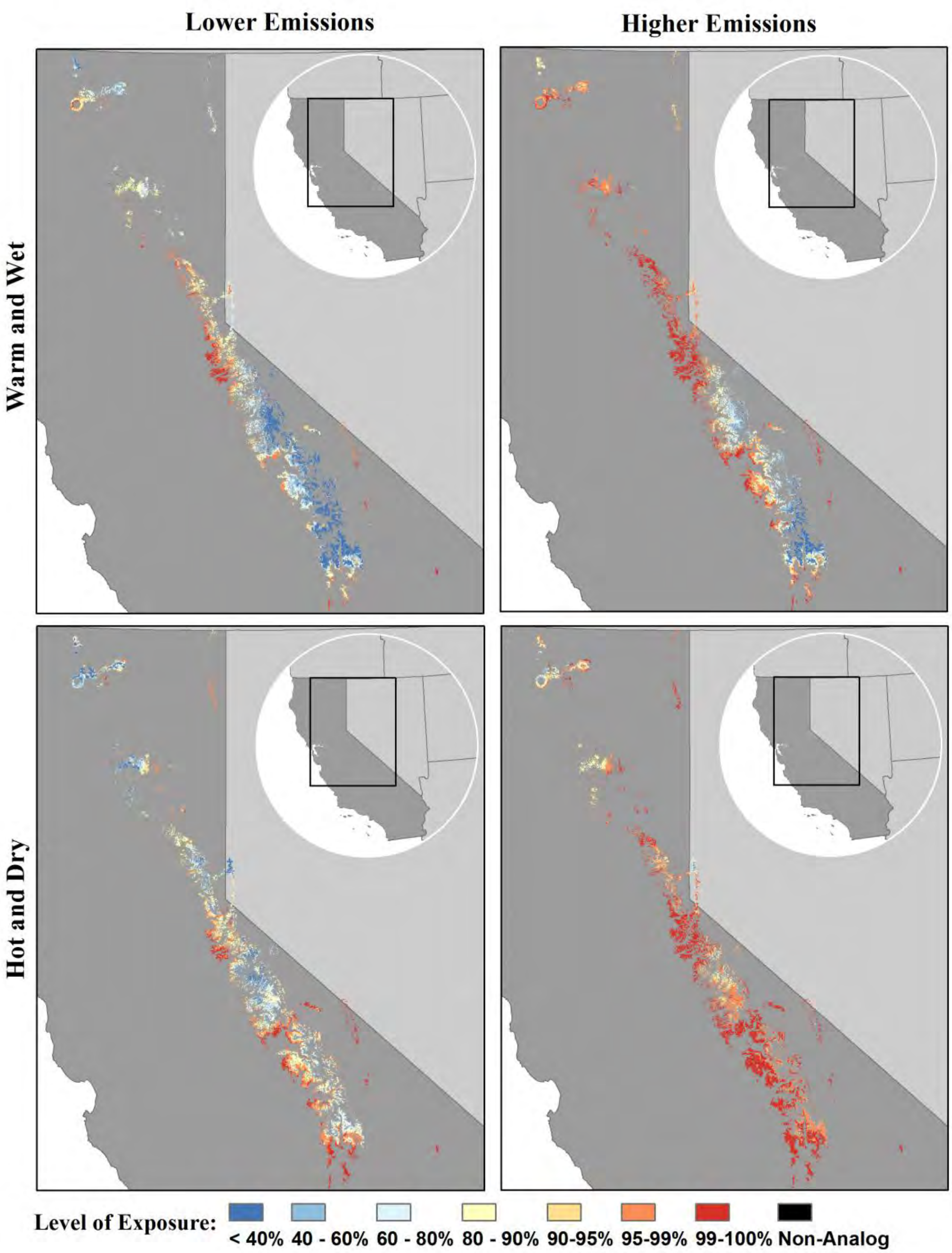


Figure 21. Maps of Projected Climate Exposure for Macrogroup 20. The climate exposure level for macrogroup 20 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 21 is derived from the PCA charts (Figure 22), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

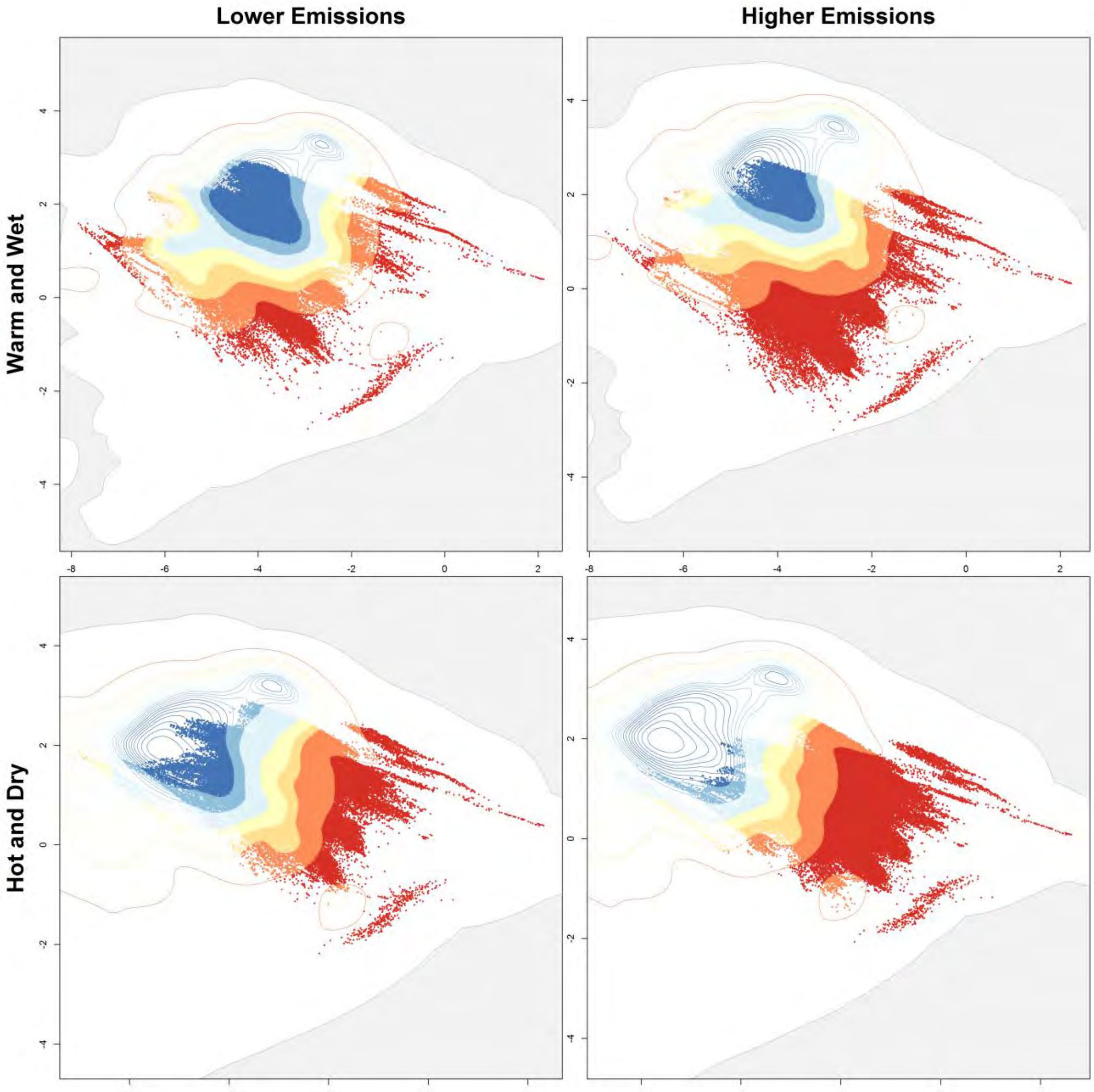


Figure 22. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 20. The PCA charts are two dimensional representations of climate exposure for macrogroup 20 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 11). In the current time period, macrogroup 20 occupies 9,390 km^2. By the end of the century, there will be between 280 km^2 (3%) and 5,254 km^2 (56%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,737 km^2 (19%) and 7,928 km^2 (84%) of this type will be climatically exposed by the end of century.

Table 11. Percentage of the Current Extent of Macrogroup 20 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1,878	1,878	1,878	1,879	938	470	376	90	4
1980-2010 (%)	20.00	20.00	20.00	20.01	9.99	5.01	4.00	0.96	0.04
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	15.33	18.26	15.83	24.67	14.30	5.48	4.92	1.22	0.00
2040-2069 (%)	19.12	18.46	14.53	19.63	11.88	6.68	6.60	3.10	0.00
2070-2099 (%)	12.65	14.59	11.40	17.31	15.56	9.99	11.35	7.15	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	14.14	15.49	16.89	27.34	14.04	5.65	4.77	1.68	0.00
2040-2069 (%)	14.44	16.24	12.40	17.50	13.76	9.98	9.95	5.72	0.00
2070-2099 (%)	3.93	4.98	6.69	12.44	9.21	9.36	22.56	30.84	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	27.44	24.05	17.89	14.89	6.90	3.65	4.01	1.16	NA
2040-2069 (%)	3.49	15.57	15.75	24.70	15.62	8.88	10.79	5.20	NA
2070-2099 (%)	1.00	5.27	7.52	20.66	19.19	13.01	19.65	13.70	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	25.60	25.90	17.57	14.87	7.28	3.18	4.20	1.40	NA
2040-2069 (%)	0.94	3.73	5.60	18.11	18.52	14.19	23.36	15.54	0.00
2070-2099 (%)	0.00	0.16	0.81	2.01	5.11	7.49	29.01	55.42	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 20 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 23), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 31,844 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

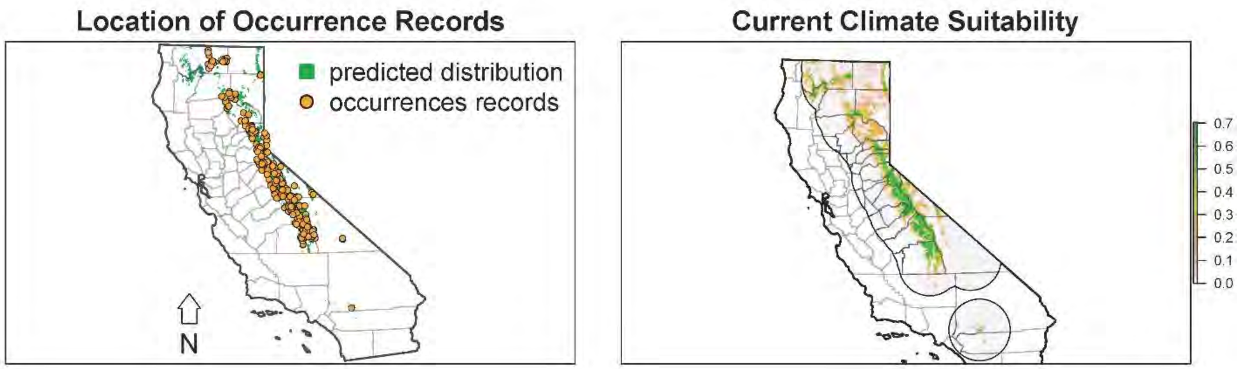


Figure 23. Map of Points Selected from the Extent of Macrogroup 20 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 20. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 20 (Figure 24). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 20, between 10,755 km^2 (34%) and 30,230 km^2 (95%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 1,614 km^2 (5%) and 21,088 km^2 (66%) will remain climatically suitable, and between 58 km^2 (0.2%) and 668 km^2 (2%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 12.

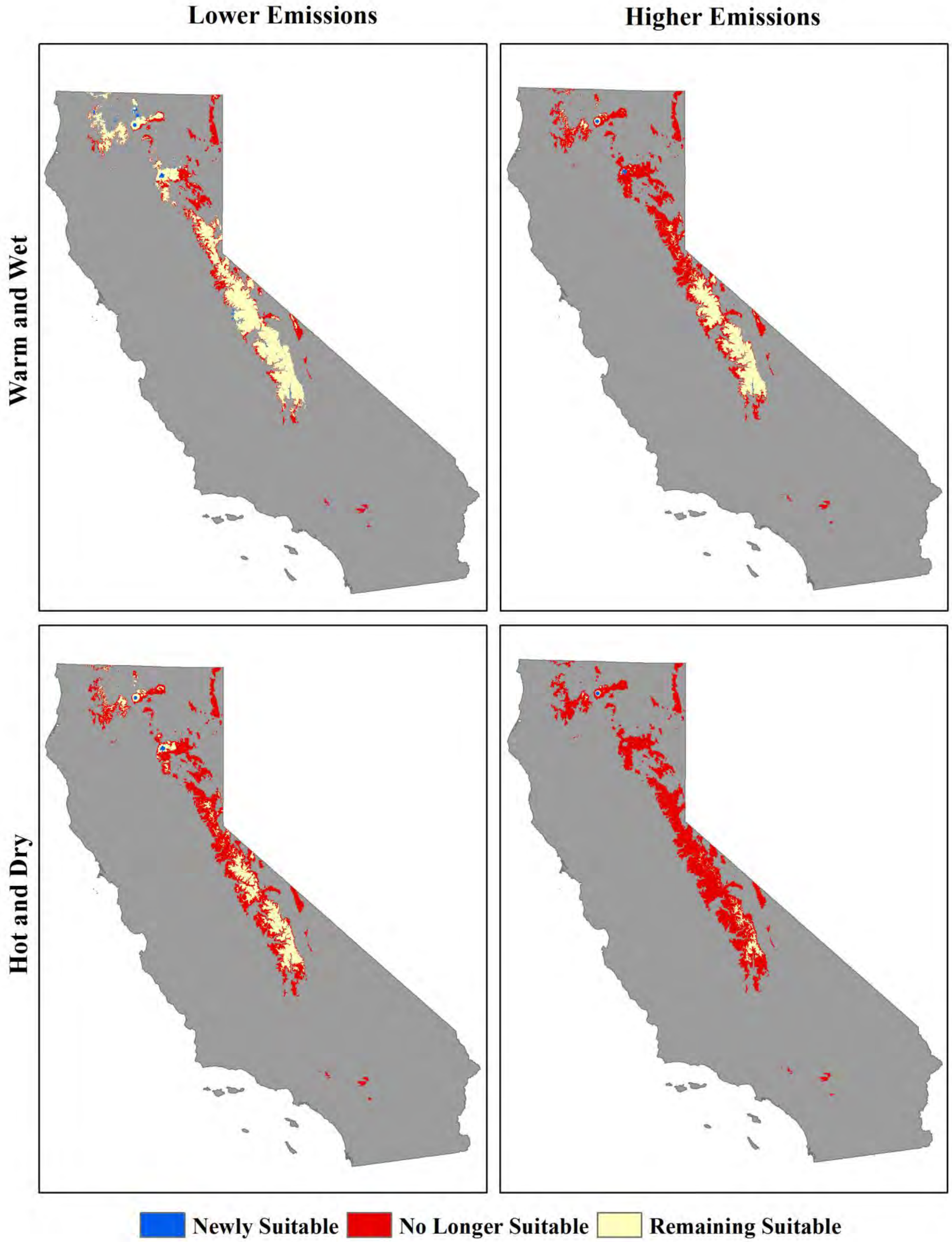


Figure 24. Maps of the Projected Climatically Suitable Range for Macrogroup 20. Maps showing the modeled climatically suitable range for macrogroup 20 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 12.Area of Projected Climatic Suitability for Macrogroup 20. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 20, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	10,755	21,088	668	34%	66%	2%
CNRM CM5 - RCP 8.5	21,246	10,598	148	67%	33%	0%
MIROC ESM - RCP 4.5	22,998	8,846	149	72%	28%	0%
MIROC ESM - RCP 8.5	30,230	1,614	58	95%	5%	0%

MG023: Macrogroup Californian-Vancouverian Montane and Foothill Forest
Common Name: North Coastal Mixed Evergreen and Montane Conifer Forests

This broad macrogroup is representative of the cool-temperate forests which occur in the Pacific states from the Puget Sound area south into the higher mountains of southern California and adjacent Baja Mexico. In California, these range inland from the immediate coast and experience warm, relatively dry summers and cool rainy to cool snowy winters. All of these forests average cooler and wetter than macrogroup 9 (California Foothill and Valley Forests and Woodlands).

There is relatively broad overlap between the three groups comprising this macrogroup. The moist coastal mixed evergreen has (or had) tanoak, madrone, giant chinquapin (*Chrysolepis chrysophylla*) mixed frequently with Douglas-fir, but also mixes with big leaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*) in upland settings. The more interior mixed evergreen forests have cooler winters and warmer summers than the moist coastal group above, and contain Oregon oak (*Quercus garryana*) and drier Douglas-fir with canyon oak mixes. At higher elevations inland and farther south in the mountains, forests of montane conifers include bigcone Douglas-fir (*Pseudotsuga macrocarpa*) (southern CA) and Santa Lucia fir (*Abies bracteata*) (Central CA coast), ponderosa pine mixed with incense-cedar (*Calocedrus decurrens*), and up in elevation through stands of mixed white fir, sugar pine, and Jeffrey pine.

The group with coastal mixed evergreen forests is closest to WHR habitat Douglas fir (DFR), but also includes montane hardwood conifer (MHC). Pure stands of tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), and chinquapin (*Chrysolepis sempervirens*) go to montane hardwood (MHW). The interior mixed evergreen component includes Klamath mixed conifer (KMC), montane hardwood conifer (MHC) (with mixes of canyon oak, Douglas-fir), and some of Douglas fir (DFR). Finally, the montane conifer forest includes eastside pine (EPN) as well as the more broadly interpreted Sierran mixed conifer (SMC) habitat; although the understory differences suggest a more great basin flavor, the eastside pine habitat is easily included in this group with broad overlap at the alliance level of Jeffrey pine, ponderosa pine, white fir (*Abies concolor*) and other alliances. Several other WHR types are nested within this group including: white fir (WFR), Klamath mixed conifer (KMC), montane hardwood conifer (MHC), Jeffrey pine (JPN), and ponderosa pine (PPN).

Macrogroup 23 is comprised of approximately eight WHR types for which we scored 12 representative dominant species. The statewide extent for the current time period cover 53,263 km^2, here shown classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 25). Using the current climate conditions for the extent of Macrogroup 23, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

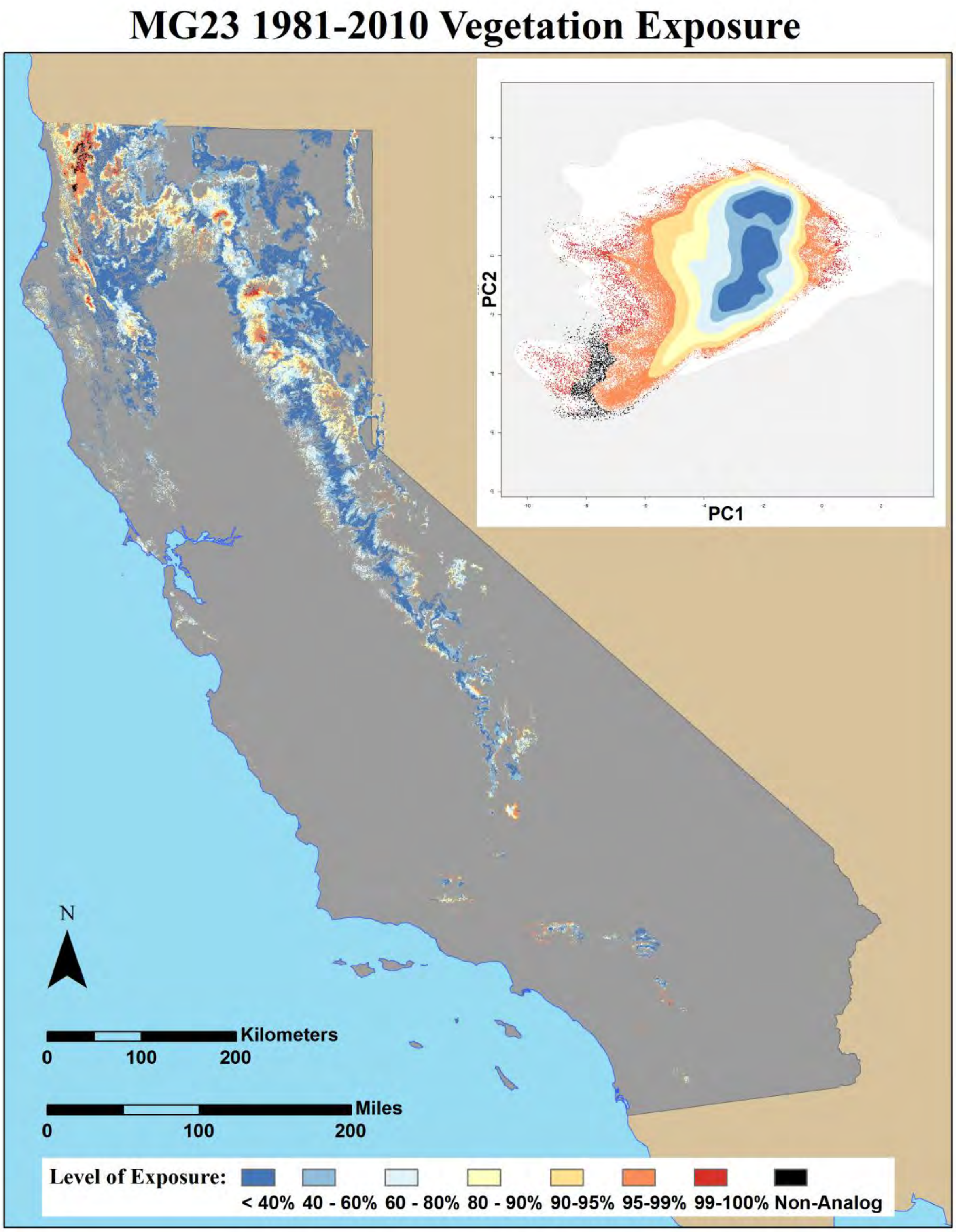


Figure 25. Map of Current Climate Suitability for Macrogroup 23. The 2015 mapped extent of macrogroup 23, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 23 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 13). The overall or grand mean for macrogroup 23 was found to be 2.86 for sensitivity and adaptive capacity.

Table 13. Sensitivity and Adaptive Capacity Rankings for Macrogroup 23. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 23.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Repro-ductive Lifespan**	**Fire**	**Recruit-ment Mode /Fecundity**	**Seed Long-evity**	
Lithocarpus densiflorus	3	3	4	3	2	5	5	1	1	**3.0**
Arbutus menziesii	2	2	2	2	2	5	2	1	3	**2.3**
Quercus kelloggii	3	2	3	3	2	5	5	3	2	**3.1**
Acer macro-phyllum	2	2	4	3	3	2	5	1	1	**2.6**
Quercus garryana	3	2	4	3	2	5	5	1	1	**2.9**
Pseudotsuga menziesii	3	3	5	3	4	5	1	3	1	**3.1**
Pseudotsuga macrocarpa	3	3	4	2	3	5	5	1	1	**3.0**
Abies concolor	2	2	2	2	4	5	1	5	1	**2.7**
Pinus jeffreyi	2	3	4	2	3	5	1	3	2	**2.8**
Calocedrus decurrens	3	3	5	2	3	5	1	5	1	**3.1**
Pinus lambertiana	3	3	5	2	4	5	1	2	1	**2.9**
Pinus ponderosa	3	3	5	2	4	5	4	4	1	**3.4**
Mean	**2.64**	**2.55**	**3.82**	**2.45**	**2.91**	**4.73**	**2.91**	**2.36**	**1.36**	
Grand Mean	**2.86**				**Mean**	**3.18**		**Mean**	**2.21**	

Projected Climate Exposure

The future climate exposure for macrogroup 23 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 26).

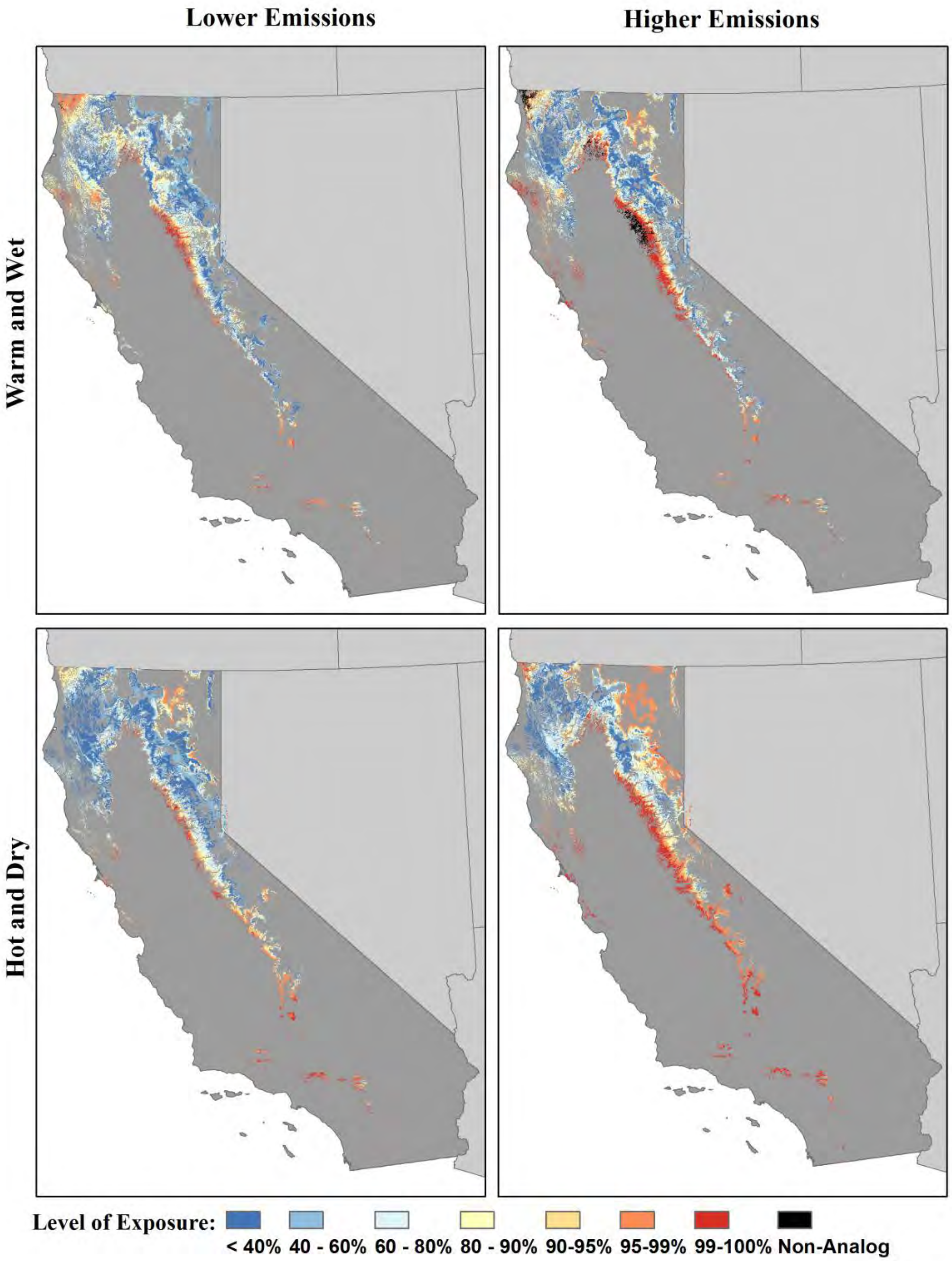


Figure 26. Maps of Projected Climate Exposure for Macrogroup 23. The climate exposure level for macrogroup 23 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 26 is derived from the PCA charts (Figure 27), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

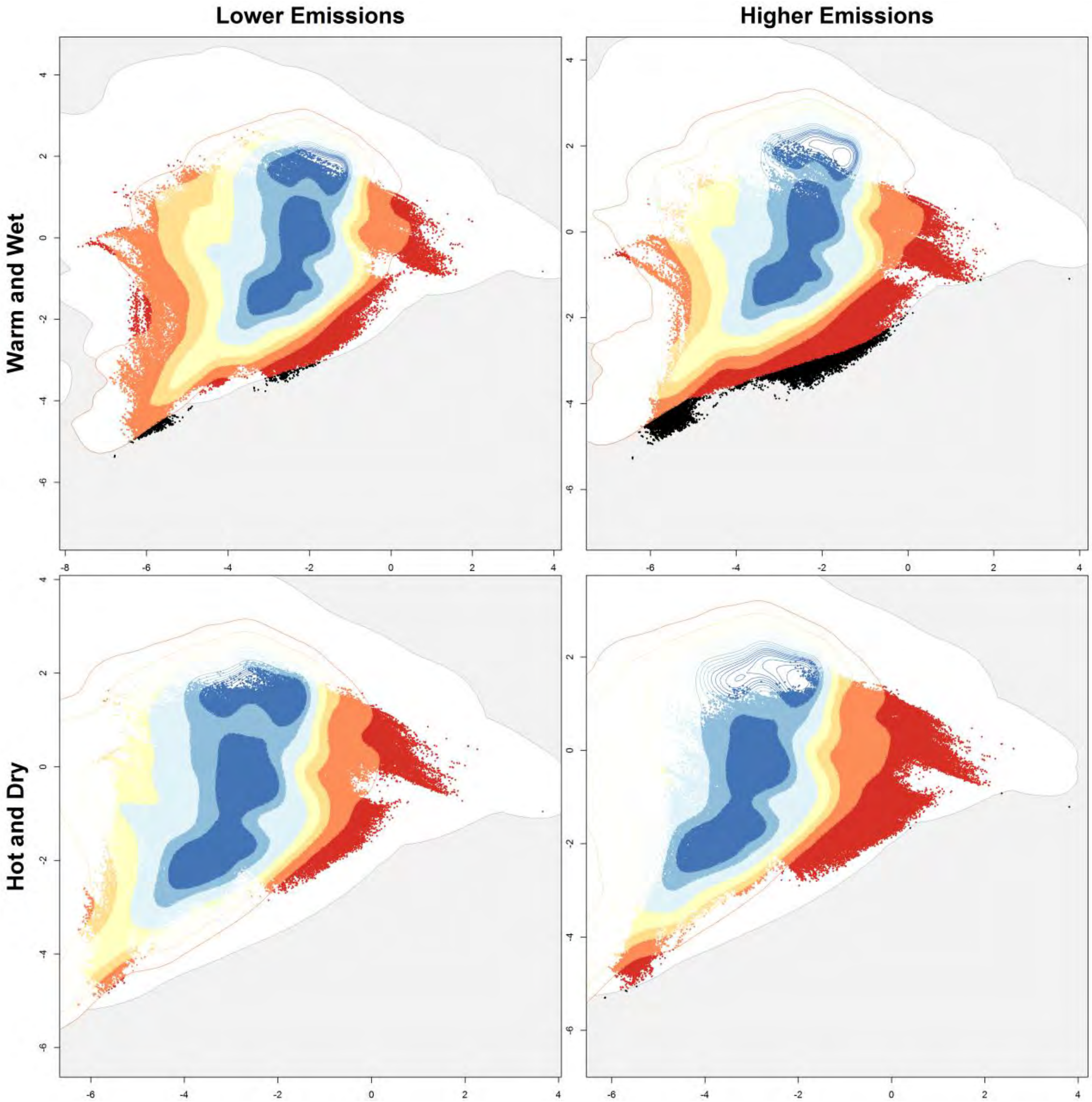


Figure 27. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 23. The PCA charts are two dimensional representations of climate exposure for macrogroup 23 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 14). In the current time period, macrogroup 23 occupies 53,263 km^2. By the end of the century, there will be between 25,543 km^2 (48%) and 39,477 km^2 (74%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 5,992 km^2 (11%) and 17,944 km^2 (34%) of this type will be climatically exposed by the end of century.

Table 14. Percentage of the Current Extent of Macrogroup 23 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	Non Analog
1980-2010 (km^2)	10,654	10,650	10,648	10,655	5,328	2,660	2,132	395	139
1980-2010 (%)	20.00	20.00	19.99	20.01	10.00	4.99	4.00	0.74	0.26
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	9.55	12.78	17.60	28.02	16.87	9.07	5.28	0.82	0.00
2040-2069 (%)	7.08	14.95	24.37	26.73	14.45	6.85	4.55	1.01	0.00
2070-2099 (%)	6.86	14.47	21.05	25.62	14.01	6.73	7.74	3.43	0.09
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	7.45	13.41	17.79	27.76	17.38	10.06	5.37	0.78	0.00
2040-2069 (%)	7.15	15.60	22.94	26.22	12.95	6.04	6.34	2.73	0.02
2070-2099 (%)	9.40	15.83	14.89	20.19	10.25	7.75	9.07	9.57	3.04
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	15.46	17.24	22.58	25.62	10.87	4.80	3.09	0.34	NA
2040-2069 (%)	17.67	21.19	24.55	18.22	7.79	3.81	5.32	1.45	NA
2070-2099 (%)	14.61	19.82	21.45	18.23	8.00	6.13	8.17	3.59	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	14.72	18.25	23.68	25.80	9.66	4.30	3.20	0.39	NA
2040-2069 (%)	15.64	19.97	22.34	17.46	7.91	5.87	7.80	3.01	0.00
2070-2099 (%)	5.84	11.00	11.78	19.34	10.10	8.26	20.49	13.19	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 23 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 28), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 96,558 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

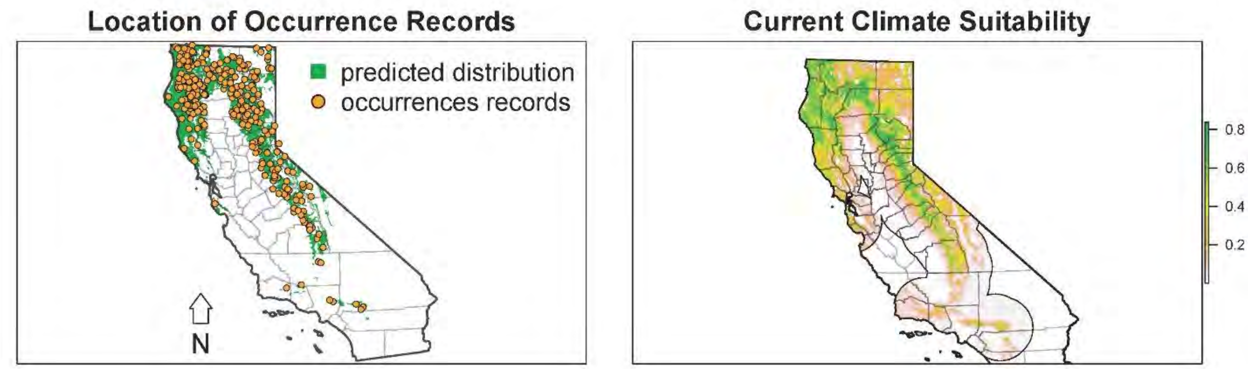


Figure 28. Map of Points Selected from the Extent of Macrogroup 23 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 23. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 23 (Figure 29). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 23, between 10,547 km^2 (11%) and 66,967 km^2 (69%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 29,591 km^2 (31%) and 86,012 km^2 (89%) will remain climatically suitable, and between 8,834 km^2 (9%) and 13,666 km^2 (14%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 15.

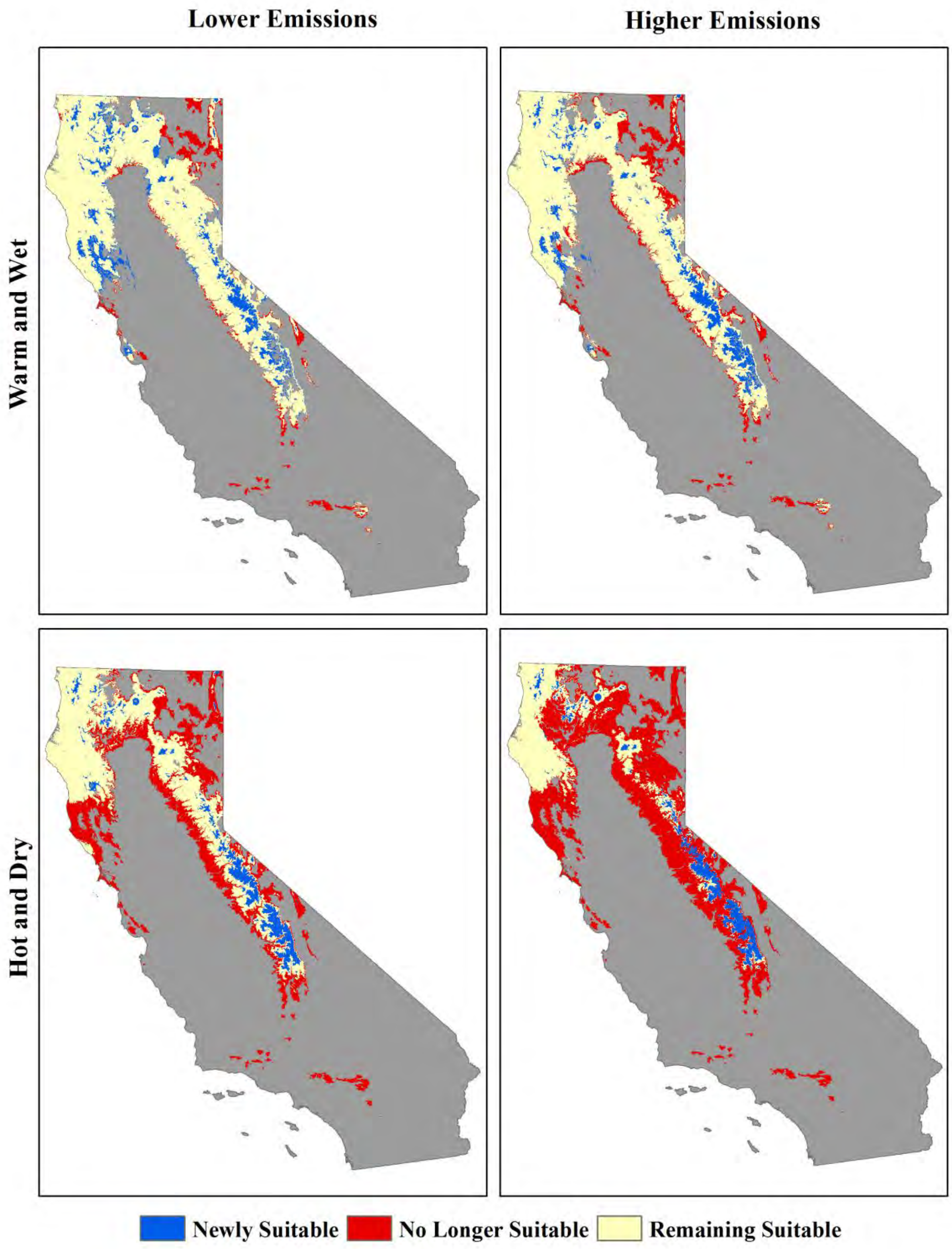


Figure 29. Maps of the Projected Climatically Suitable Range for Macrogroup 23. Maps showing the modeled climatically suitable range for macrogroup 23 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 15. Area of Projected Climatic Suitability for Macrogroup 23. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 23, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	10,547	86,012	13,666	11%	89%	14%
CNRM CM5 - RCP 8.5	18,117	78,441	11,424	19%	81%	12%
MIROC ESM - RCP 4.5	41,976	54,582	9,530	43%	57%	10%
MIROC ESM - RCP 8.5	66,967	29,591	8,834	69%	31%	9%

MG024: Macrogroup Vancouverian Rainforest
Common Name: Pacific NW Conifer Forests

This is the Pacific Northwest temperate rainforest, which includes the giant conifer forests ranging from the central California coast, all the way up to southeastern Alaska. Mild winters with massive amounts of rain (and some snow north of California) and a maritime climate, with cool summers with either fog (in California) or some summer rain (north of California) are typical.

In California, most characterized by coast redwood, but also includes stands of Sitka spruce (*Picea sitchensis*), western red-cedar (*Thuja plicata*), Port Orford-cedar (*Chamaecyparis lawsoniana*), grand fir (*Abies grandis*), and shore pine (*Pinus contorta contorta*).

The best single WHR match for this macrogroup is redwood (*Sequoia sempervirens*) (RDW).

Macrogroup 24 is comprised of one WHR type for which we scored one representative dominant species. The statewide extent for the current time period cover 4,502 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 30). Using the current climate conditions for the extent of Macrogroup 24, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

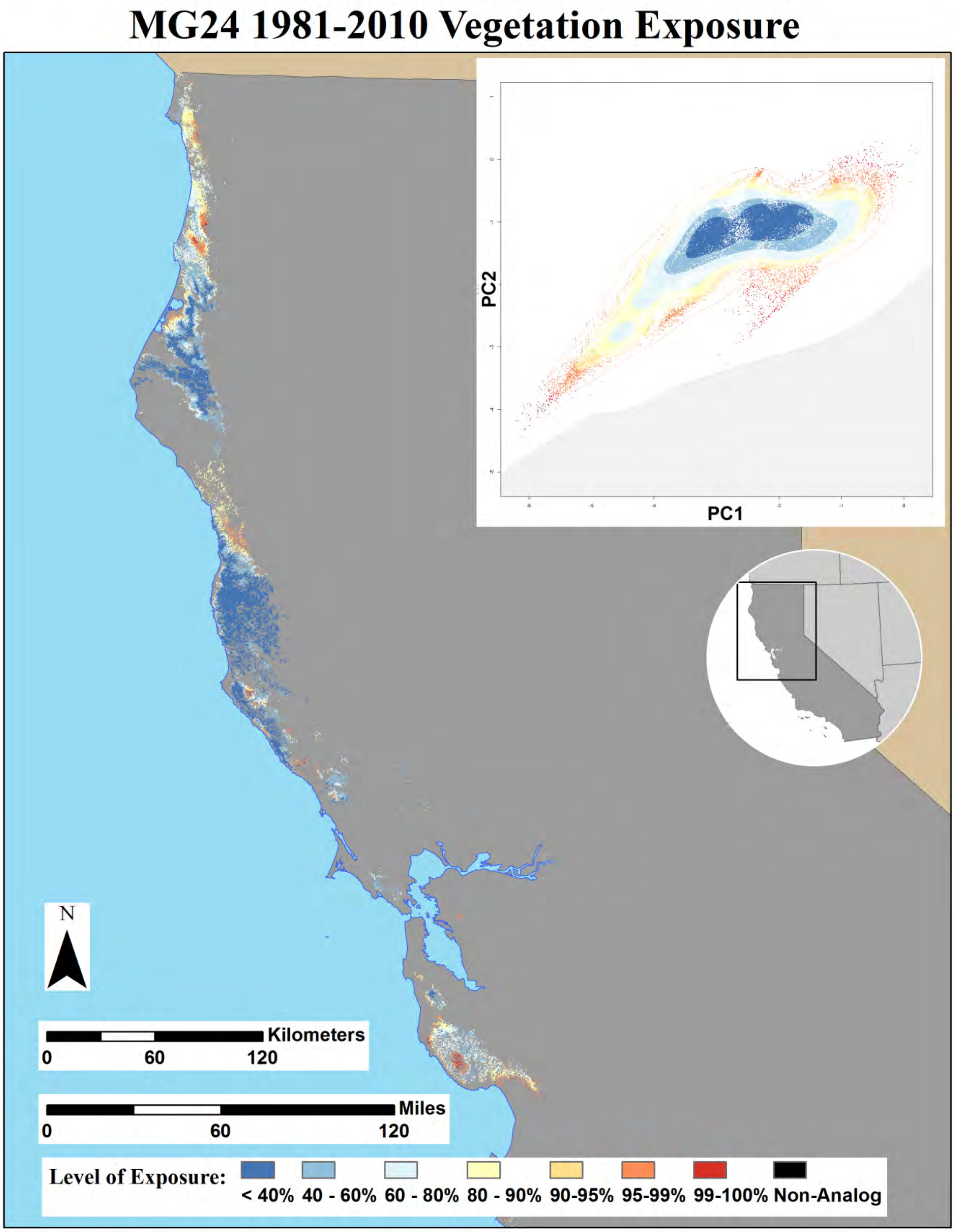


Figure 30. Map of Current Climate Suitability for Macrogroup 24. The 2015 mapped extent of macrogroup 24, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 24 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 16). The overall or grand mean for macrogroup 24 was found to be 2.89 for sensitivity and adaptive capacity.

Table 16. Sensitivity and Adaptive Capacity Rankings for Macrogroup 24. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 24.

	Sensitivity						Adaptive Capacity			Species Score
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Sequoia sempervirens	2	2	4	3	3	5	5	1	1	**2.9**
Mean	**2.00**	**2.00**	**4.00**	**3.00**	**3.00**	**5.00**	**5.00**	**1.00**	**1.00**	
Grand Mean	**2.89**				**Mean**	**3.17**		**Mean**	**2.33**	

Projected Climate Exposure

The future climate exposure for macrogroup 24 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 31).

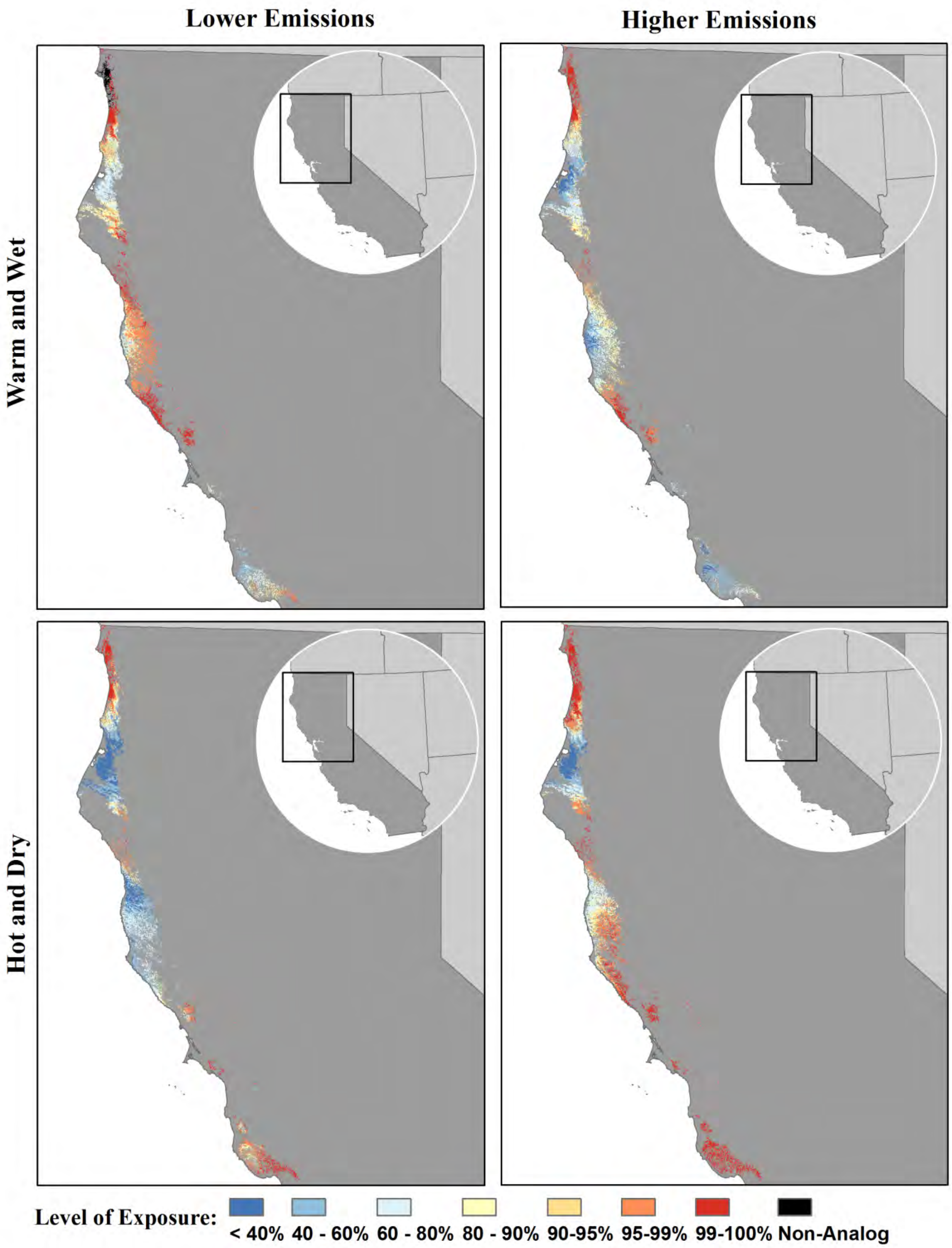


Figure 31. Maps of Projected Climate Exposure for Macrogroup 24. The climate exposure level for macrogroup 24 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 31 is derived from the PCA charts (Figure 32), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

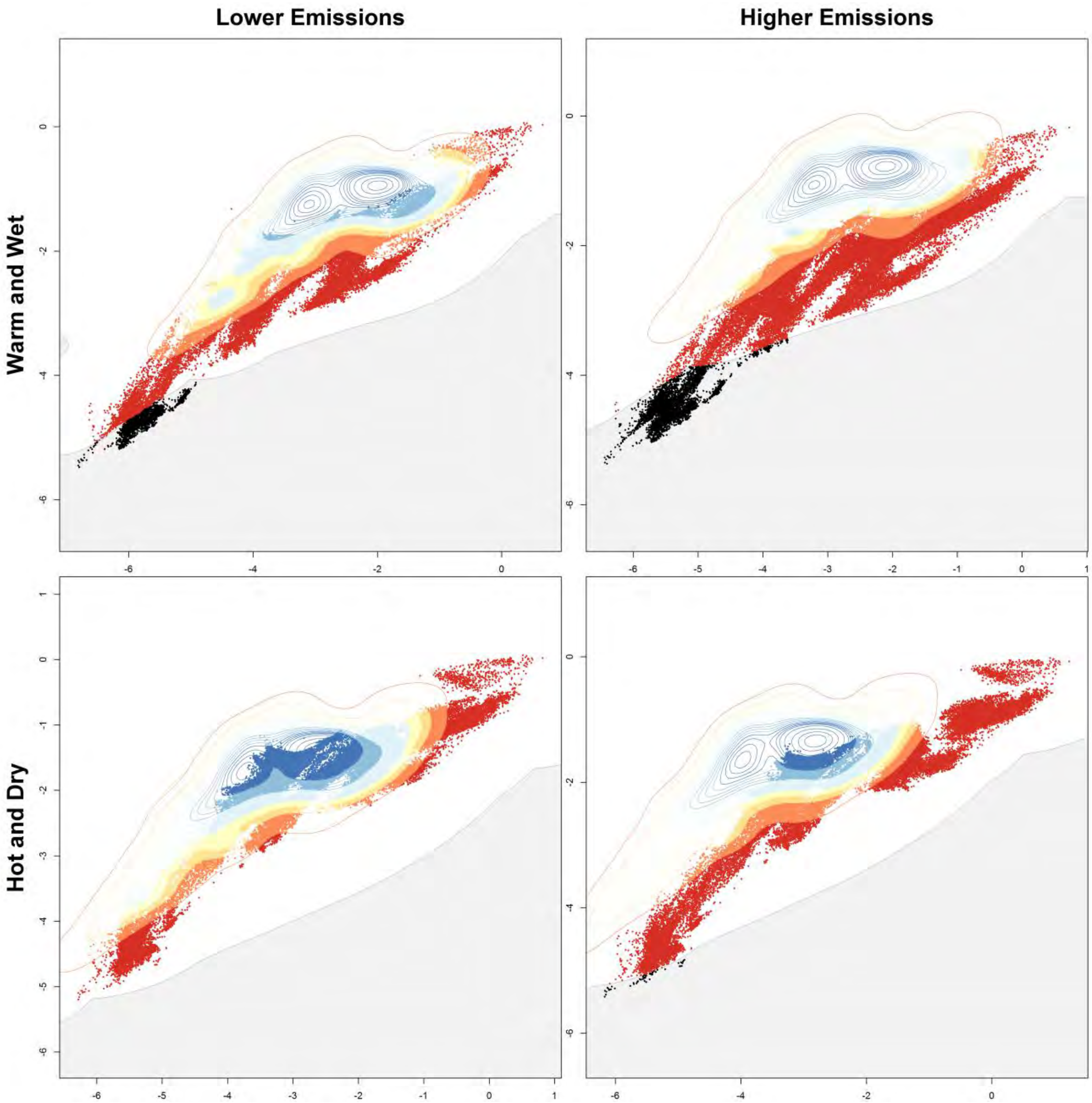


Figure 32. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 24. The PCA charts are two dimensional representations of climate exposure for macrogroup 24 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 17). In the current time period, macrogroup 24 occupies 4,502 km^2. By the end of the century, there will be between 34 km^2 (1%) and 2,893 km^2 (64%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,082 km^2 (24%) and 3,990 km^2 (89%) of this type will be climatically exposed by the end of century.

Table 17. Percentage of the Current Extent of Macrogroup 24 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	900	900	900	901	450	225	180	45	0
1980-2010 (%)	20.00	20.00	20.00	20.01	9.99	5.00	4.01	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	3.43	13.73	23.61	26.09	7.85	6.30	9.53	9.46	0.00
2040-2069 (%)	1.34	8.23	20.50	27.69	12.35	7.26	10.56	12.09	0.00
2070-2099 (%)	0.00	0.06	3.85	20.66	12.71	12.10	26.20	20.74	3.69
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.92	7.50	19.30	28.34	14.48	7.88	8.75	12.83	0.00
2040-2069 (%)	0.29	1.65	14.26	25.64	13.15	12.73	14.18	15.72	2.37
2070-2099 (%)	0.00	0.00	0.00	0.76	3.37	7.24	23.96	56.56	8.11
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	25.39	17.87	16.47	17.03	8.47	4.75	6.77	3.26	NA
2040-2069 (%)	7.33	22.24	15.61	23.36	7.75	6.98	8.22	8.52	NA
2070-2099 (%)	6.82	15.49	21.95	20.00	6.03	5.68	10.19	13.84	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	18.51	25.01	16.81	15.34	9.47	5.69	7.01	2.16	NA
2040-2069 (%)	8.11	17.27	13.78	27.57	6.47	4.85	8.23	13.73	0.00
2070-2099 (%)	1.83	7.60	6.53	15.16	7.61	8.36	17.41	35.41	0.09

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 24 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 33), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 22,849 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

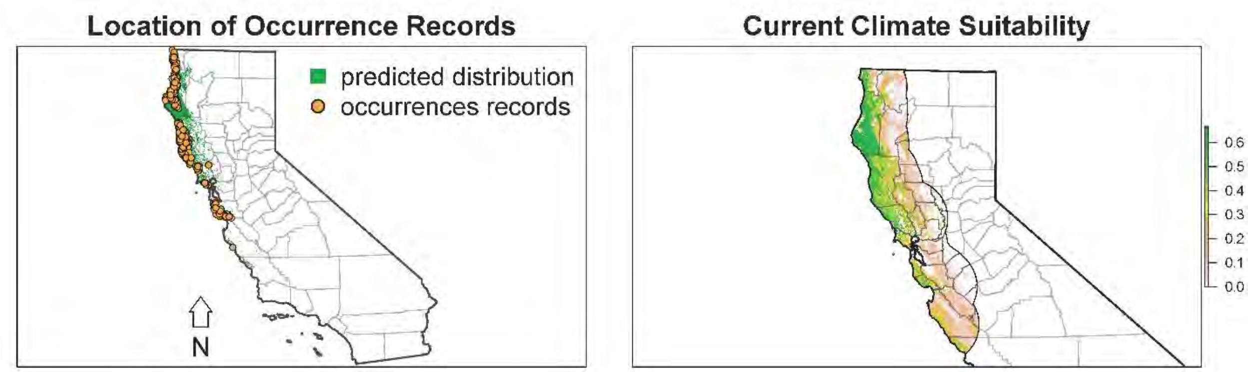


Figure 33. Map of Points Selected from the Extent of Macrogroup 24 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 24. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 24 (Figure 34). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 24, between 6,122 km^2 (27%) and 18,586 km^2 (81%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 4,263 km^2 (19%) and 16,727 km^2 (73%) will remain climatically suitable, and between 1,317 km^2 (6%) and 3,112 km^2 (14%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 18.

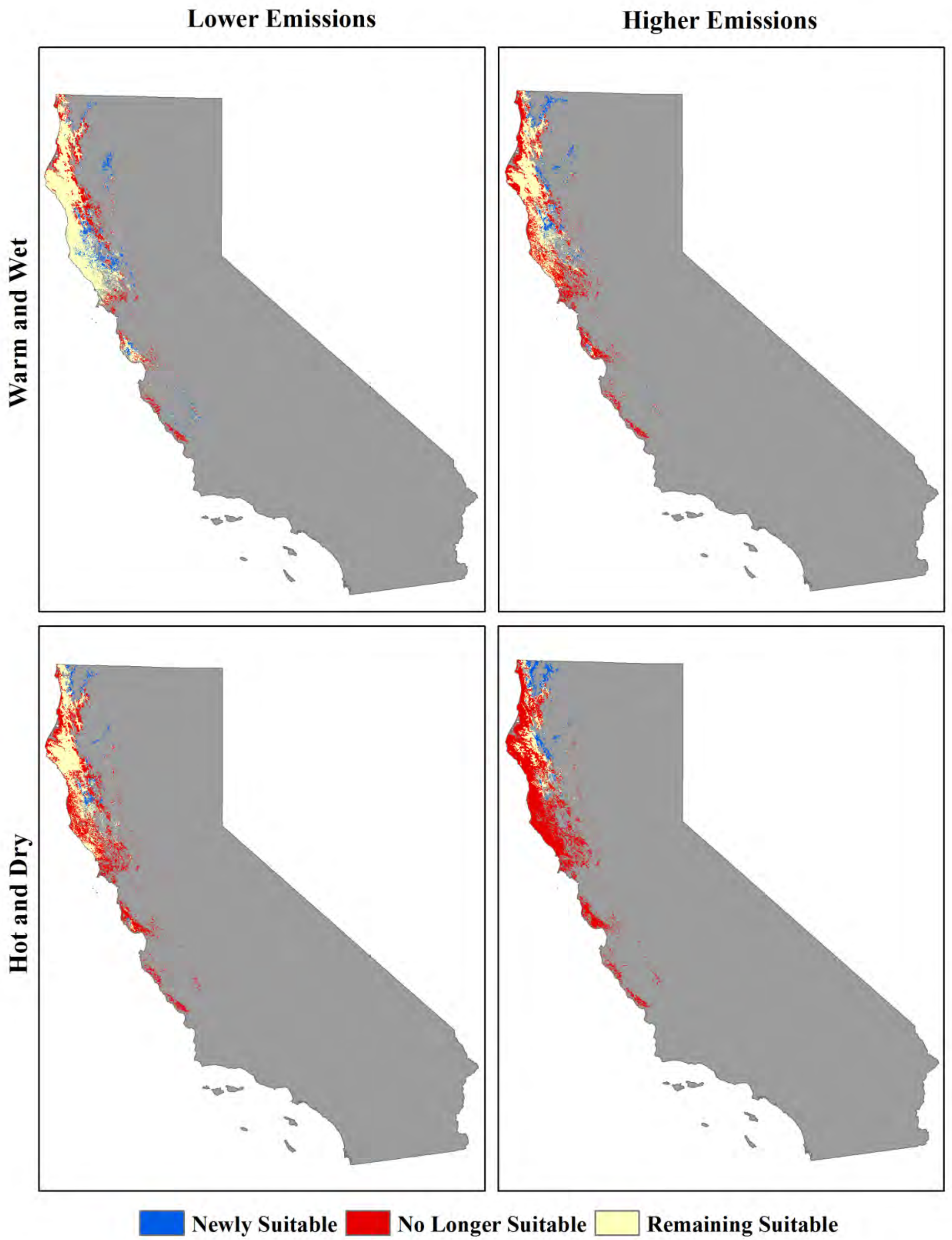


Figure 34. Maps of the Projected Climatically Suitable Range for Macrogroup 24. Maps showing the modeled climatically suitable range for macrogroup 24 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 18. Area of Projected Climatic Suitability for Macrogroup 24. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 24, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	6,122	16,727	3,112	27%	73%	14%
CNRM CM5 - RCP 8.5	11,137	11,712	2,496	49%	51%	11%
MIROC ESM - RCP 4.5	12,105	10,745	1,317	53%	47%	6%
MIROC ESM - RCP 8.5	18,586	4,263	2,025	81%	19%	9%

MG025: Macrogroup Vancouverian Subalpine Forest
Common Name: Pacific Northwest Subalpine Forest

This macrogroup includes montane conifer forests and woodlands adapted to very high winter snowfall, from montane to subalpine altitudes. Snow loads here are the greatest anywhere in North America, and persist well into the summer. Tree germination is also limited in some cases by the short period the ground is not covered by snow.

Characteristic trees include red fir (*Abies magnifica*), mountain hemlock (*Tsuga mertensiana*), western white pine (*Pinus monticola*), and in the Klamath Mountains, isolated pacific silver fir (*Abies amabilis*), cascade subalpine fir (*Abies lasiocarpa*), and yellow cedar (*Callitropsis nootkatensis*) stands.

The WHR types included in this macrogroup are red fir (RFR) and part of subalpine conifer (SCN) with mountain hemlock, western white pine, pacific silver fir, and subalpine fir (Klamath Mtns).

Macrogroup 25 is comprised of approximately two WHR types for which we scored five representative dominant species. The statewide extent for the current time period cover 1,000 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 35). Using the current climate conditions for the extent of Macrogroup 25, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

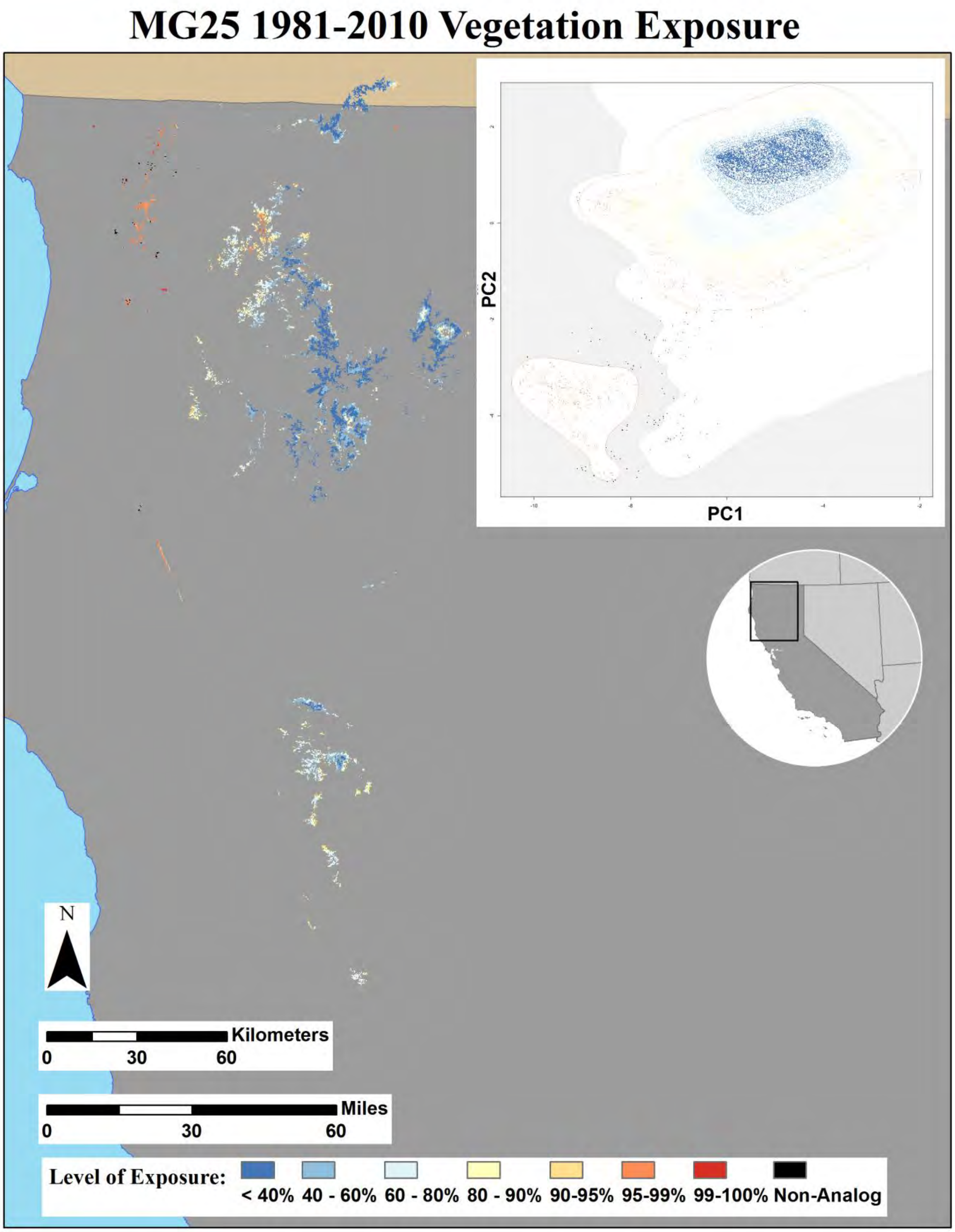


Figure 35. Map of Current Climate Suitability for Macrogroup 25. The 2015 mapped extent of macrogroup 25, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 25 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 19). The overall or grand mean for macrogroup 25 was found to be 2.38 for sensitivity and adaptive capacity.

Table 19. Sensitivity and Adaptive Capacity Rankings for Macrogroup 25. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 25.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Abies amabilis	2	2	1	3	3	5	1	3	2	**2.4**
Abies lasiocarpa	2	2	1	2	3	5	1	4	1	**2.3**
Abies magnifica	2	2	5	2	3	5	1	3	1	**2.7**
Callitropsis nootkatensis	2	2	2	2	3	3	2	3	1	**2.2**
Tsuga mertensiana	3	2	1	2	3	3	1	4	1	**2.2**
Mean	**2.20**	**2.00**	**2.00**	**2.20**	**3.00**	**4.20**	**1.20**	**3.40**	**1.20**	
Grand Mean	**2.38**				**Mean**	**2.60**		**Mean**	**1.93**	

Projected Climate Exposure

The future climate exposure for macrogroup 25 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 36).

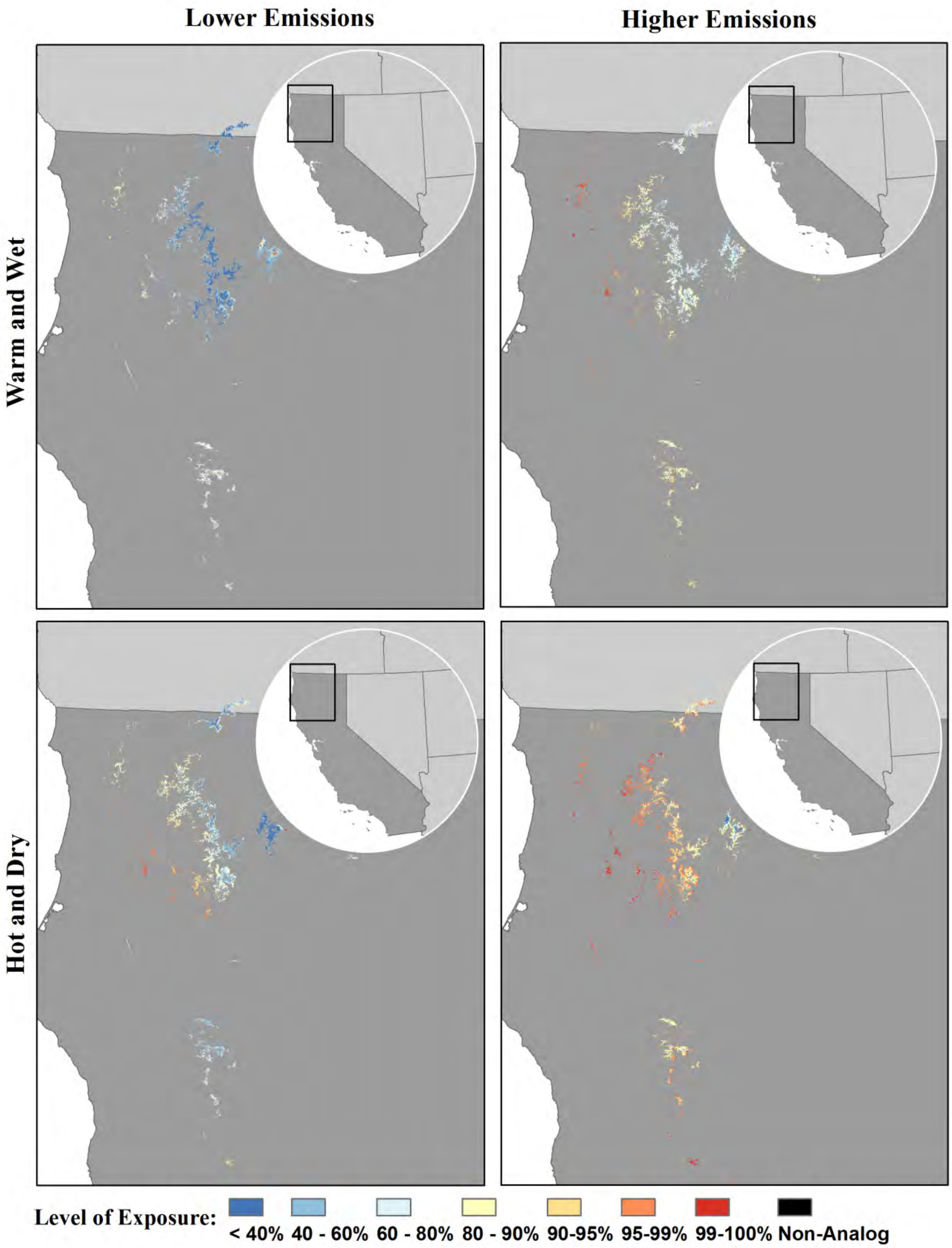


Figure 36. Maps of Projected Climate Exposure for Macrogroup 25. The climate exposure level for macrogroup 25 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 36 is derived from the PCA charts (Figure 37), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

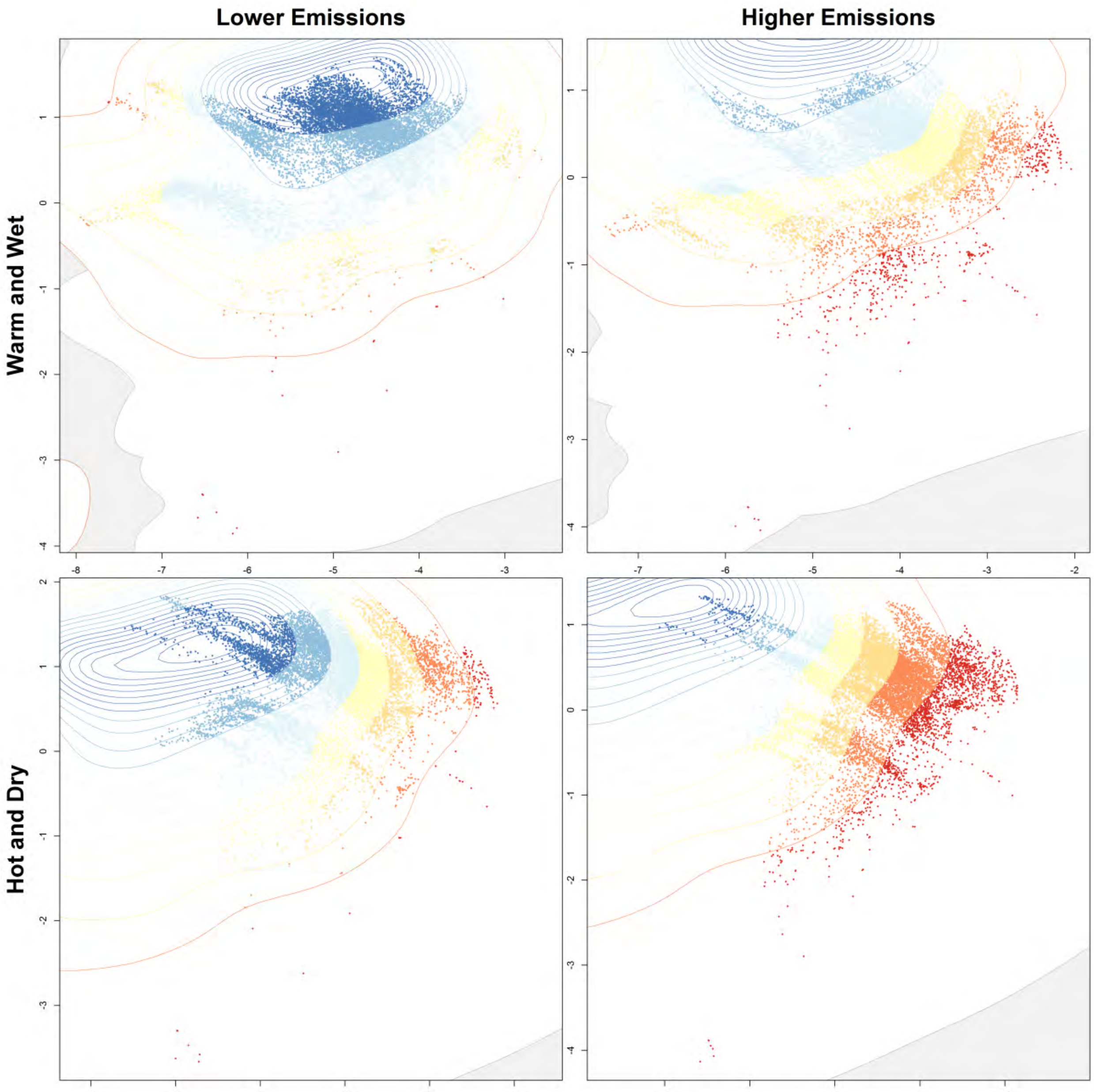


Figure 37. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 25. **T**he PCA charts are two dimensional representations of climate exposure for macrogroup 25 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 20). In the current time period, macrogroup 25 occupies 1,000 km^2. By the end of the century, there will be between 69 km^2 (7%) and 908 km^2 (91%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 6 km^2 (1%) and 443 km^2 (44%) of this type will be climatically exposed by the end of century.

Table 20. Percentage of the Current Extent of Macrogroup 25 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	200	200	200	200	100	50	40	5	5
1980-2010 (%)	19.99	20.00	20.00	20.01	10.01	5.00	3.99	0.55	0.45
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	37.75	24.69	18.75	9.99	4.52	3.16	1.05	0.09	0.00
2040-2069 (%)	44.14	20.57	16.45	12.73	5.47	0.49	0.09	0.06	0.00
2070-2099 (%)	12.41	20.26	33.04	25.03	6.36	2.32	0.45	0.14	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	43.08	23.53	14.96	9.59	4.77	3.48	0.51	0.07	0.00
2040-2069 (%)	16.53	22.86	29.31	25.09	4.46	1.43	0.20	0.11	0.00
2070-2099 (%)	0.00	0.00	4.96	42.07	28.54	14.11	6.58	3.73	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	24.31	38.99	23.62	8.80	2.58	1.34	0.31	0.06	NA
2040-2069 (%)	8.34	14.71	34.89	25.74	8.13	5.71	2.39	0.08	NA
2070-2099 (%)	3.99	7.15	20.54	30.28	22.17	9.49	5.55	0.83	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	18.55	33.47	30.47	9.70	4.81	2.17	0.71	0.12	NA
2040-2069 (%)	4.27	7.68	22.49	30.31	21.47	8.45	4.72	0.60	0.00
2070-2099 (%)	0.52	0.71	1.38	4.24	18.72	30.18	30.96	13.28	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 25 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 38), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 4,805 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

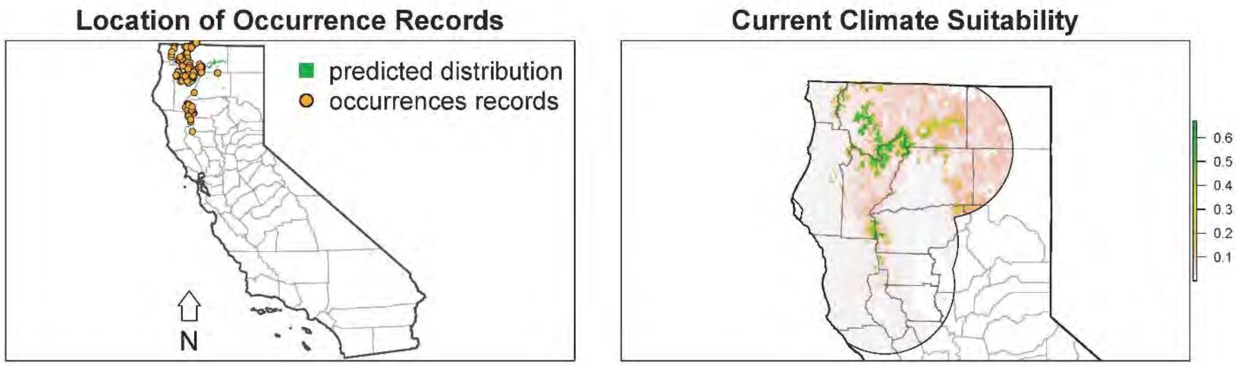


Figure 38. Map of Points Selected from the Extent of Macrogroup 25 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 25. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 25 (Figure 39). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 25, between 2,890 km^2 (60%) and 4,493 km^2 (6%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 313 km^2 (7%) and 1,916 km^2 (40%) will remain climatically suitable, and between 13 km^2 (0.3%) and 1,259 km^2 (26%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 21.

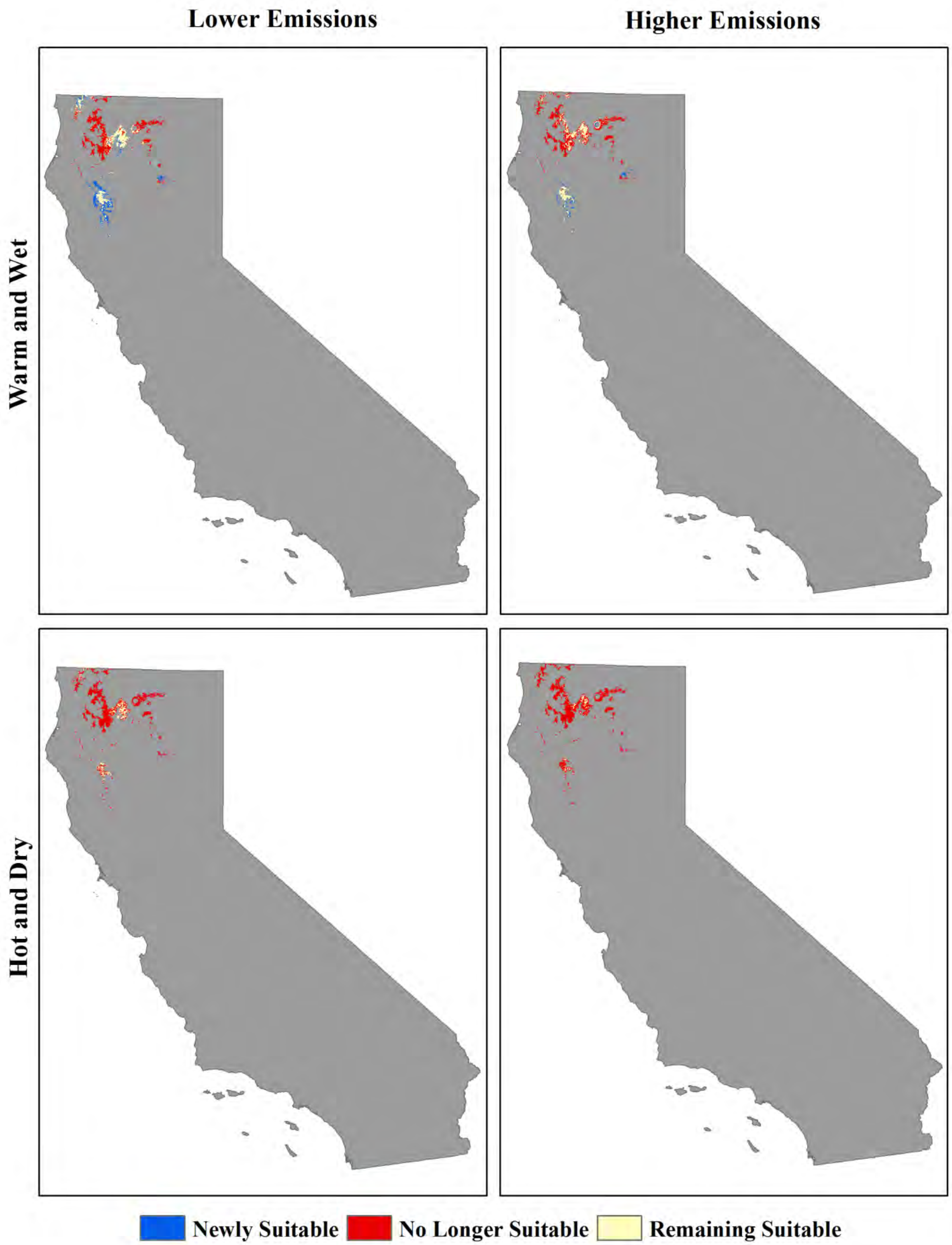


Figure 39. Maps of the Projected Climatically Suitable Range for Macrogroup 25. Maps showing the modeled climatically suitable range for macrogroup 25 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 21. Area of Projected Climatic Suitability for Macrogroup 25. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 25, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	2,890	1,916	1,259	60%	40%	26%
CNRM CM5 - RCP 8.5	3,245	1,560	424	68%	32%	9%
MIROC ESM - RCP 4.5	4,079	726	23	85%	15%	0%
MIROC ESM - RCP 8.5	4,493	313	13	93%	7%	0%

MG026: Macrogroup Intermountain Basins Piñyon –Juniper Woodland
Common Name: Great Basin Piñyon -Juniper Woodland

This macrogroup includes all mixed and pure piñyon and juniper stands in trans-montane California. These are largely found in the Mojave Desert mountains, and in the mountains of the Modoc Plateau, and Great Basin. They also occur on the eastern slopes of the Sierra Nevada and the Peninsular Ranges and the northern slopes of the Transverse Ranges. Outliers occur west of the Sierra Crest in Kings Canyon, and in the mountains of Ventura and Santa Barbara counties.

Utah juniper (*Juniperus osteosperma*), single-leaf piñyon (*Pinus monophylla*) and western juniper (*Juniperus occidentalis*) in the northeastern part of California) are the main tree species, with species of sagebrush (*Artemisia spp*.), mountain mahogany (*Cercocarpus* spp.), bitterbrush (*Purshia* spp.) and other cool-desert shrubs and grasses associated.

The single best WHR category is: piñyon -juniper (PJN), but also includes WHR habitat: juniper (JUN). Both of these together encompass the breadth of the macrogroup. This analysis uses the tree species named above, while the shrub scores are included in other macrogroup tables.

Macrogroup 26 is comprised of approximately two WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 10,874 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 40). Using the current climate conditions for the extent of Macrogroup 26, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

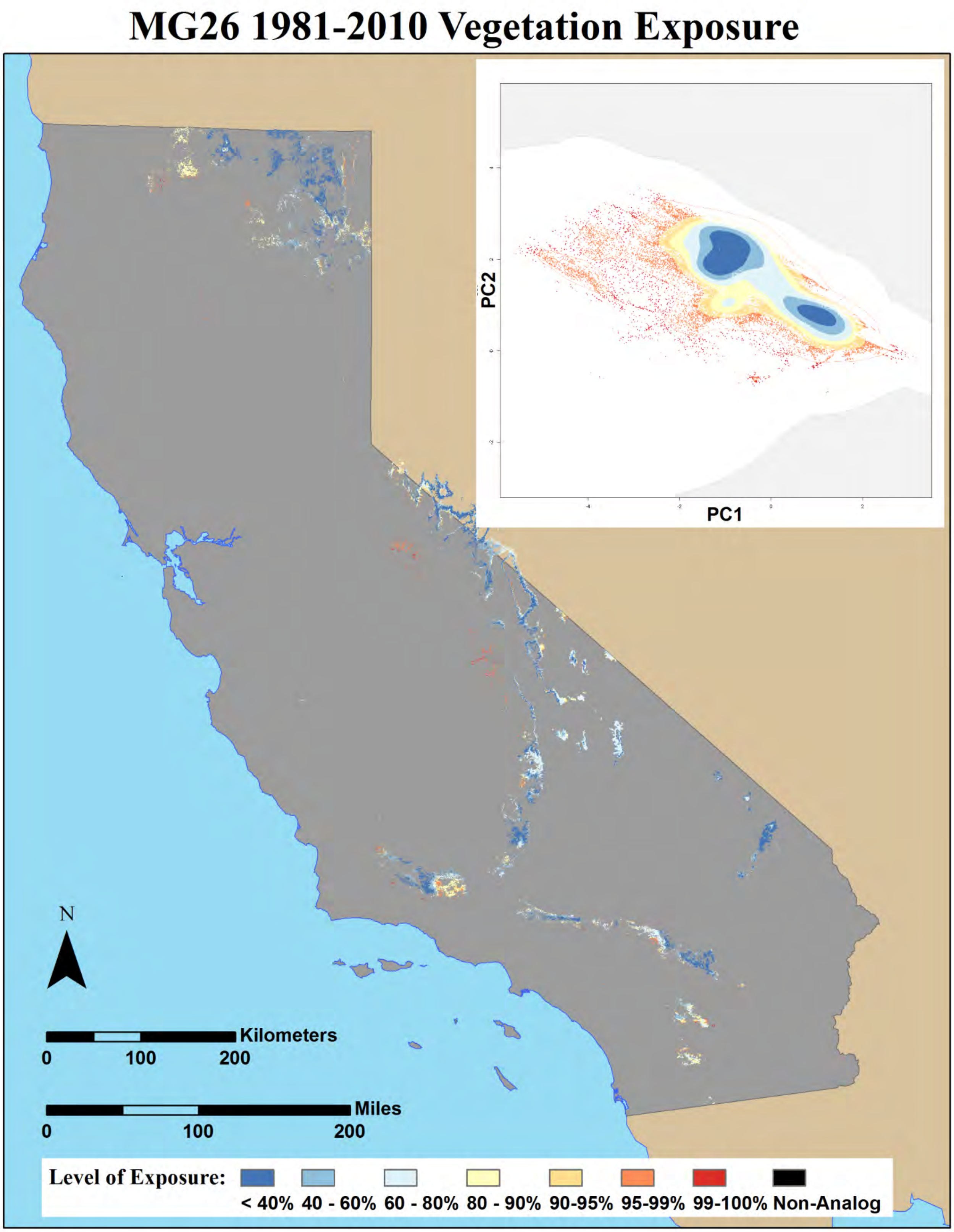


Figure 40. Map of Current Climate Suitability for Macrogroup 26. The 2015 mapped extent of macrogroup 26, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 26 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 22). The overall or grand mean for macrogroup 26 was found to be 2.33 for sensitivity and adaptive capacity.

Table 22. Sensitivity and Adaptive Capacity Rankings for Macrogroup 26. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 26.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Pinus monophylla	2	3	1	3	3	5	1	1	1	**2.2**
Juniperus occidentalis	3	3	1	2	3	3	2	1	3	**2.3**
Juniperus osteosperma	3	3	1	3	3	3	2	1	3	**2.4**
Mean	**2.67**	**3.00**	**1.00**	**2.67**	**3.00**	**3.67**	**1.67**	**1.00**	**2.33**	
Grand Mean	**2.33**				**Mean**	**2.50**		**Mean**	**1.67**	

Projected Climate Exposure

The future climate exposure for macrogroup 26 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 41).

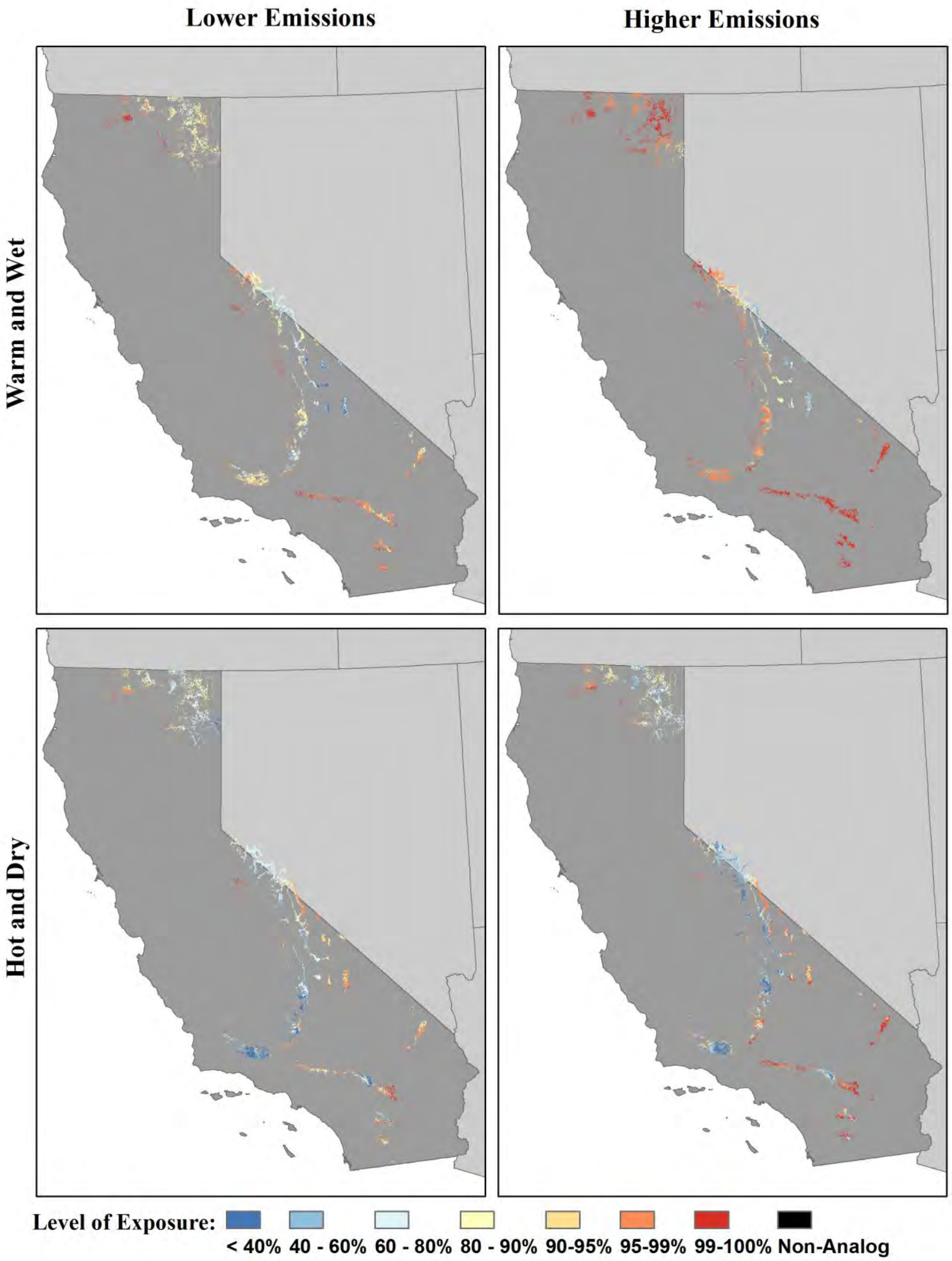


Figure 41. Maps of Projected Climate Exposure for Macrogroup 26. The climate exposure level for macrogroup 26 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 41 is derived from the PCA charts (Figure 42), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

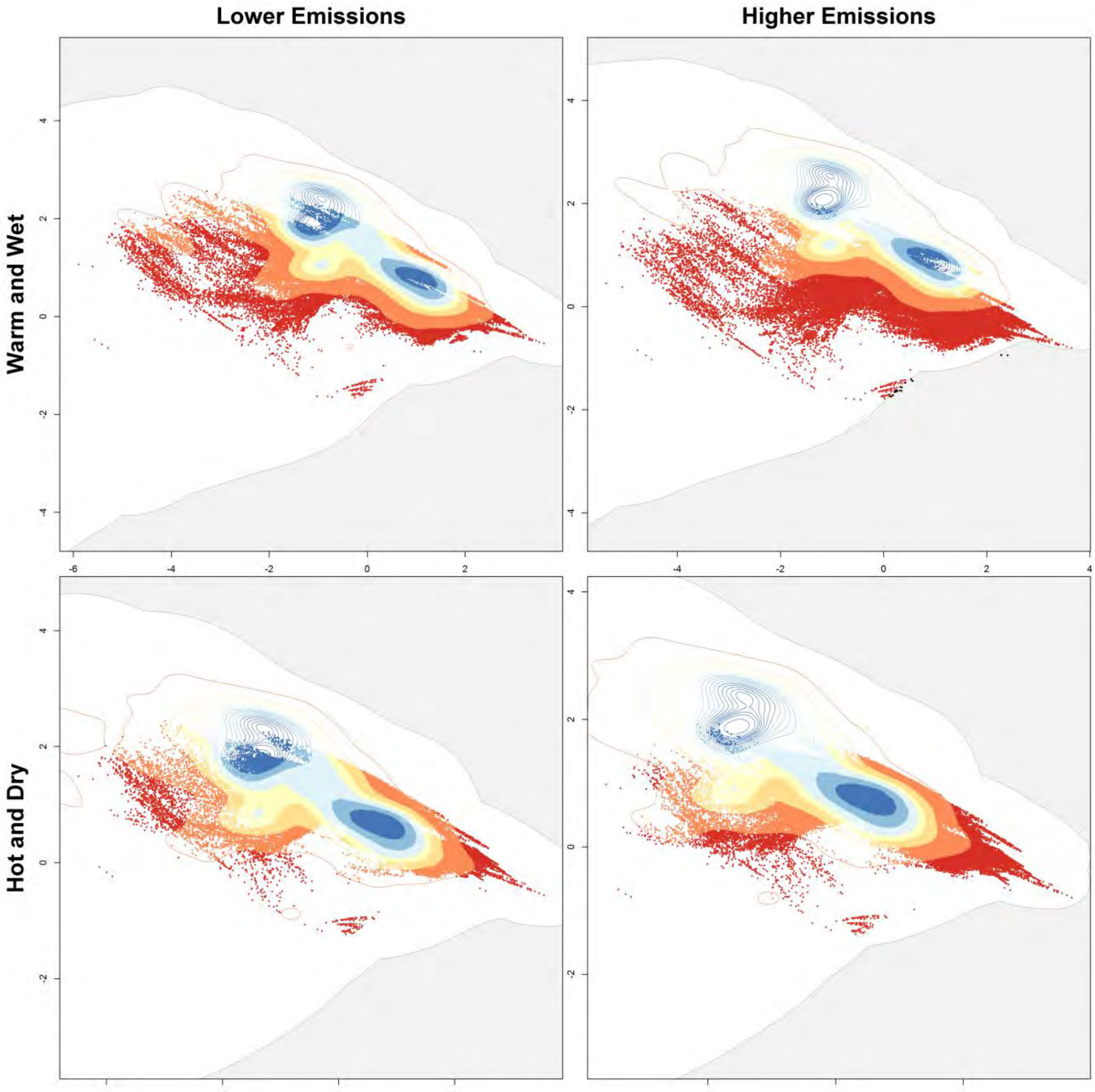


Figure 42. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 26. The PCA charts are two dimensional representations of climate exposure for macrogroup 26 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called “non-analog” conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 23). In the current time period, macrogroup 26 occupies 10,874 km^2. By the end of the century, there will be between 1,239 km^2 (11%) and 5,919 km^2 (54%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,733 km^2 (16%) and 7,840 km^2 (72%) of this type will be climatically exposed by the end of century.

Table 23. Percentage of the Current Extent of Macrogroup 26 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	2,175	2,176	2,174	2,175	1,088	543	436	109	0
1980-2010 (%)	20.00	20.01	19.99	20.00	10.00	4.99	4.01	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	5.78	6.92	13.15	23.69	13.85	15.17	16.28	5.14	0.00
2040-2069 (%)	3.13	4.00	11.00	20.38	23.78	16.37	16.61	4.74	0.00
2070-2099 (%)	1.11	3.05	6.72	17.74	28.11	17.34	17.22	8.70	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	5.34	5.21	10.91	20.38	15.63	19.47	17.41	5.66	0.00
2040-2069 (%)	0.71	3.16	8.76	22.90	27.66	13.99	16.25	6.58	0.00
2070-2099 (%)	0.06	0.88	5.16	5.29	5.43	11.08	33.22	38.86	0.02
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	10.73	11.88	22.35	25.95	11.07	9.31	6.45	2.26	NA
2040-2069 (%)	8.05	9.00	12.49	30.95	16.17	12.93	8.36	2.04	NA
2070-2099 (%)	5.23	6.22	10.04	32.94	17.82	11.81	13.08	2.86	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	18.18	14.43	19.93	22.25	8.72	7.87	6.52	2.10	NA
2040-2069 (%)	5.18	6.33	11.12	31.19	19.14	11.32	13.07	2.65	0.00
2070-2099 (%)	4.82	8.11	16.26	20.10	11.35	11.12	15.71	12.53	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 26 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 43), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 70,593 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

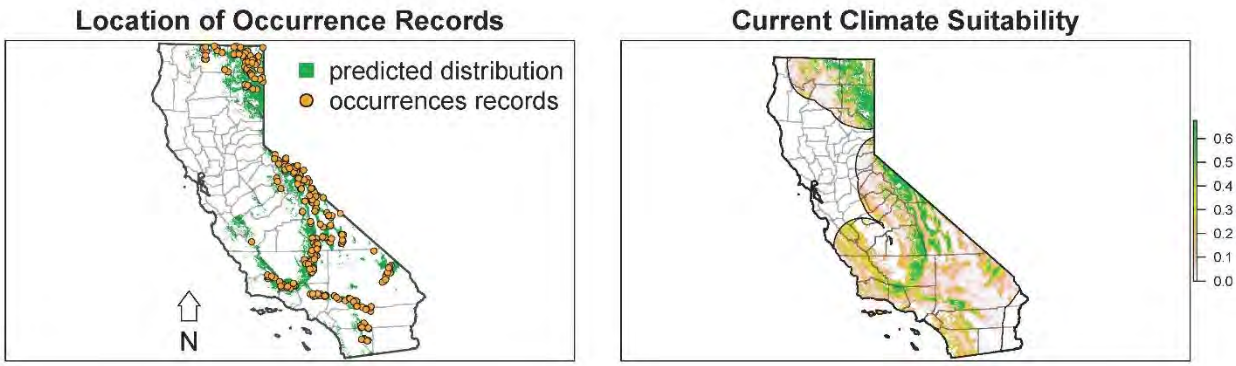


Figure 43. Map of Points Selected from the Extent of Macrogroup 26 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 26. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 26 (Figure 44). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 26, between 27,429 km^2 (39%) and 48,886 km^2 (69%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 21,707 km^2 (31%) and 43,164 km^2 (61%) will remain climatically suitable, and between 3,036 km^2 (4%) and 14,185 km^2 (20%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 24.

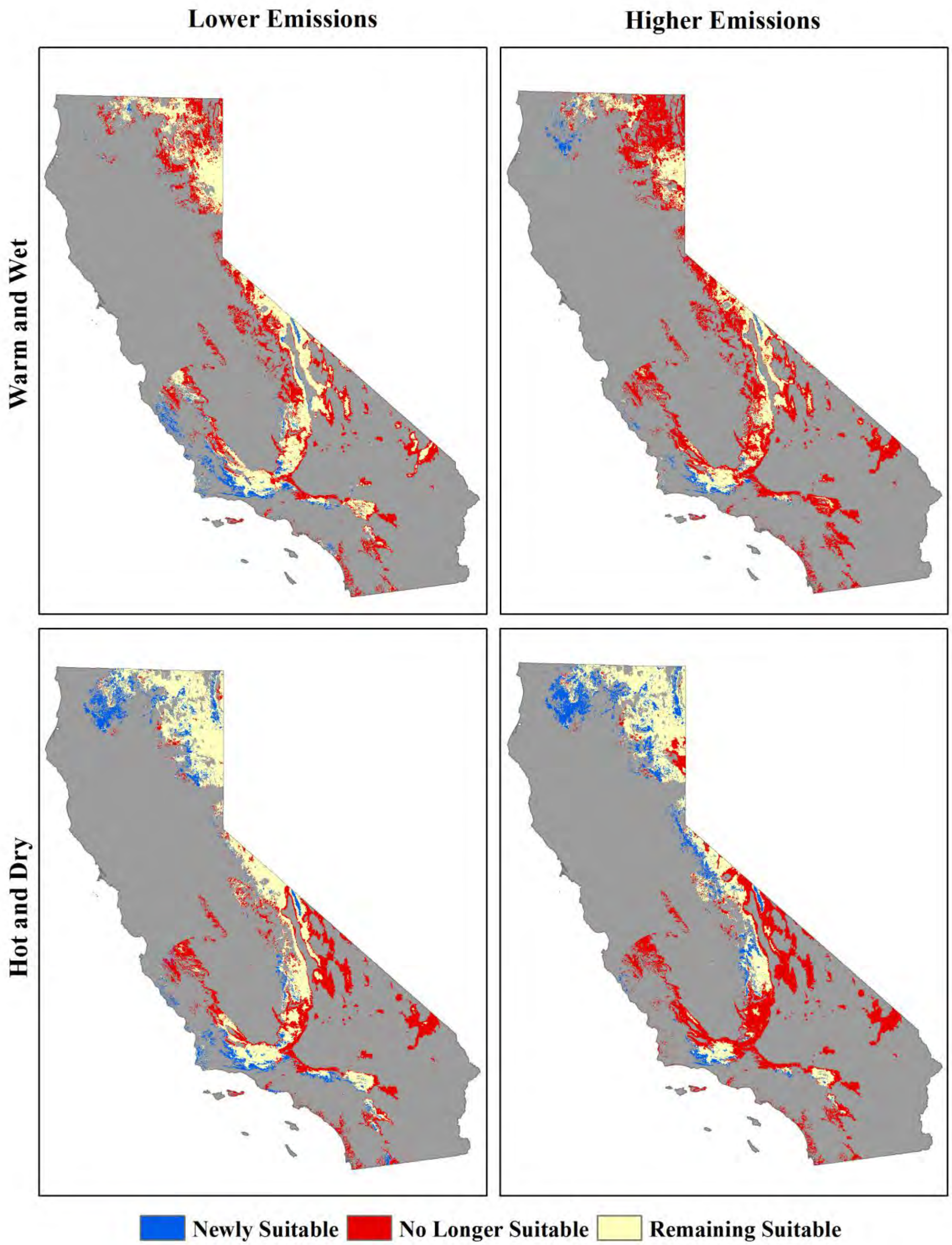


Figure 44. Maps of the Projected Climatically Suitable Range for Macrogroup 26. Maps showing the modeled climatically suitable range for macrogroup 26 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 24. Area of Projected Climatic Suitability for Macrogroup 26. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 26, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	35,540	35,053	5,361	50%	50%	8%
CNRM CM5 - RCP 8.5	48,886	21,707	3,036	69%	31%	4%
MIROC ESM - RCP 4.5	27,429	43,164	12,042	39%	61%	17%
MIROC ESM - RCP 8.5	35,896	34,697	14,185	51%	49%	20%

MG027: Macrogroup Introduced North American Mediterranean Woodland and Forest Common Name: Non-Native Forest and Woodlands

This macrogroup is limited in concept to naturalized (self-perpetuating, and regenerating) stands of trees that have been introduced and are adapted to the Californian climate. Tree species in this macrogroup tend to come from other mediterranean climates (Australia, western South America, the Mediterranean basin), but may also be from other similar warm temperate climates (New Zealand).

This macrogroup includes a number of broad leaf sclerophyll tree species in the genera eucalyptus, acacia (from Australia) but also schinus (South American pepper trees), myoporum (from New Zealand), etc. In some cases it is difficult to individuate planted groves from self -perpetuating stands, although technically the two concepts are different according the rules of the USNVC (semi-natural stands, versus cultural vegetation).

The single best WHR choice for this macrogroup is eucalyptus (EUC), but can also include small parts of urban areas.

Macrogroup 27 is comprised of approximately one WHR type for which we scored one representative dominant genus, Eucalyptus. The statewide extent for the current time period cover 224 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 45). Using the current climate conditions for the extent of Macrogroup 27, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

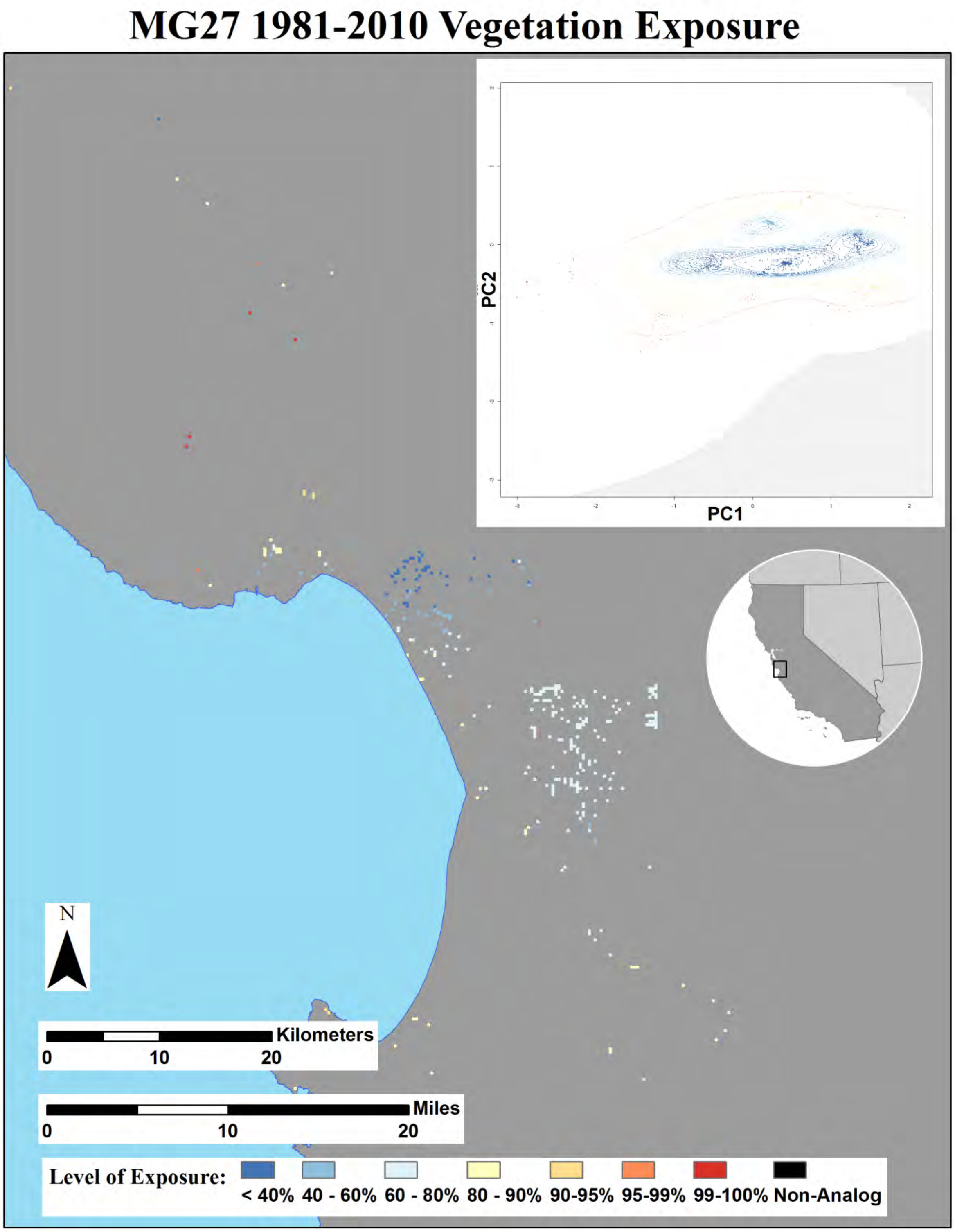


Figure 45. Map of Current Climate Suitability for Macrogroup 27. The 2015 mapped extent of macrogroup 27, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 27 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to

germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 25). The overall or grand mean for macrogroup 27 was found to be 3.56 for sensitivity and adaptive capacity.

Table 25. Sensitivity and Adaptive Capacity Rankings for Macrogroup 27. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 27.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Eucalyptus sp	3	3	4	3	2	4	5	3	5	**3.6**
Grand Mean	**3.56**				**Mean**	**3.17**		**Mean**	**4.33**	

Projected Climate Exposure

The future climate exposure for macrogroup 27 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 46).

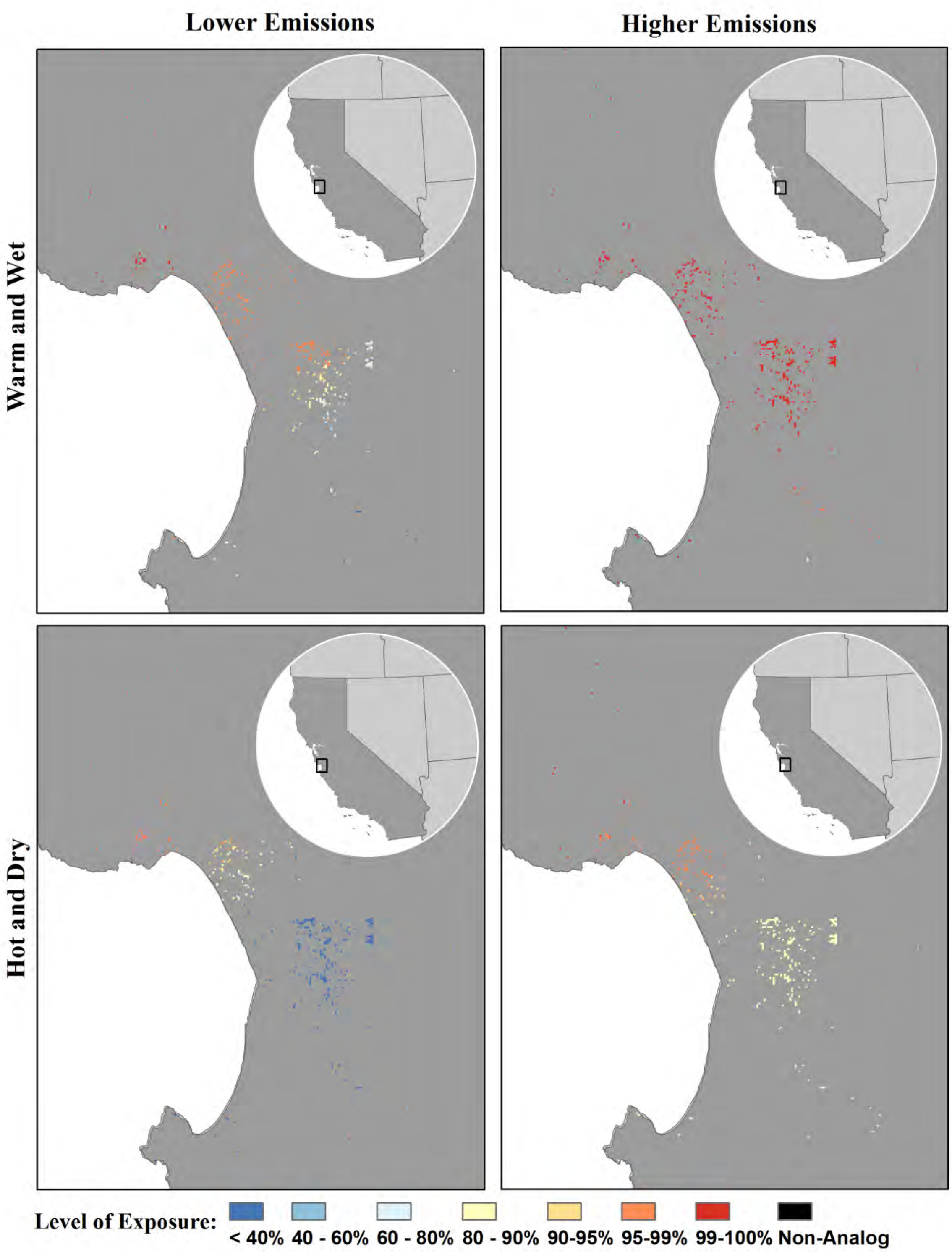


Figure 46. Maps of Projected Climate Exposure for Macrogroup 27. The climate exposure level for macrogroup 27 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 46 is derived from the PCA charts (Figure 47), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

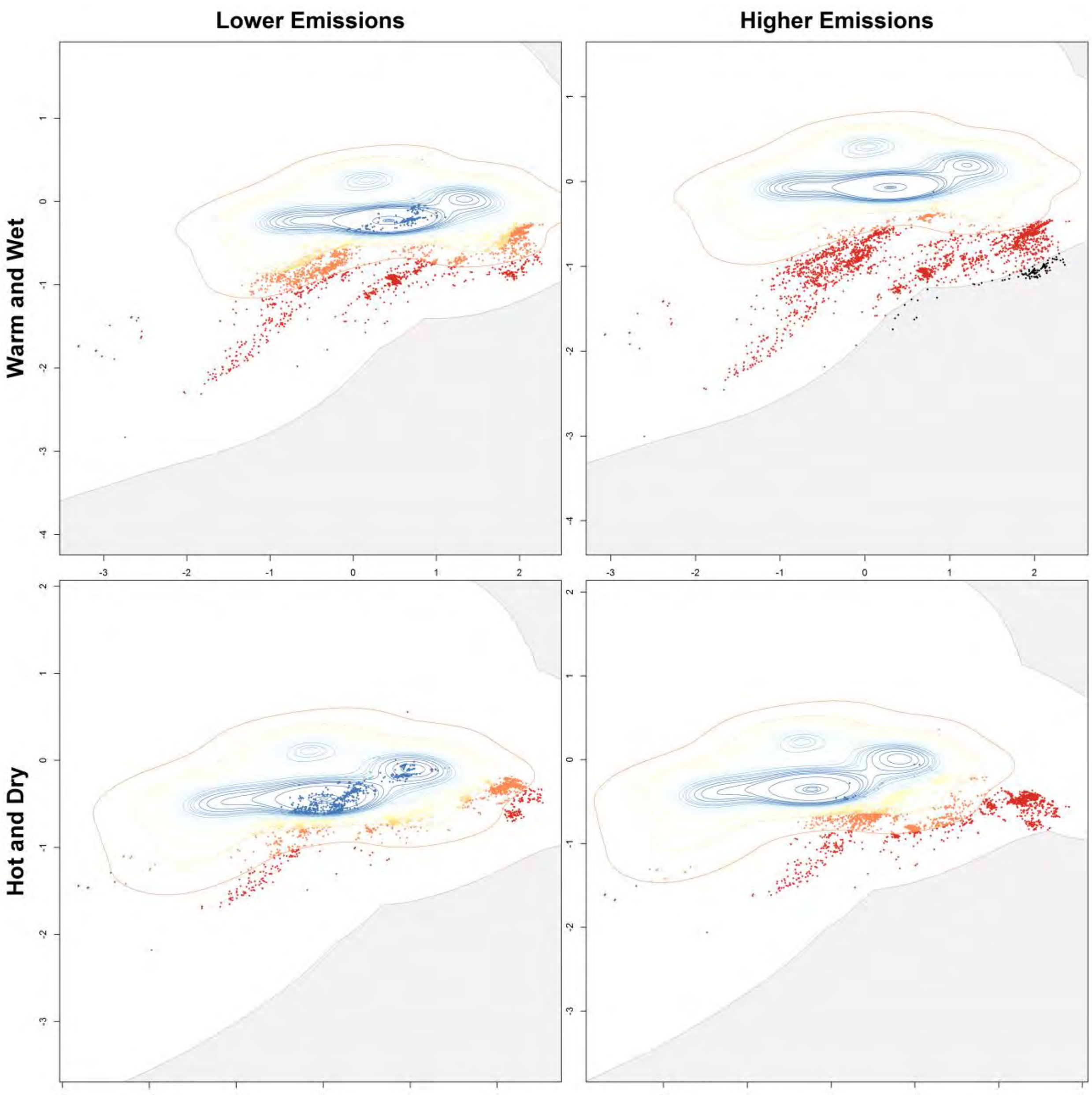


Figure 47. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 27. The PCA charts are two dimensional representations of climate exposure for macrogroup 27 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 26). In the current time period, macrogroup 27 occupies 224 km^2. By the end of the century, there will be between 2 km^2 (1%) and 73 km^2 (32%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 80 km^2 (36%) and 218 km^2 (97%) of this type will be climatically exposed by the end of century.

Table 26. Percentage of the Current Extent of Macrogroup 27 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	45	44	45	45	22	11	9	2	0
1980-2010 (%)	20.09	19.83	20.03	20.06	9.98	5.01	4.00	1.01	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	6.99	8.75	3.32	19.93	21.39	6.53	25.39	7.70	0.00
2040-2069 (%)	9.82	3.64	2.28	6.21	23.18	15.31	24.54	15.02	0.00
2070-2099 (%)	7.74	1.79	0.59	2.24	4.62	12.19	36.12	34.72	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	9.33	4.49	3.87	17.23	19.90	9.27	27.02	8.91	0.00
2040-2069 (%)	9.53	2.83	1.46	2.02	6.27	12.97	35.44	29.49	0.00
2070-2099 (%)	0.00	0.07	0.13	0.88	1.04	0.52	8.65	85.18	3.54
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	17.59	26.30	14.43	25.46	7.67	4.52	2.86	1.17	NA
2040-2069 (%)	17.62	14.82	10.34	21.42	13.43	9.92	11.51	0.94	NA
2070-2099 (%)	9.14	14.17	3.32	5.75	15.25	16.64	27.34	8.39	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	19.70	26.59	11.90	24.71	9.33	3.25	3.71	0.81	NA
2040-2069 (%)	19.47	13.39	7.51	5.40	22.72	4.10	21.72	5.69	0.00
2070-2099 (%)	0.00	0.39	0.68	3.22	16.61	5.17	31.40	42.52	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 27 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 48), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 36,348 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

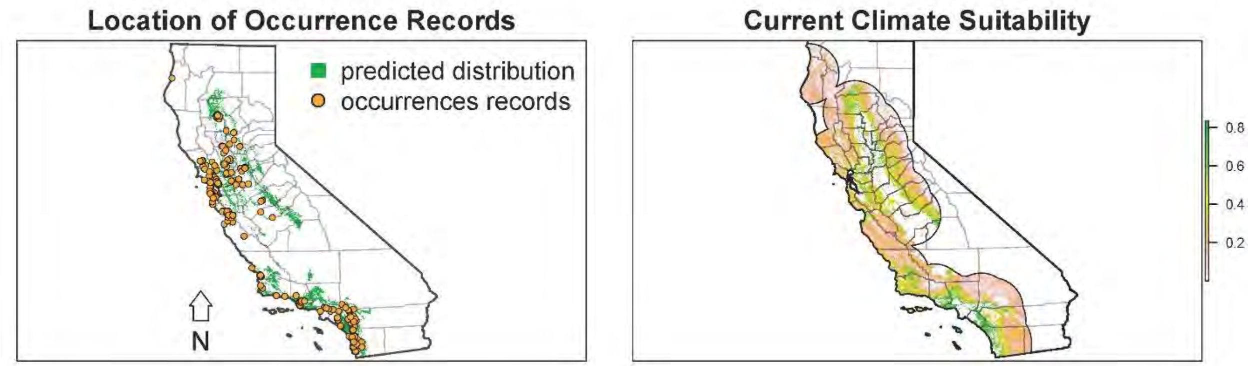


Figure 48. Map of Points Selected from the Extent of Macrogroup 27 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 27. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 27 (Figure 49). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 27, between 2,257 km^2 (6%) and 6,316 km^2 (17%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 30,032 km^2 (83%) and 34,091 km^2 (94%) will remain climatically suitable, and between 19,036 km^2 (52%) and 54,791 km^2 (151%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 27.

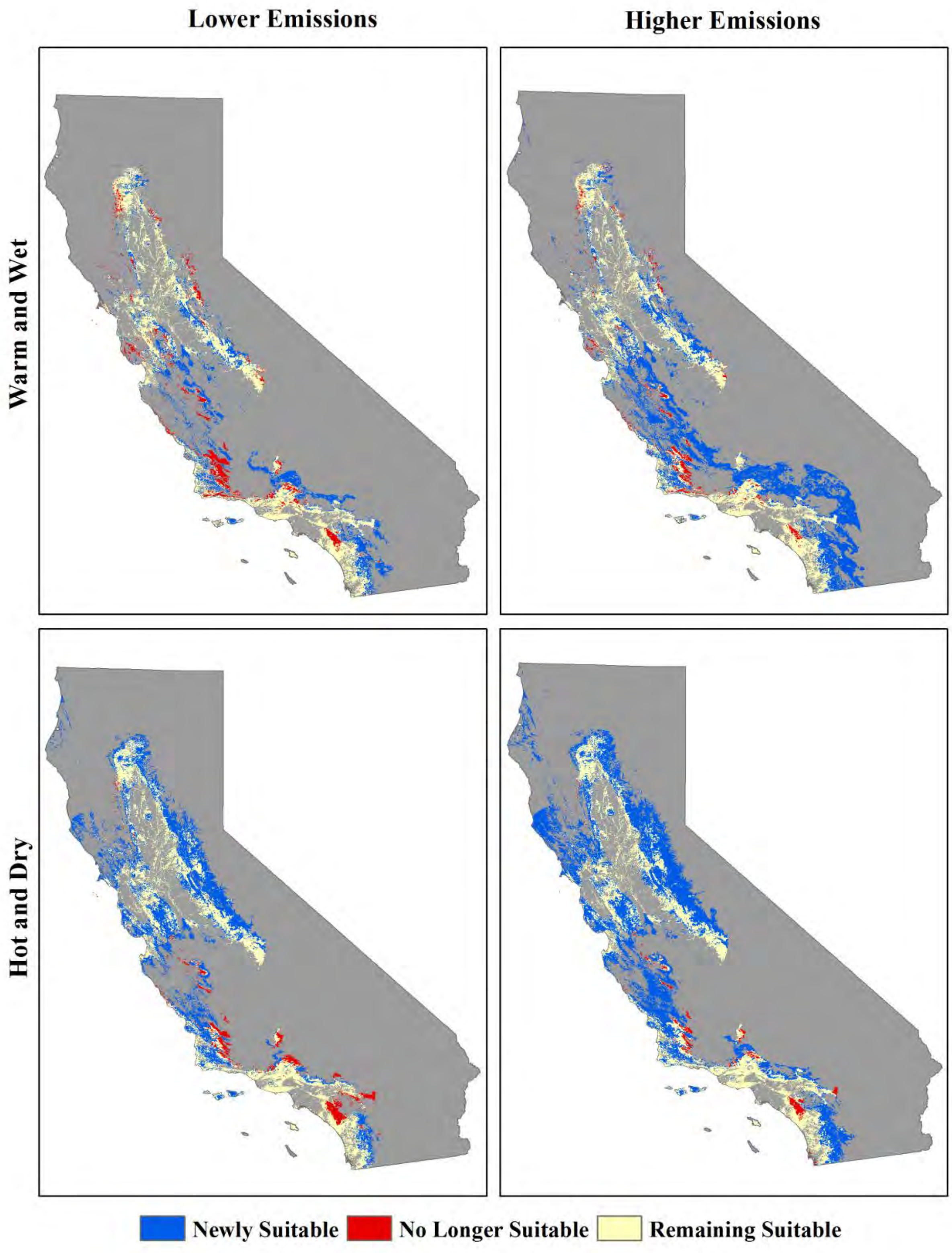


Figure 49. Maps of the Projected Climatically Suitable Range for Macrogroup 27. Maps showing the modeled climatically suitable range for macrogroup 27 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 27. Area of Projected Climatic Suitability for Macrogroup 27. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 27, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	6,316	30,032	19,036	17%	83%	52%
CNRM CM5 - RCP 8.5	3,801	32,547	41,869	10%	90%	115%
MIROC ESM - RCP 4.5	4,348	32,000	34,981	12%	88%	96%
MIROC ESM - RCP 8.5	2,257	34,091	54,791	6%	94%	151%

MG034: Vancouverian Flooded and Swamp Forest Macrogroup [formerly treated as part of Macrogroup Western Cordilleran Montane–Boreal Riparian Scrub and Forest] Common Name: North Coastal Riparian and Montane Riparian Forest and Woodland

This is a new synthesis of parts of the older concept treated under Western Cordilleran Montane–Boreal Riparian Scrub and Forest. Revisions of the NVCS have split the tree-dominated forest and woodlands of the cool temperate parts of the state from the riparian scrubs. These riparian forests occur along the major rivers and streams in the outer and middle North Coast Ranges, and along the foothill and lower montane reaches of rivers and streams in the Klamath, Cascades, Sierra Nevada, Modoc Plateau, Transverse, and Peninsular ranges. Unlike the Warm Southwest Riparian Forest Macrogroup, surrounding upland vegetation is mainly conifer dominated and not broadleaf evergreen or deciduous woodland/forest.

Black cottonwood (*Populus trichocarpa*), Oregon ash (*Fraxinus latifolia*), red alder (*Alnus rubra*), white alder (*Alnus rhombifolia*), and shining willow (*Salix lucida* ssp. *lasiandra*) are the principal diagnostic tree species. Most of the stands of this macrogroup are surrounded by cool temperate coniferous forest either from the coastal belt or the mid elevation montane coniferous belt. Thus, lesser numbers of conifers may intermix with the deciduous dominants. These include redwood, Douglas-fir, Sitka spruce, grand fir, and western hemlock in the north coastal stands, while ponderosa pine, incense-cedar, white fir, red fir, may mix with the montane stands.

The single best relationship is with montane riparian (MRI), although this would only include the black cottonwood, tree alders, ash and shining willow-dominated stands. The shrubby willows, alders and other shrubby riparian species of the higher mountains would be included in the macrogroup Western North American Montane-Subalpine Wet Shrubland and Wet Meadow.

Macrogroup 34 is comprised of approximately one WHR types for which we scored four representative dominant species. The statewide extent for the current time period cover 1,832 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 50). Using the current climate conditions for the extent of Macrogroup 34, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

MG34 1981-2010 Vegetation Exposure

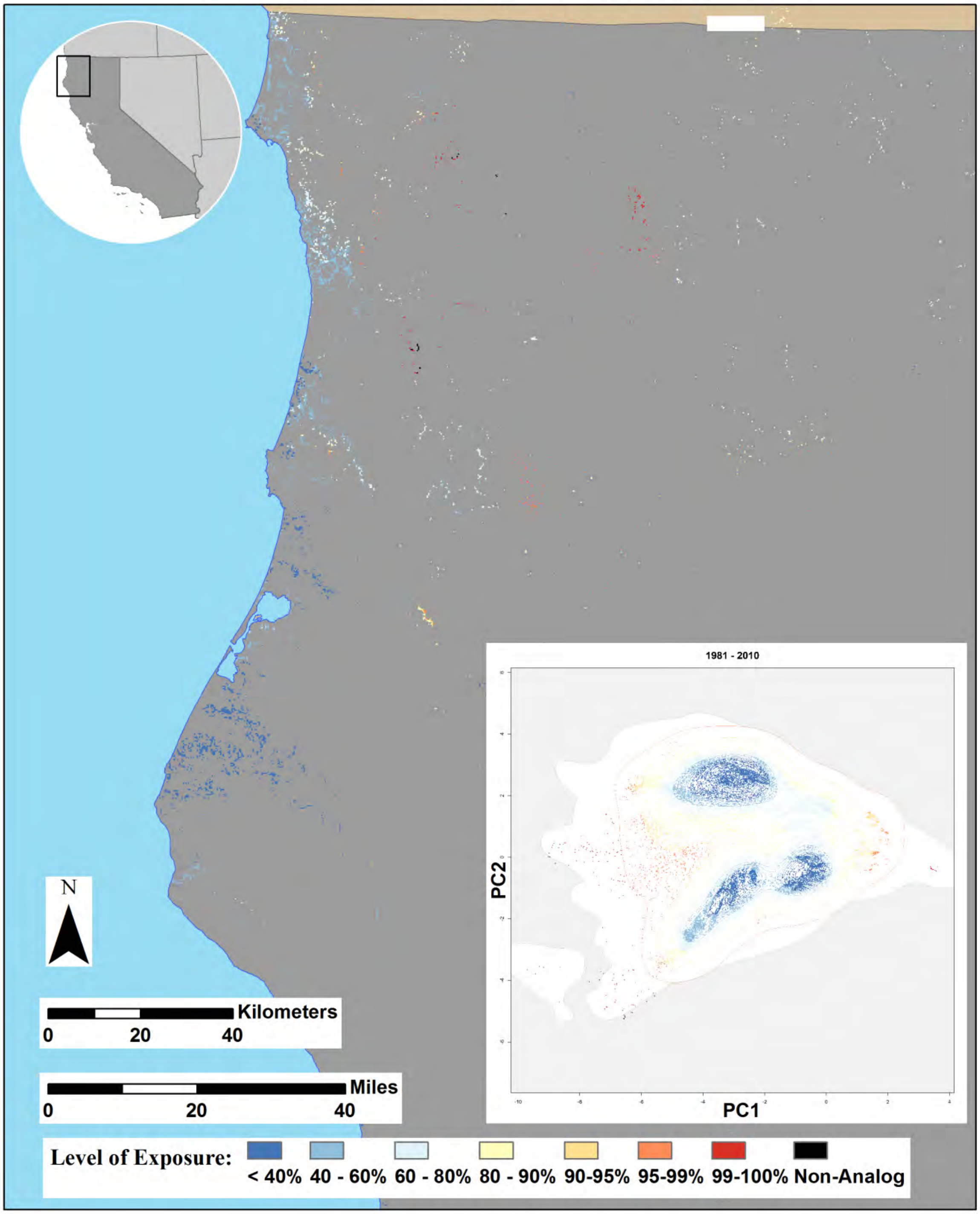


Figure 50. Map of Current Climate Suitability for Macrogroup 34. The 2015 mapped extent of macrogroup 34, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure. Note that this illustration shows only the north coast portion of the range because the type is difficult to see across larger areas, but the type also includes montane riparian found throughout the Sierra Nevada mountains and elsewhere.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 34 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 28). The overall or grand mean for macrogroup 34 was found to be 3.00 for sensitivity and adaptive capacity.

Table 28. Sensitivity and Adaptive Capacity Rankings for Macrogroup 34. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 34. Three species are included for the WHR type Montane Riparian (MRI). Riparian shrubs and willows are not included in this type. -

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Populus trichocarpa	4	3	4	3	3	3	5	5	1	**3.4**
Alnus rhombifolia	3	2	4	3	3	2	5	4	1	**3.0**
Alnus rubra	2	2	2	3	3	2	1	4	1	**2.2**
Fraxinus latifolia	2	3	4	1	3	3	5	4	5	**3.3**
Mean	**2.75**	**2.50**	**3.50**	**2.50**	**3.00**	**2.50**	**3.67**	**4.25**	**2.00**	
Grand Mean	**3.00**				**Mean**	**2.79**		**Mean**	**3.42**	

Projected Climate Exposure

The future climate exposure for macrogroup 34 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 51).

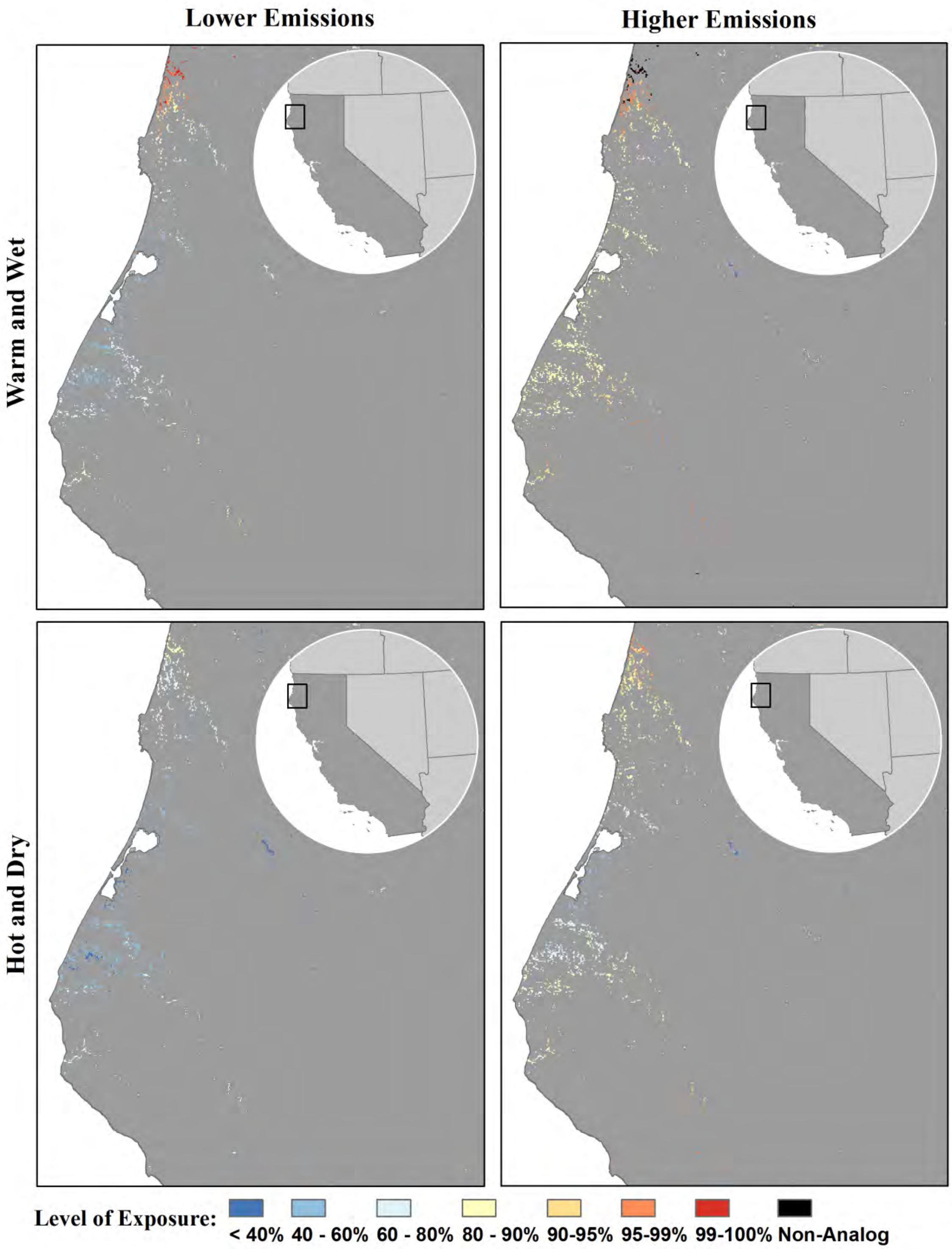


Figure 51. Maps of Projected Climate Exposure for Macrogroup 34. The climate exposure level for macrogroup 34 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 51 is derived from the PCA charts (Figure 52), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

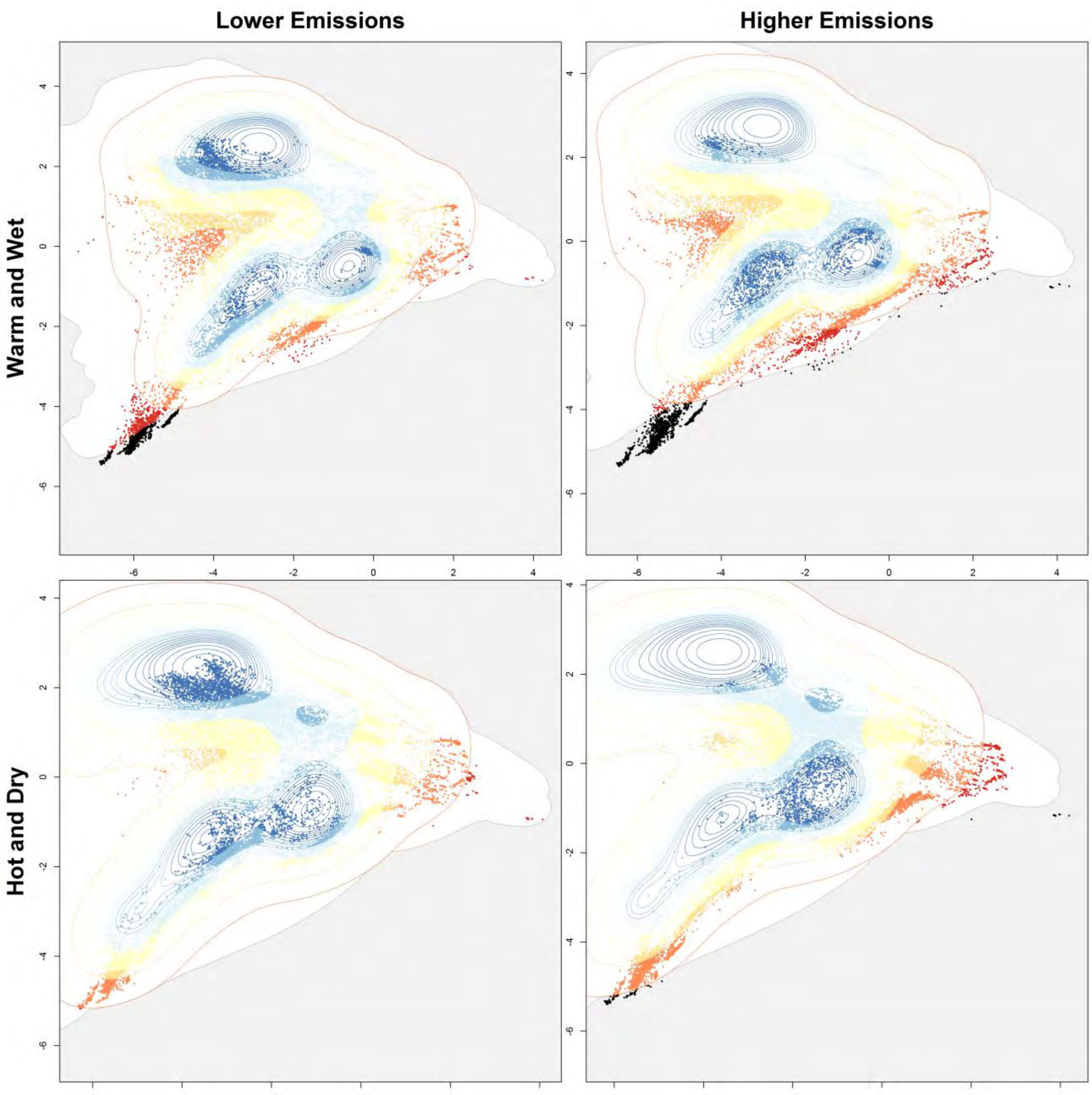


Figure 52. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 34. The PCA charts are two dimensional representations of climate exposure for macrogroup 34 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 29). In the current time period, macrogroup 34 occupies 1,188 km^2. By the end of the century, there will be between 312 km^2 (26%) and 690 km^2 (58%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 78 km^2 (7%) and 307 km^2 (26%) of this type will be climatically exposed by the end of century.

Table 29. Percentage of the Current Extent of Macrogroup 34Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	238	237	238	238	119	59	48	11	1
1980-2010 (%)	20.00	19.99	20.00	20.01	10.00	4.99	4.01	0.89	0.10
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	9.73	20.74	13.49	18.46	17.76	8.11	8.25	3.47	0.00
2040-2069 (%)	2.03	16.93	21.22	20.08	18.33	7.14	9.51	4.75	0.00
2070-2099 (%)	0.91	5.55	15.82	26.61	23.10	8.37	10.48	3.20	5.96
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	5.65	20.62	16.34	17.77	18.44	7.63	7.78	5.78	0.00
2040-2069 (%)	2.48	7.61	18.42	24.29	22.29	7.70	9.68	4.06	3.47
2070-2099 (%)	1.06	6.14	7.24	11.84	36.31	11.54	12.20	4.71	8.94
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	16.17	19.68	14.28	22.10	15.15	4.42	7.20	1.00	NA
2040-2069 (%)	10.37	16.12	16.55	22.09	25.78	3.94	5.02	0.13	NA
2070-2099 (%)	6.55	6.61	15.04	29.89	31.42	3.93	6.14	0.42	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	17.81	19.64	15.90	20.69	15.24	4.82	5.53	0.36	NA
2040-2069 (%)	6.39	11.60	15.47	26.68	30.48	3.65	5.50	0.23	0.00
2070-2099 (%)	1.95	3.75	9.17	31.09	26.71	9.37	14.56	2.81	0.60

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 34 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 53), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 107,960 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

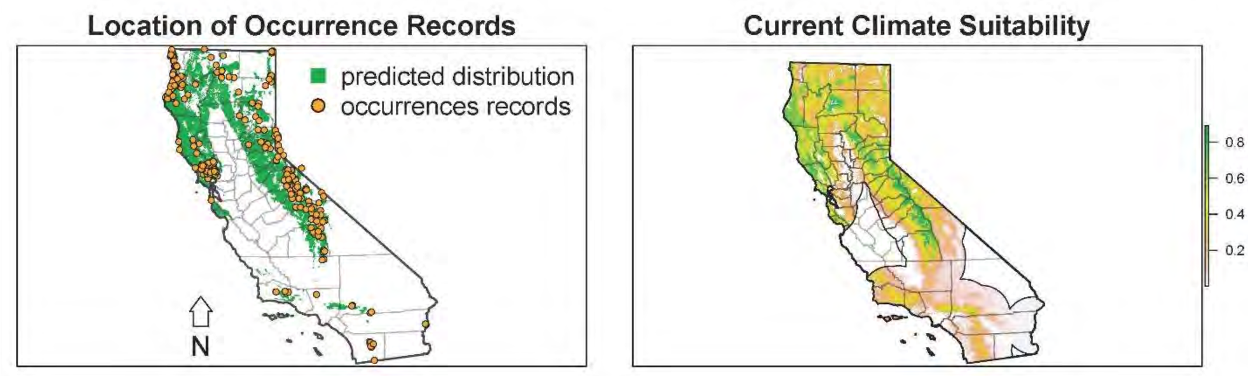


Figure 53. Map of Points Selected from the Extent of Macrogroup 34 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 34. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 34 (Figure 54). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 34, between 24,299 km^2 (23%) and 42,537 km^2 (39%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 65,423 km^2 (61%) and 83,660 km^2 (77%) will remain climatically suitable, and between 12,486 km^2 (12%) and 24,528 km^2 (23%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 30.

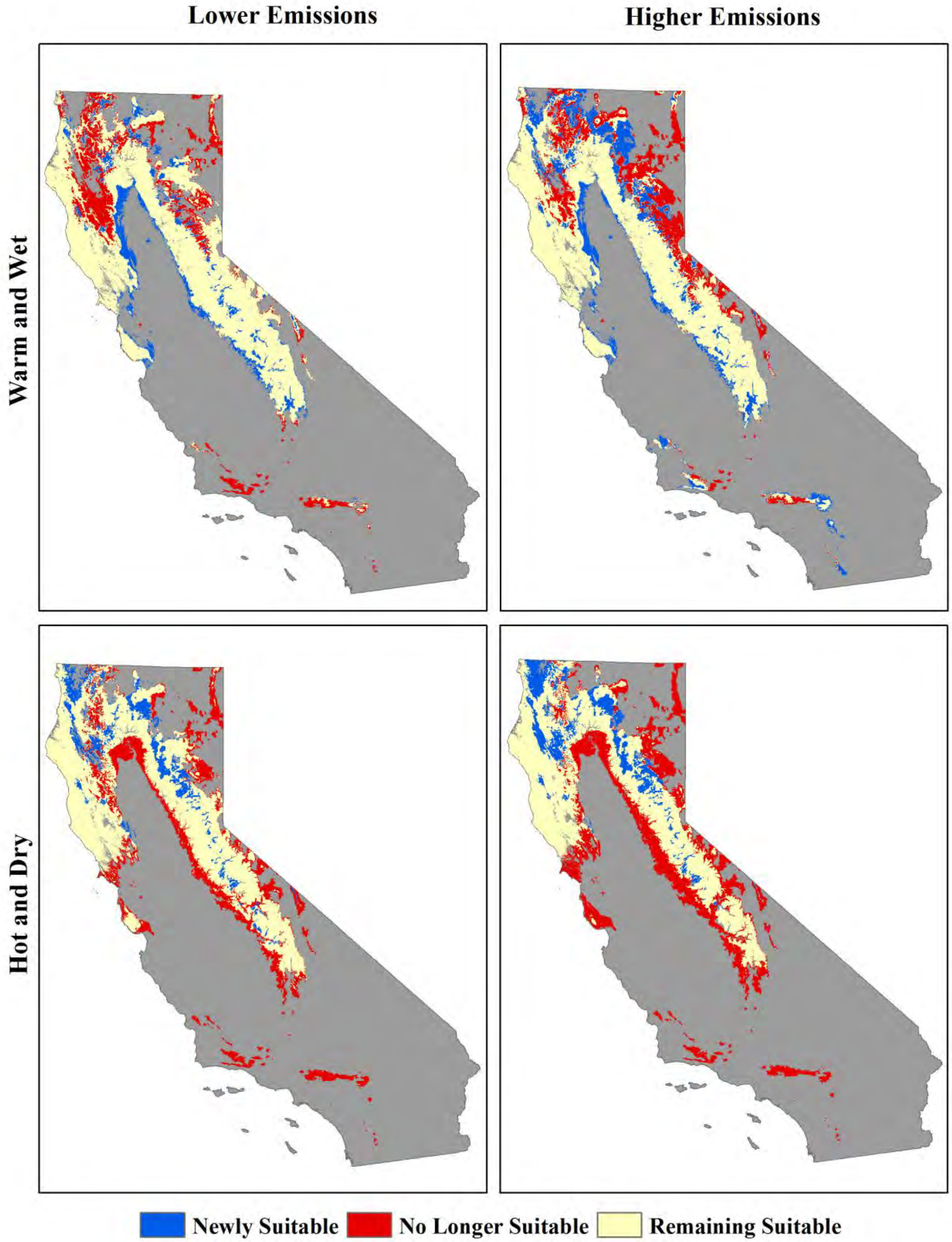


Figure 54. Maps of the Projected Climatically Suitable Range for Macrogroup 34. Maps showing the modeled climatically suitable range for macrogroup 34 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 30. Area of Projected Climatic Suitability for Macrogroup 34. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 34, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	24,299	83,660	14,682	23%	77%	14%
CNRM CM5 - RCP 8.5	27,347	80,613	24,528	25%	75%	23%
MIROC ESM - RCP 4.5	33,204	74,756	12,486	31%	69%	12%
MIROC ESM - RCP 8.5	42,537	65,423	14,987	39%	61%	14%

MG036: Warm Southwest Riparian Forest Macrogroup [formerly treated Macrogroup Southwestern North American Riparian, Flooded and Swamp Forest]
Common Name: American Southwestern Riparian Forest and Woodland

The Great Valley, South Coast, and warm desert riparian forests and thickets are included in this macrogroup. The range of the main indicator trees and shrubs are the southwestern United States and northern Mexico. Most stands of this macrogroup occur below 4,000 ft. elevation and are replaced by the cool-temperate version of riparian (Montane and North Coast Riparian Forest and Scrub) in the mountains and on the north coast.

Diagnostic species include Fremont cottonwood (*Populus fremontii*), black and red willow (*Salix gooddingii*, *S. laevigata*), California sycamore (*Platanus racemosa*), California wild grape (*Vitis californica*), arroyo willow (*Salix lasiolepis*), narrow-leaf willow (*Salix exigua*), button-bush (*Cephalanthus* sp.), spice bush (*Calycanthus occidentalis*) and California fan palm (*Washingtonia filifera*, native stands in the warm desert). Most stands are found in permanently moist settings or riparian settings where sub-surface water is available year-round.

This macrogroup includes two WHR types, the desert palm oasis (POS), and the much more widespread valley-foothill riparian (VRI).

Macrogroup 36 is comprised of approximately two WHR types for which we scored five representative dominant species. The statewide extent for the current time period cover 1,832 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 55). Using the current climate conditions for the extent of Macrogroup 36, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

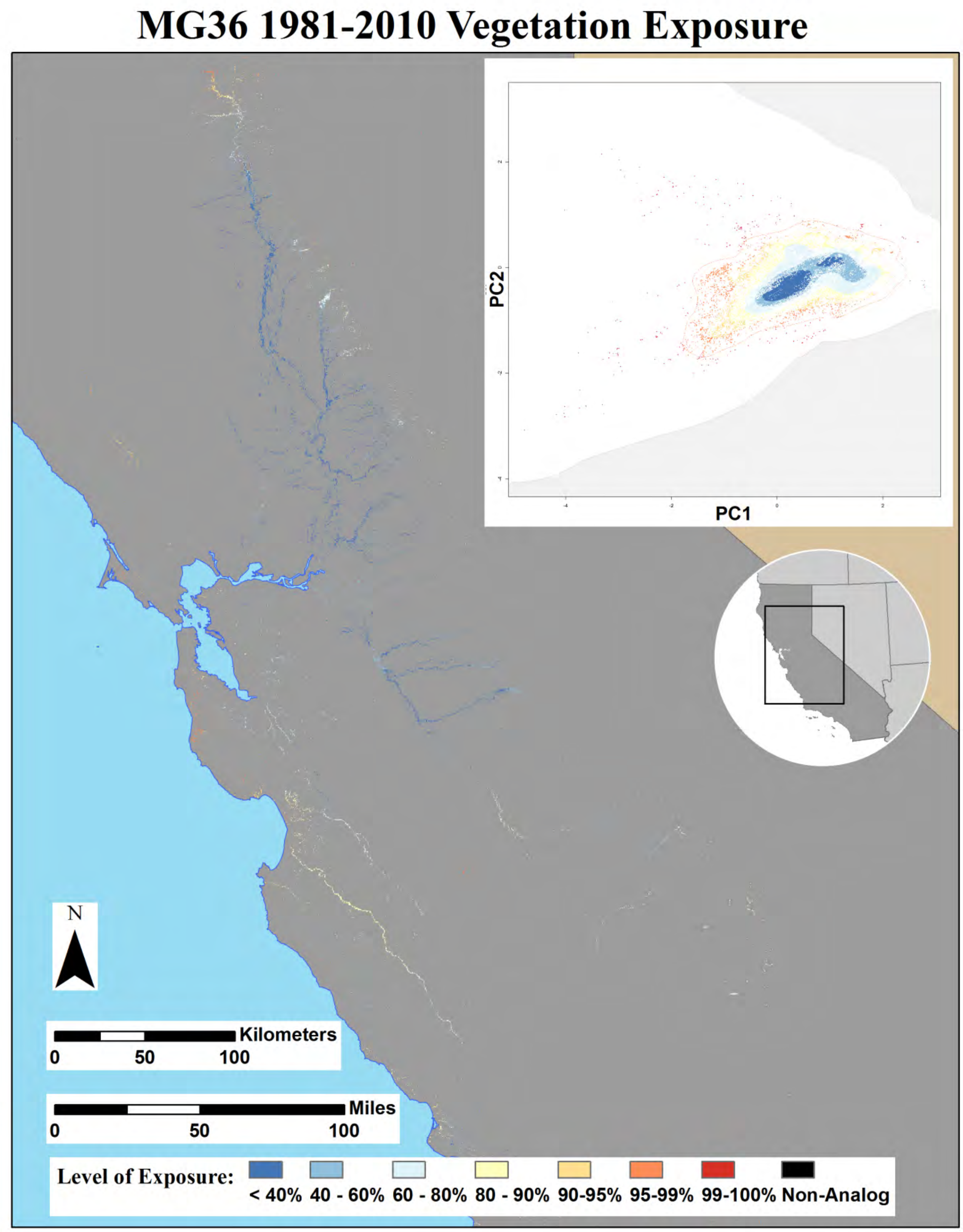


Figure 55. Map of Current Climate Suitability for Macrogroup 36. The 2015 mapped extent of macrogroup 36, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 36 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to

germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 31). The overall or grand mean for macrogroup 36 was found to be 3.2 for sensitivity and adaptive capacity.

Table 31. Sensitivity and Adaptive Capacity Rankings for Macrogroup 36. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 36.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Washingtonia filifera	4	3	4	3	1	3	5	5	3	**3.4**
Populus fremontii	4	3	3	3	5	3	3	5	1	**3.2**
Platanus racemosa	4	3	2	2	3	5	3	4	1	**3.1**
Salix gooddingii	4	3	4	1	3	2	5	5	1	**3.1**
Salix laevigata	4	3	4	3	3	3	5	2	1	**3.1**
Mean	**4.00**	**3.00**	**3.40**	**2.40**	**3.00**	**3.20**	**4.20**	**4.20**	**1.40**	
Grand Mean	**3.20**				**Mean**	**3.17**		**Mean**	**3.27**	

Projected Climate Exposure

The future climate exposure for macrogroup 36 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 56).

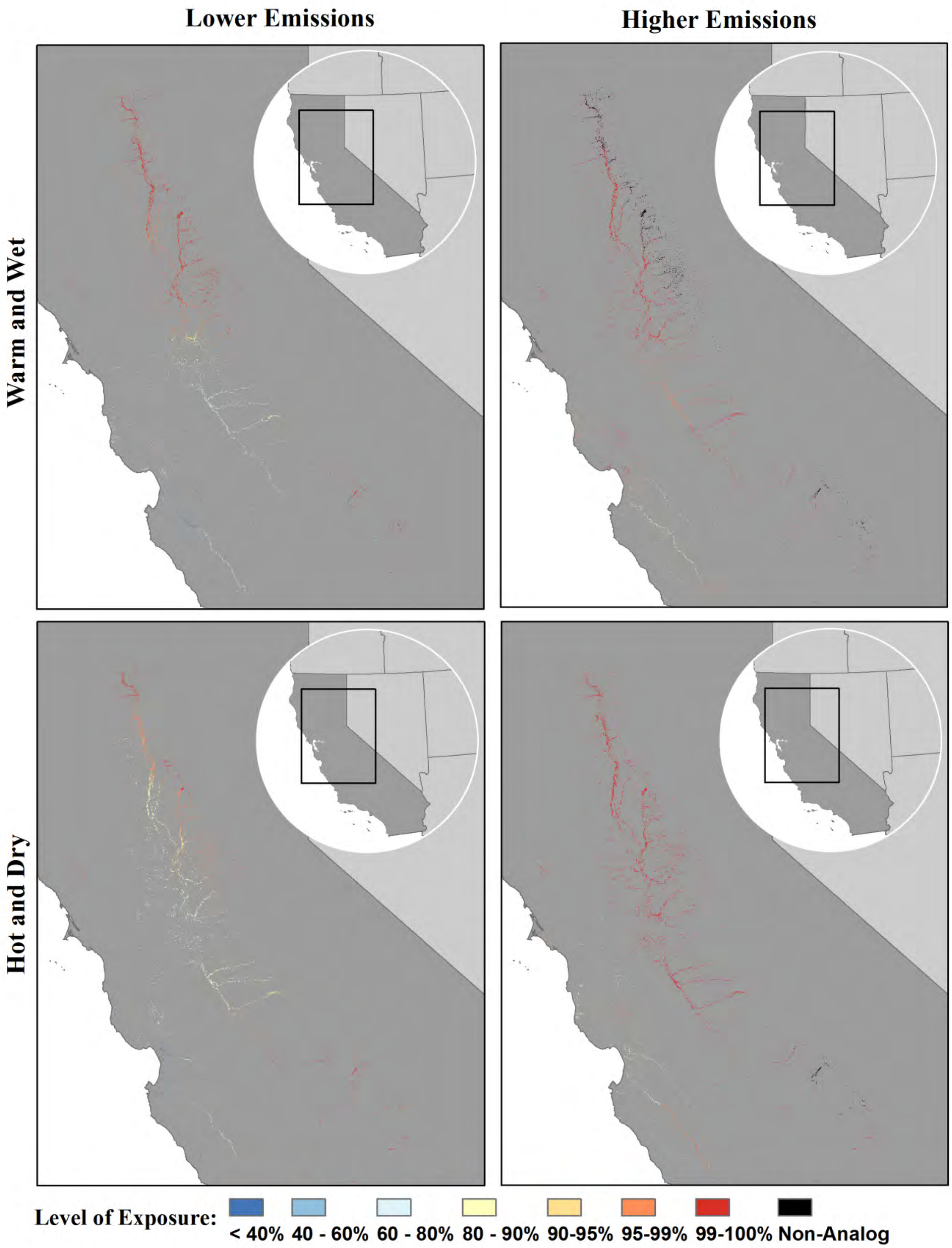


Figure 56. Maps of Projected Climate Exposure for Macrogroup 36. The climate exposure level for macrogroup 36 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 56 is derived from the PCA charts (Figure 57), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

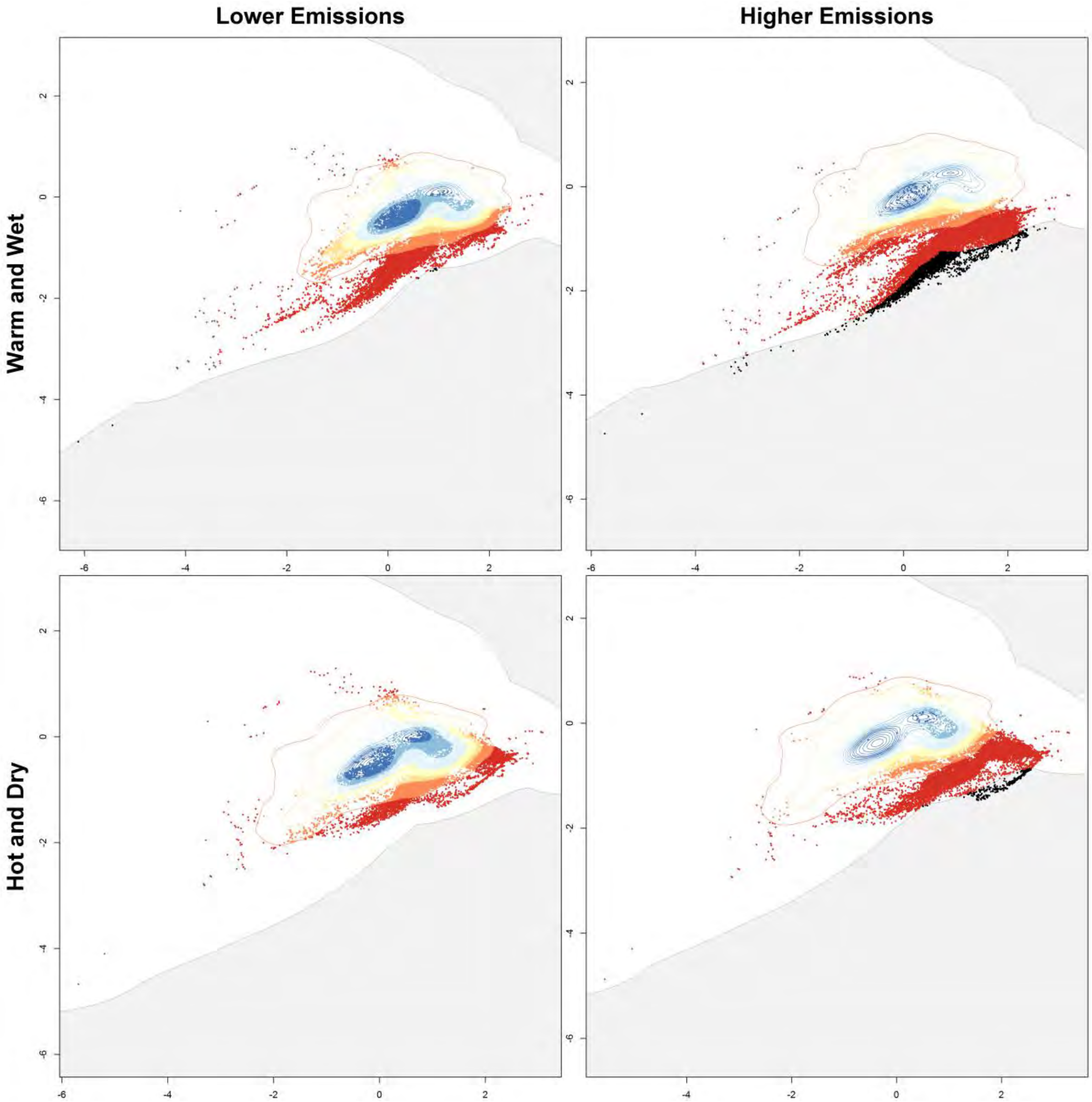


Figure 57. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 36. The PCA charts are two dimensional representations of climate exposure for macrogroup 36 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called “non-analog” conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 32). In the current time period, macrogroup 36 occupies 1,832 km^2. By the end of the century, there will be between 40 km^2 (2%) and 501 km^2 (27%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 783 km^2 (43%) and 1,620 km^2 (88%) of this type will be climatically exposed by the end of century.

Table 32. Percentage of the Current Extent of Macrogroup 36 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	367	366	367	366	183	92	73	18	0
1980-2010 (%)	20.01	20.00	20.00	20.00	10.01	5.00	3.98	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.12	5.91	15.29	25.95	15.67	10.54	16.64	7.87	0.00
2040-2069 (%)	2.61	4.79	10.59	19.77	13.24	12.64	22.62	13.74	0.00
2070-2099 (%)	2.62	2.90	4.93	13.62	9.18	10.06	20.47	36.18	0.05
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	2.16	5.32	13.14	24.31	14.88	13.16	17.93	9.10	0.00
2040-2069 (%)	2.65	3.18	7.14	14.76	9.44	9.37	25.34	28.11	0.00
2070-2099 (%)	0.18	0.21	0.35	1.44	4.81	4.62	12.93	61.16	14.30
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	2.35	8.45	26.85	33.89	14.44	5.24	7.15	1.63	NA
2040-2069 (%)	2.36	6.05	14.03	26.93	17.05	12.87	13.79	6.93	NA
2070-2099 (%)	1.12	2.54	8.88	14.83	18.07	11.81	22.92	19.84	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	3.55	10.00	28.39	31.05	14.73	5.80	5.30	1.19	NA
2040-2069 (%)	1.89	3.56	9.90	23.02	15.90	12.13	19.03	14.56	0.00
2070-2099 (%)	0.00	0.10	1.16	7.09	5.18	2.75	5.25	76.92	1.54

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 36 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 58), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 38,862 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

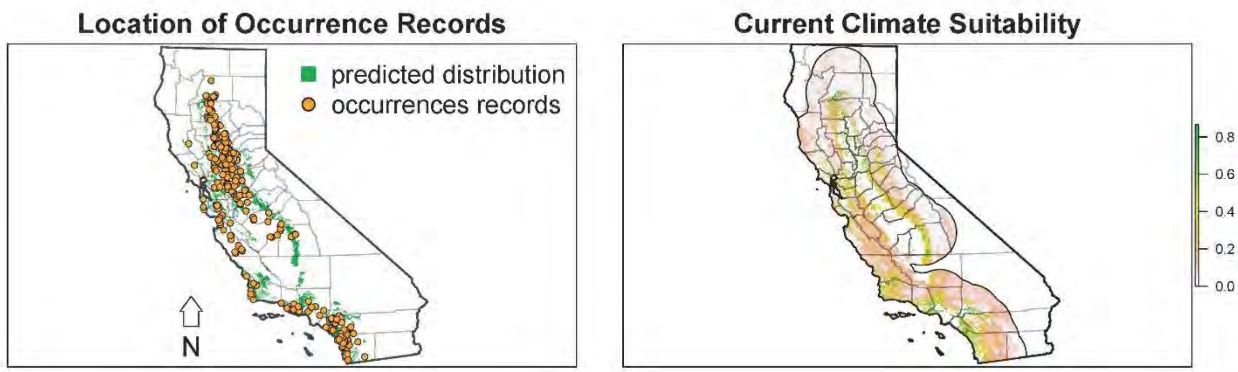


Figure 58. Map of Points Selected from the Extent of Macrogroup 36 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 36. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 36 (Figure 59). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 36, between 6,012 km^2 (15%) and 9,442 km^2 (24%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 29,420 km^2 (76%) and 32,850 km^2 (85%) will remain climatically suitable, and between 12,239 km^2 (31%) and 44,402 km^2 (114%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 33.

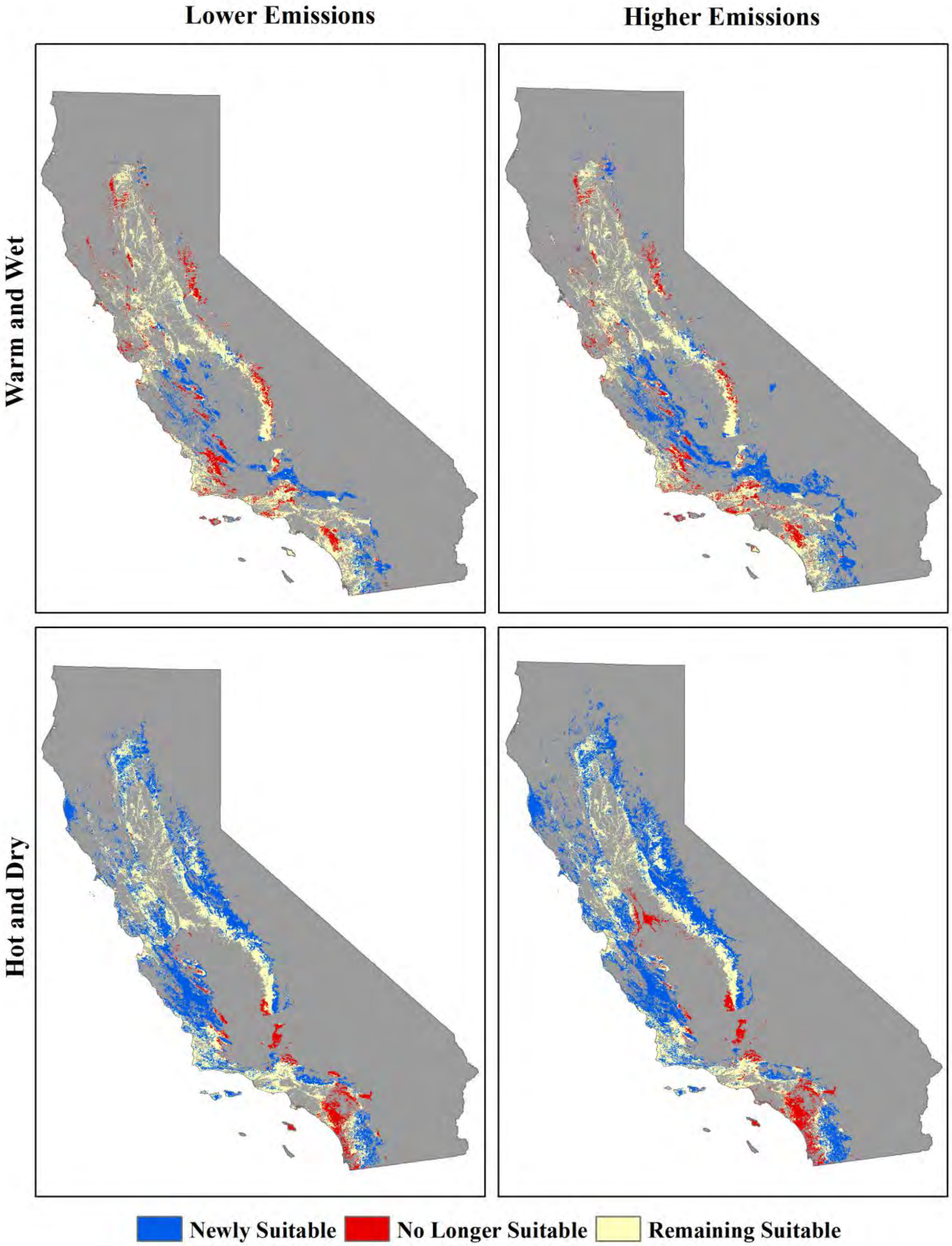


Figure 59. Maps of the Projected Climatically Suitable Range for Macrogroup 36. Maps showing the modeled climatically suitable range for macrogroup 36 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 33. Area of Projected Climatic Suitability for Macrogroup 36. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 36, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	9,442	29,420	12,239	24%	76%	31%
CNRM CM5 - RCP 8.5	8,868	29,994	21,104	23%	77%	54%
MIROC ESM - RCP 4.5	6,012	32,850	35,472	15%	85%	91%
MIROC ESM - RCP 8.5	7,746	31,116	44,402	20%	80%	114%

MG043: Macrogroup California Chaparral
Common Name: Chaparral

This macrogroup includes all chaparral (evergreen sclerophyll-leaved shrublands) below the zone of regular snow accumulation in the mountains. The chaparral occurs throughout Mediterranean climate parts of California, from the Klamath Mountains to the Mexican border. It is represented by a wide variety of floristic alliances, but in general can be grouped into coastal (maritime), xeric (dry, sunny slopes), mesic (cooler, shady slopes), and lower montane (somewhat frost sensitive) types. All of these groupings have different characteristic species and fire regimes.

The core diagnostic species are shrubs with evergreen thickened leaves including many species of manzanita, ceanothus, scrub oaks, and other characteristic shrubs: toyon (*Heteromeles arbutifolia*), chamise (*Adenostoma fasciculatum*), flannel-bush (*Fremontodendron* sp.), silk-tassel bush (*Garrya* sp.), and many others. Most of these species are endemic to the California floristic province and are adapted to the Mediterranean climate. Many shrubs tend to break down into their fire response; including obligate-seeding, and resprouting strategies.

The single best WHR category for this macrogroup is: mixed chaparral (MCH), but also includes the chamise-redshank chaparral (CRC) type.

Macrogroup 43 is comprised of approximately two WHR types for which we scored five representative dominant species. The statewide extent for the current time period cover 27,148 km^2, here shown classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 60). Using the current climate conditions for the extent of Macrogroup 43, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

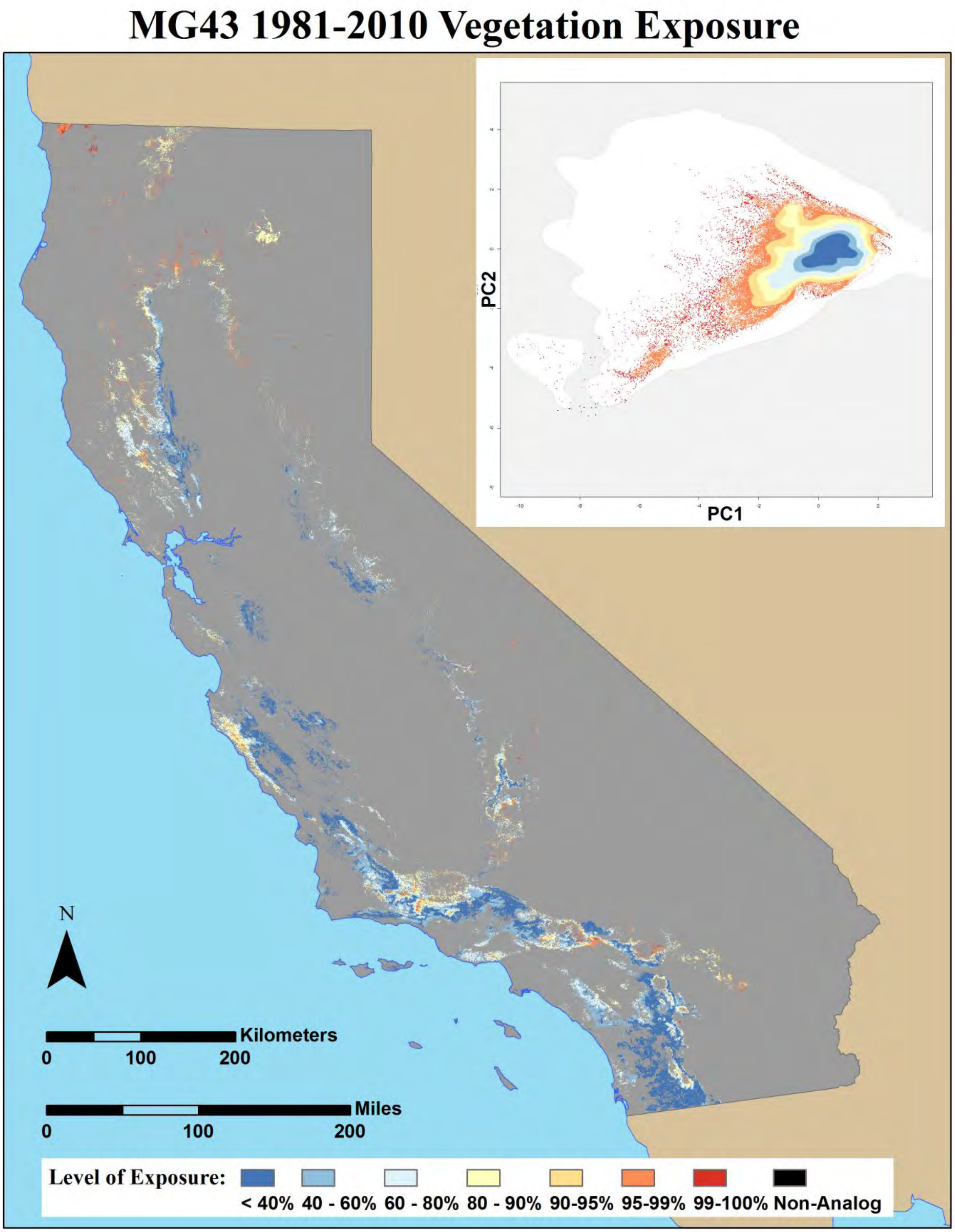


Figure 60. Map of Current Climate Suitability for Macrogroup 43. The 2015 mapped extent of macrogroup 43, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 43 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 34). The overall or grand mean for macrogroup 43 was found to be 3.04 for sensitivity and adaptive capacity.

Table 34. Sensitivity and Adaptive Capacity Rankings for Macrogroup 43. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 43. *Quercus durata* was used to represent all shrub oaks, also true for representative species of *Arctostaphylos* and *Ceanothus*.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Arctostaphylos viscida	4	3	1	4	2	2	1	4	5	**2.9**
Ceanothus cuneatus	4	3	1	4	3	2	2	3	5	**3.0**
Adenostoma fasciculatum	4	3	4	4	2	3	5	4	3	**3.6**
Heteromeles arbutifolia	4	3	4	2	2	3	3	3	1	**2.8**
Quercus durata	4	3	4	3	2	2	5	3	1	**3.0**
Mean	**4.00**	**3.00**	**2.80**	**3.40**	**2.20**	**2.40**	**3.20**	**3.00**	**3.00**	
Grand Mean	**3.04**				**Mean**	**2.97**		**Mean**	**3.20**	

Projected Climate Exposure

The future climate exposure for macrogroup 43 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 61).

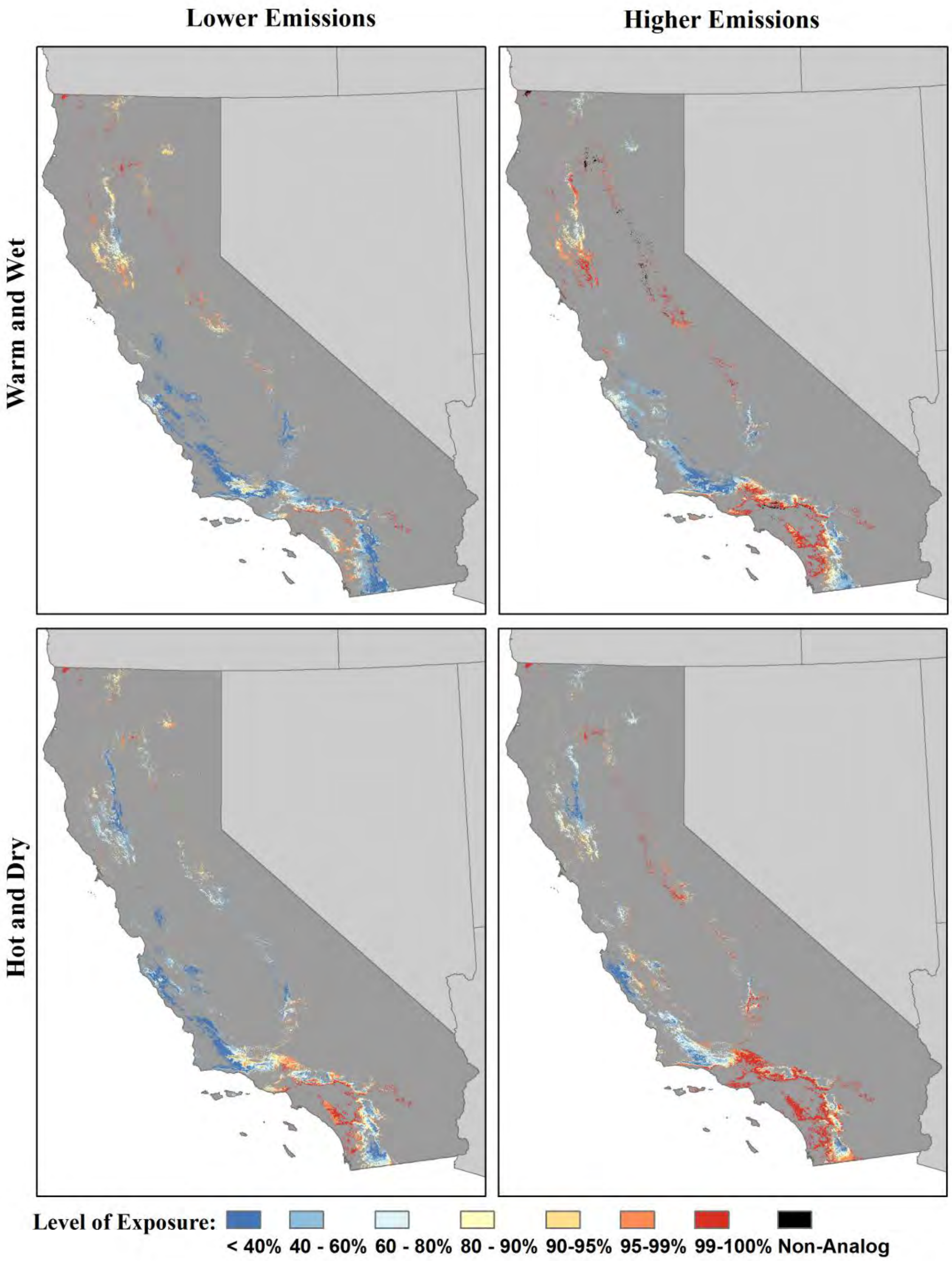


Figure 61. Maps of Projected Climate Exposure for Macrogroup 43. The climate exposure level for macrogroup 43 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 61 is derived from the PCA charts (Figure 62), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

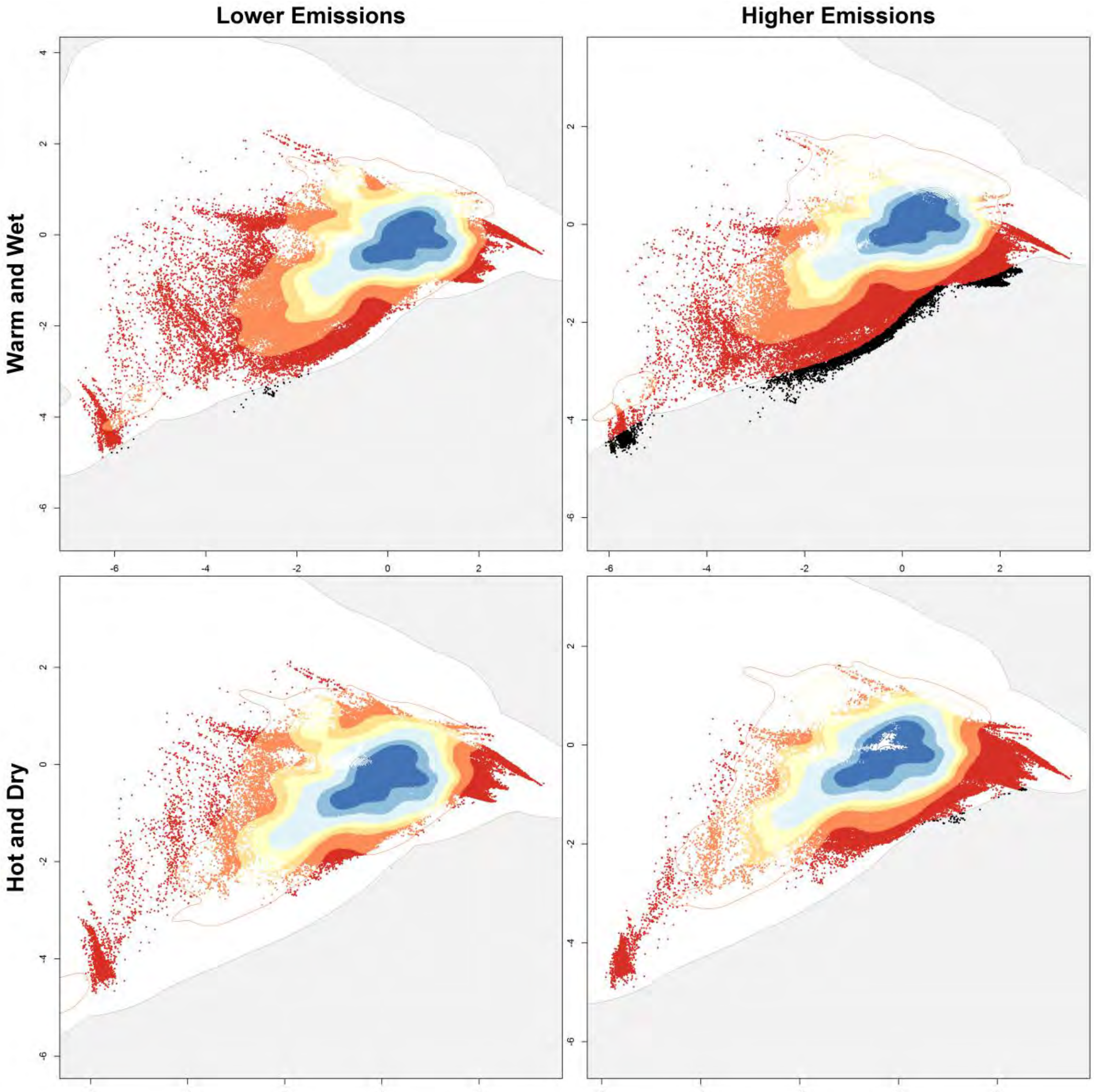


Figure 62. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 43. The PCA charts are two dimensional representations of climate exposure for macrogroup 43 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 35). In the current time period, macrogroup 43 occupies 27,148 km^2. By the end of the century, there will be between 10,984 km^2 (40%) and 18,009 km^2 (66%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 4,288 km^2 (16%) and 11,417 km^2 (42%) of this type will be climatically exposed by the end of century.

Table 35. Percentage of the Current Extent of Macrogroup 43 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	5,430	5,427	5,433	5,429	2,715	1,356	1,088	268	2
1980-2010 (%)	20.00	19.99	20.01	20.00	10.00	4.99	4.01	0.99	0.01
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	20.93	16.34	18.92	18.56	10.51	5.82	5.61	3.31	0.00
2040-2069 (%)	22.81	14.55	17.79	19.14	10.36	6.22	5.81	3.32	0.00
2070-2099 (%)	16.82	18.88	16.01	14.64	8.68	9.18	10.29	5.50	0.01
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	20.24	16.93	18.71	17.73	10.73	6.24	6.03	3.39	0.00
2040-2069 (%)	19.10	17.02	14.93	16.53	10.37	7.47	9.30	5.28	0.00
2070-2099 (%)	4.67	8.15	19.80	15.93	7.61	5.40	14.00	22.44	2.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	21.06	14.23	16.41	19.98	10.93	8.72	6.02	2.64	NA
2040-2069 (%)	17.22	14.29	19.33	20.72	9.47	7.09	8.68	3.19	NA
2070-2099 (%)	14.69	10.56	16.42	21.38	10.35	7.72	10.75	8.13	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	19.93	13.52	17.03	20.99	11.29	8.46	6.10	2.69	NA
2040-2069 (%)	11.44	11.42	18.62	21.72	10.54	8.31	11.04	6.91	0.00
2070-2099 (%)	2.53	7.08	11.42	19.43	9.85	7.64	13.41	28.61	0.03

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 43 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 63), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 105,905 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

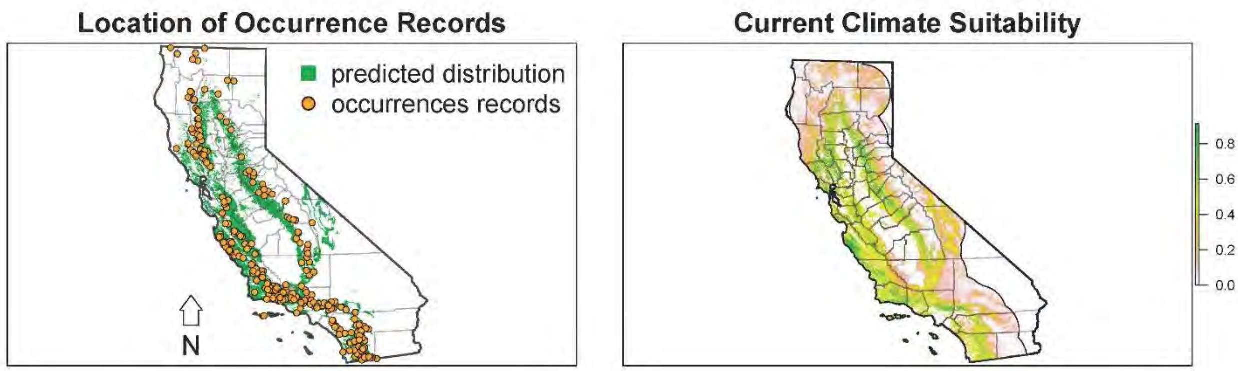


Figure 63. Map of Points Selected from the Extent of Macrogroup 43 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 43. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 43 (Figure 64). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 43, between 8,608 km^2 (8%) and 57,052 km^2 (54%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 48,853 km^2 (46%) and 97,297 km^2 (92%) will remain climatically suitable, and between 17,954 km^2 (17%) and 49,286 km^2 (47%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 36.

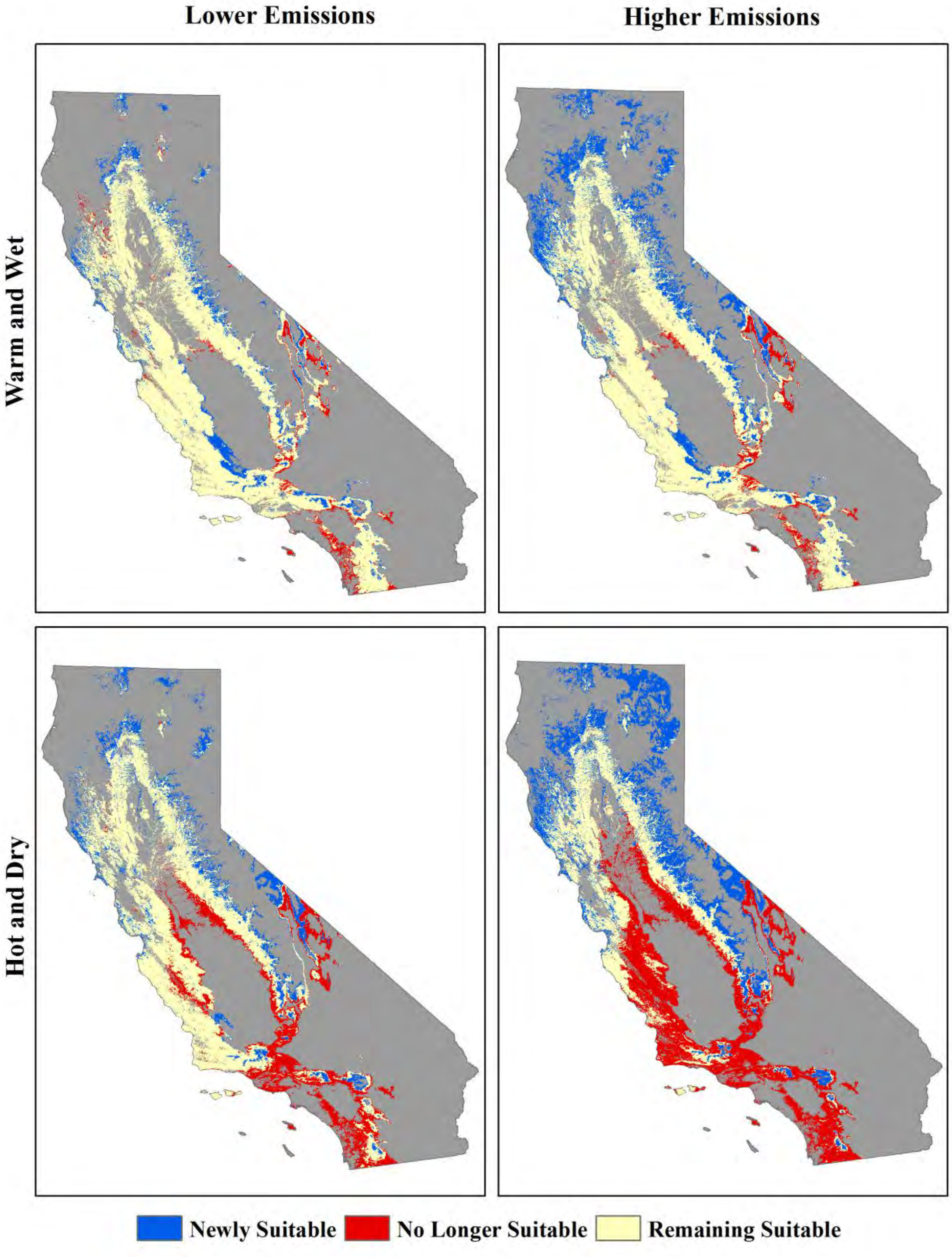


Figure 64. Maps of the Projected Climatically Suitable Range for Macrogroup 43. Maps showing the modeled climatically suitable range for macrogroup 43 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 36. Area of Projected Climatic Suitability for Macrogroup 43. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 43, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	8,608	97,297	17,954	8%	92%	17%
CNRM CM5 - RCP 8.5	9,623	96,282	37,320	9%	91%	35%
MIROC ESM - RCP 4.5	29,611	76,294	23,089	28%	72%	22%
MIROC ESM - RCP 8.5	57,052	48,853	49,286	54%	46%	47%

MG044: Macrogroup California Coastal Scrub
Common Name: Coastal Sage Scrub

This is the other main macrogroup of California shrublands. It differs from chaparral by being composed of drought-deciduous shrubs, which typically are smaller with less extensive root systems and shorter life spans. Many of the members of this macrogroup are also found in the warm deserts and show similar adaptations to hot-dry summer conditions.

California sagebrush, true sage species (*Salvia* spp.), Encelia, shrubby buckwheats (*Eriogonum* spp.), deer-weed (*Lotus scoparius*), and several other shrubs are characteristic. These scrubs are typical of relatively hot and dry slopes, and occupy finer textured soils than most chaparrals. Some members of this Macrogroup are disturbance specialists, colonizing burns or clearings, and giving-way to longer lived chaparral and other vegetation a few years after disturbance. Non-native invasive broom species also fill this role as "semi-natural" stands, and are included in this category.

The single best WHR category is coastal scrub (CSC), However, the WHR Coastal Scrub also includes all the northern coastal scrubs and not just the southern coastal drought deciduous vegetation, so it actually includes cool and warm temperate Mediterranean vegetation.

Macrogroup 44 is comprised of approximately one WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 7,501 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 65). Using the current climate conditions for the extent of Macrogroup 44, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

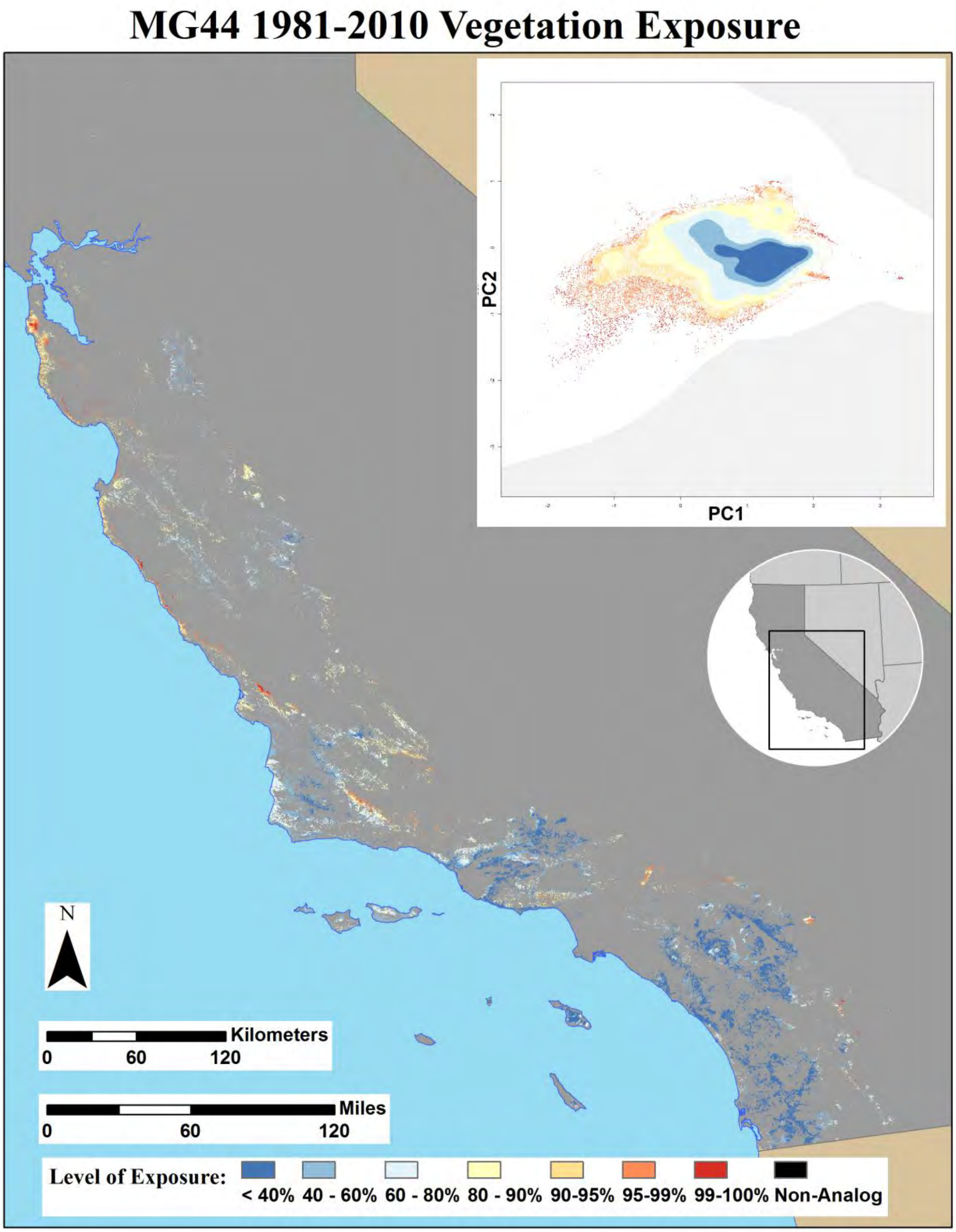


Figure 65. Map of Current Climate Suitability for Macrogroup 44. The 2015 mapped extent of macrogroup 44, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 44 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 37). The overall or grand mean for macrogroup 44 was found to be 2.78 for sensitivity and adaptive capacity.

Table 37. Sensitivity and Adaptive Capacity Rankings for Macrogroup 44. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 44.

	Sensitivity						Adaptive Capacity			Species Score
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Artemisia californica	2	2	1	3	3	2	3	2	3	**2.3**
Salvia leucophylla	2	2	2	3	4	2	4	3	5	**3.0**
Salvia mellifera	2	2	2	3	4	2	4	3	5	**3.0**
Mean	**2.00**	**2.00**	**1.67**	**3.00**	**3.67**	**2.00**	**3.67**	**2.67**	**4.33**	
Grand Mean	**2.78**				**Mean**	**2.39**		**Mean**	**3.56**	

Projected Climate Exposure

The future climate exposure for macrogroup 44 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 66).

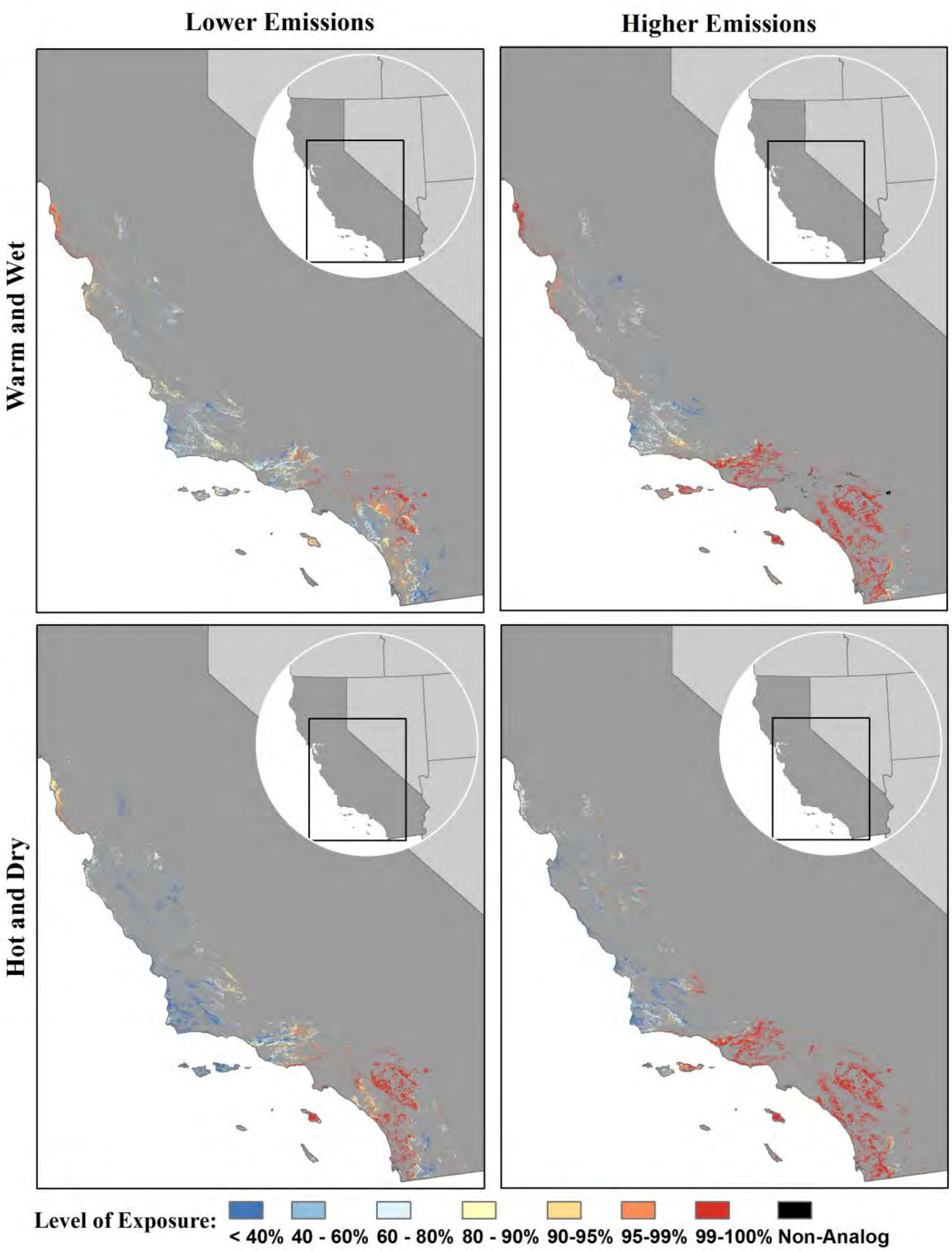


Figure 66. Maps of Projected Climate Exposure for Macrogroup 44. The climate exposure level for macrogroup 44 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 66 is derived from the PCA charts (Figure 67), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

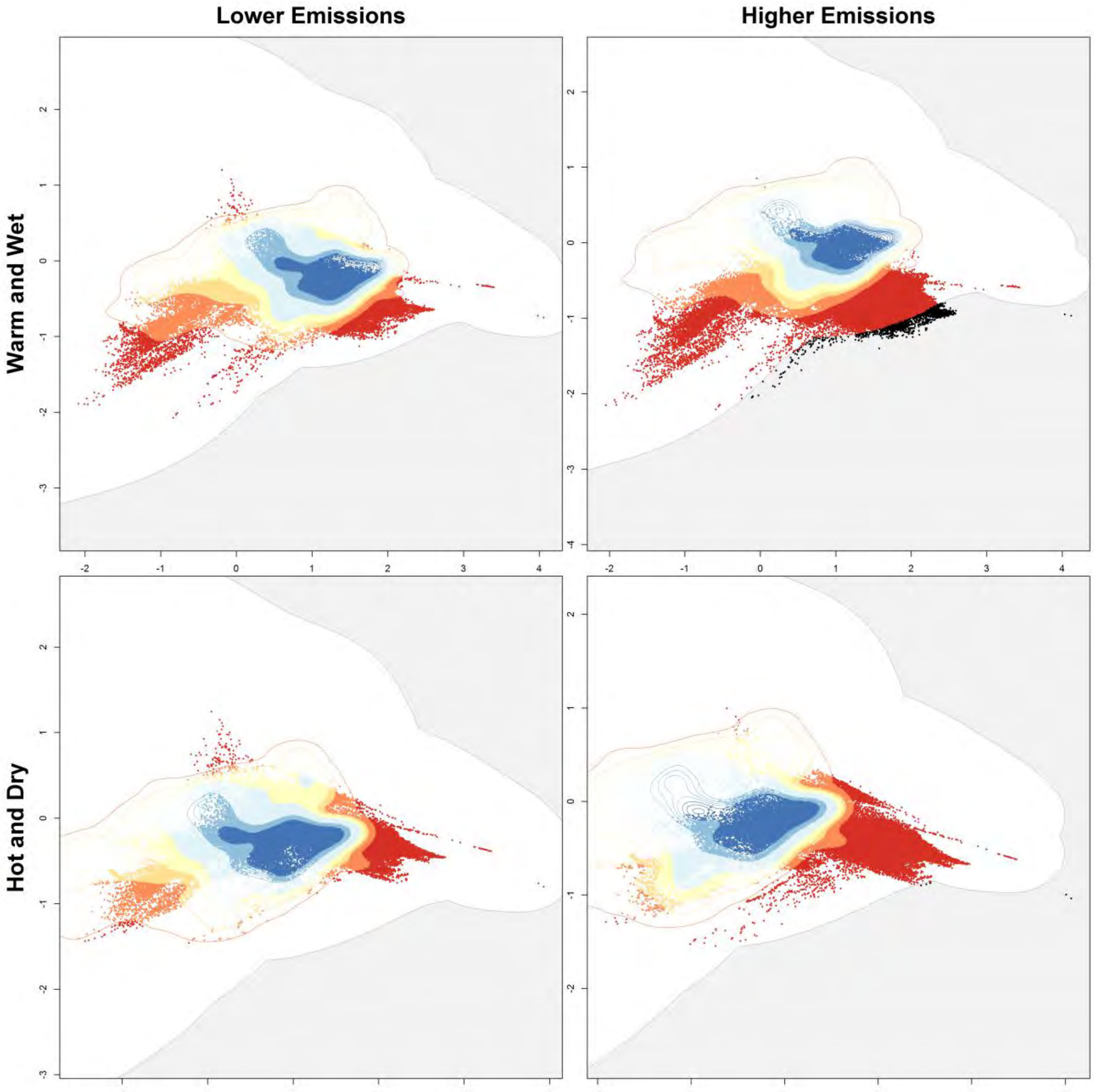


Figure 67. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 44. The PCA charts are two dimensional representations of climate exposure for macrogroup 44 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 38). In the current time period, macrogroup 44 occupies 7,501 km^2. By the end of the century, there will be between 2,175 km^2 (29%) and 4,132 km^2 (55%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,865 km^2 (25%) and 4,668 km^2 (62%) of this type will be climatically exposed by the end of century.

Table 38. Percentage of the Current Extent of Macrogroup 44 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1,501	1,500	1,500	1,500	750	375	299	75	0
1980-2010 (%)	20.01	19.99	20.00	20.00	10.00	5.00	3.99	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	15.13	13.22	18.51	29.61	11.55	6.01	4.80	1.17	0.00
2040-2069 (%)	9.29	18.42	21.62	26.40	10.59	5.17	6.22	2.28	0.00
2070-2099 (%)	3.08	11.12	15.70	25.18	11.97	8.09	14.08	10.78	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	16.04	13.61	18.16	28.98	10.93	6.14	4.52	1.63	0.00
2040-2069 (%)	4.66	13.19	16.57	24.12	10.86	7.24	14.58	8.78	0.00
2070-2099 (%)	2.37	4.73	5.11	16.79	5.16	3.61	7.50	53.33	1.41
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	19.79	14.17	26.48	24.86	7.50	4.05	2.08	1.08	NA
2040-2069 (%)	11.76	9.89	15.20	31.94	11.59	5.12	7.23	7.27	NA
2070-2099 (%)	13.77	15.92	10.05	12.49	8.19	5.82	9.55	24.21	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	19.61	11.64	26.06	27.71	8.50	3.91	1.66	0.92	NA
2040-2069 (%)	8.26	11.26	14.24	21.44	10.63	5.01	7.65	21.52	0.00
2070-2099 (%)	8.61	8.19	7.63	10.34	4.06	2.13	5.33	53.72	0.01

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 44 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 68), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 57,019 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

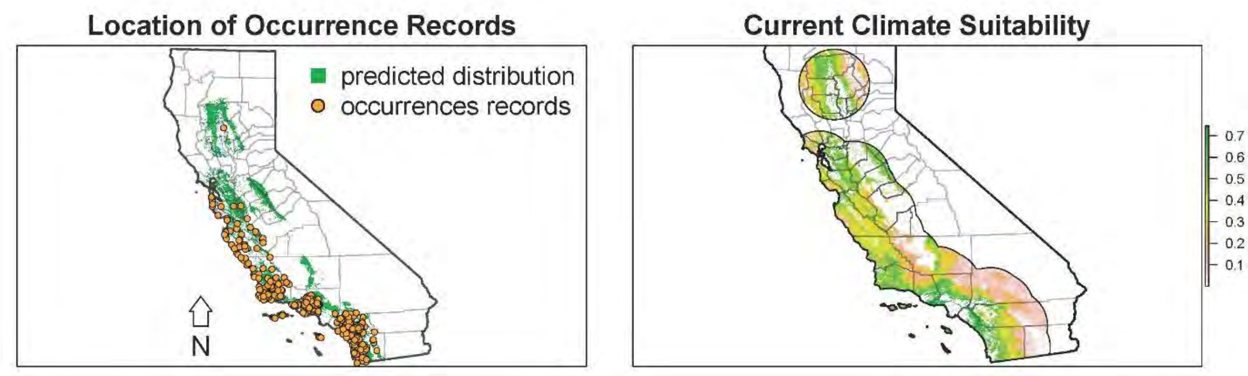


Figure 68. Map of Points Selected from the Extent of Macrogroup 44 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 44. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 44 (Figure 69). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 44, between 4,944 km^2 (9%) and 15,769 km^2 (28%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 41,250 km^2 (72%) and 52,075 km^2 (91%) will remain climatically suitable, and between 17,086 km^2 (30%) and 28,069 km^2 (49%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 39.

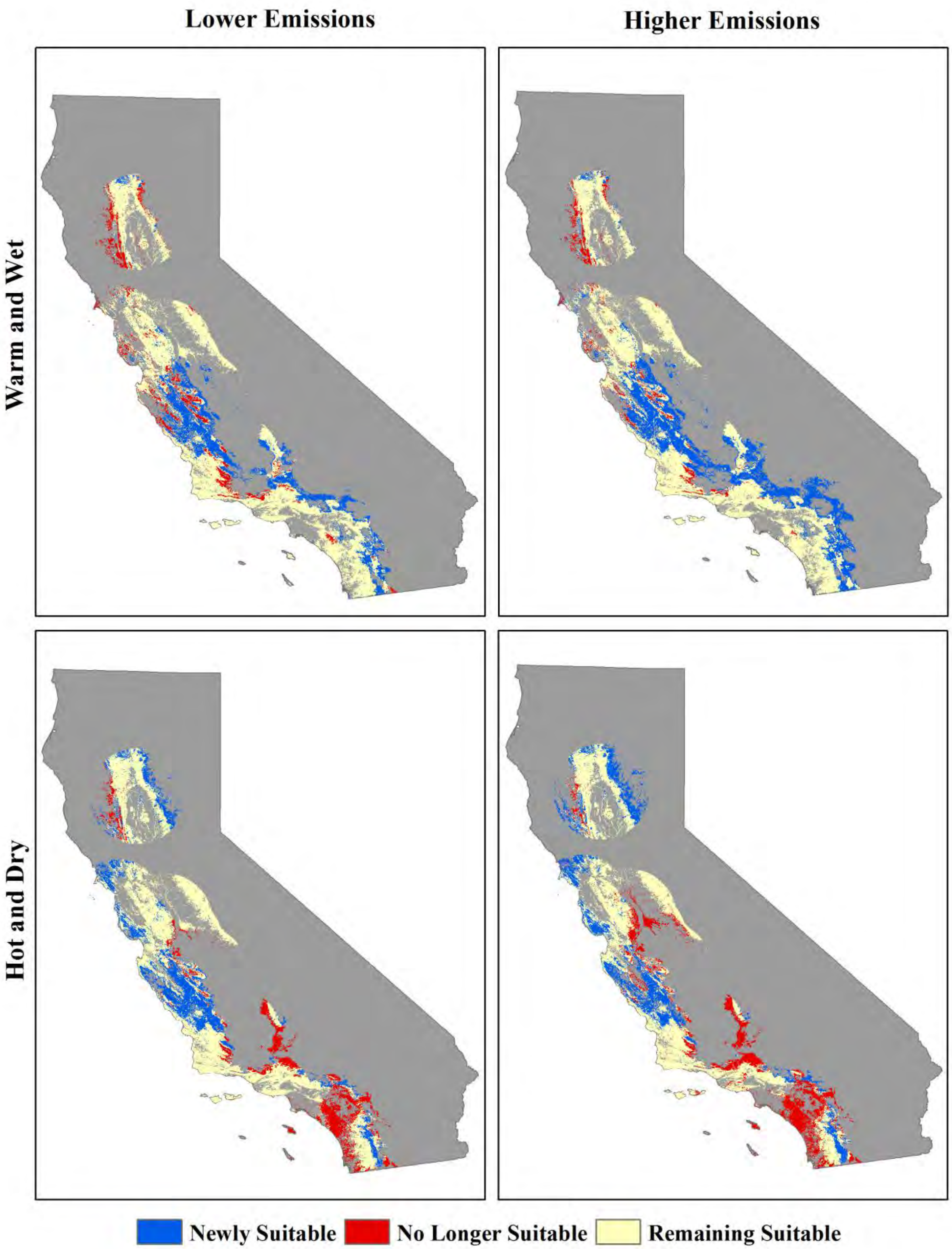


Figure 69. Maps of the Projected Climatically Suitable Rnage for Macrogroup 44. Maps showing the modeled climatically suitable range for macrogroup 44 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 39. Area of Projected Climatic Suitability for Macrogroup 44. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 44, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	7,711	49,308	17,876	14%	86%	31%
CNRM CM5 - RCP 8.5	4,944	52,075	28,069	9%	91%	49%
MIROC ESM - RCP 4.5	11,778	45,241	17,086	21%	79%	30%
MIROC ESM - RCP 8.5	15,769	41,250	17,394	28%	72%	31%

MG045: Macrogroup California Annual and Perennial Grassland
Common Name: California Grassland and Flowerfields

This macrogroup includes all annual forb/grass vegetation native and non-native, as well as native perennial grasslands growing within the California Mediterranean climate. This does not include the cool-moist north coastal terrace prairies, the montane meadow/upland grasslands, and non-native perennial pasture grasses. Stands of this macrogroup include everything from wildflower fields in the San Joaquin Valley and adjacent southern and central Coast Ranges, poppy fields of the western Mojave Desert, needlegrass grasslands of the foothills, valleys and Coast Ranges, and the largely non-native annual grasslands and weed patches in the dry, warm summer regions of California.

Native perennial grasslands include needle grass species (*Stipa, Achnatherum, Nassella*), melicgrass (*Melica* spp.) and giant wild rye (*Leymus condensatus*). Annual native forb and wildflower fields include species of poppy (*Eschscholzia*), goldfields (*Lasthenia*), popcorn flowers (*Plagiobothrys*), *Phacelia*, fiddleneck (*Amsinckia*), and others. Non-native annual grasslands composed of Eurasian species such as wild oat, brome, annual fescue, star-thistle, mustards, fennel, and others are also included in this macrogroup.

The WHR type annual grassland (AGS) is the best fit for all native flower fields and native and non-native annual grasslands. This would also include tall ruderal forbs like fennel, mustard, milk thistle, etc. The perennial California native component of the macrogroup is included within the WHR type perennial grassland, although that also includes 1) non-native perennial grasses, which mostly fall within the cool-temperate grassland macrogroup called "Vancouverian Lowland Grassland and Shrubland," and 2) native perennial grasslands largely occupying the cooler montane interior or northeastern parts of the state. The second type of WHR perennial grassland is part of the macrogroup "Western North American Temperate Grassland and Meadow."

Macrogroup 45 is comprised of approximately one WHR types for which we scored six representative dominant species. The statewide extent for the current time period cover 44,866 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 70). Using the current climate conditions for the extent of Macrogroup 45, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

MG45 1981-2010 Vegetation Exposure

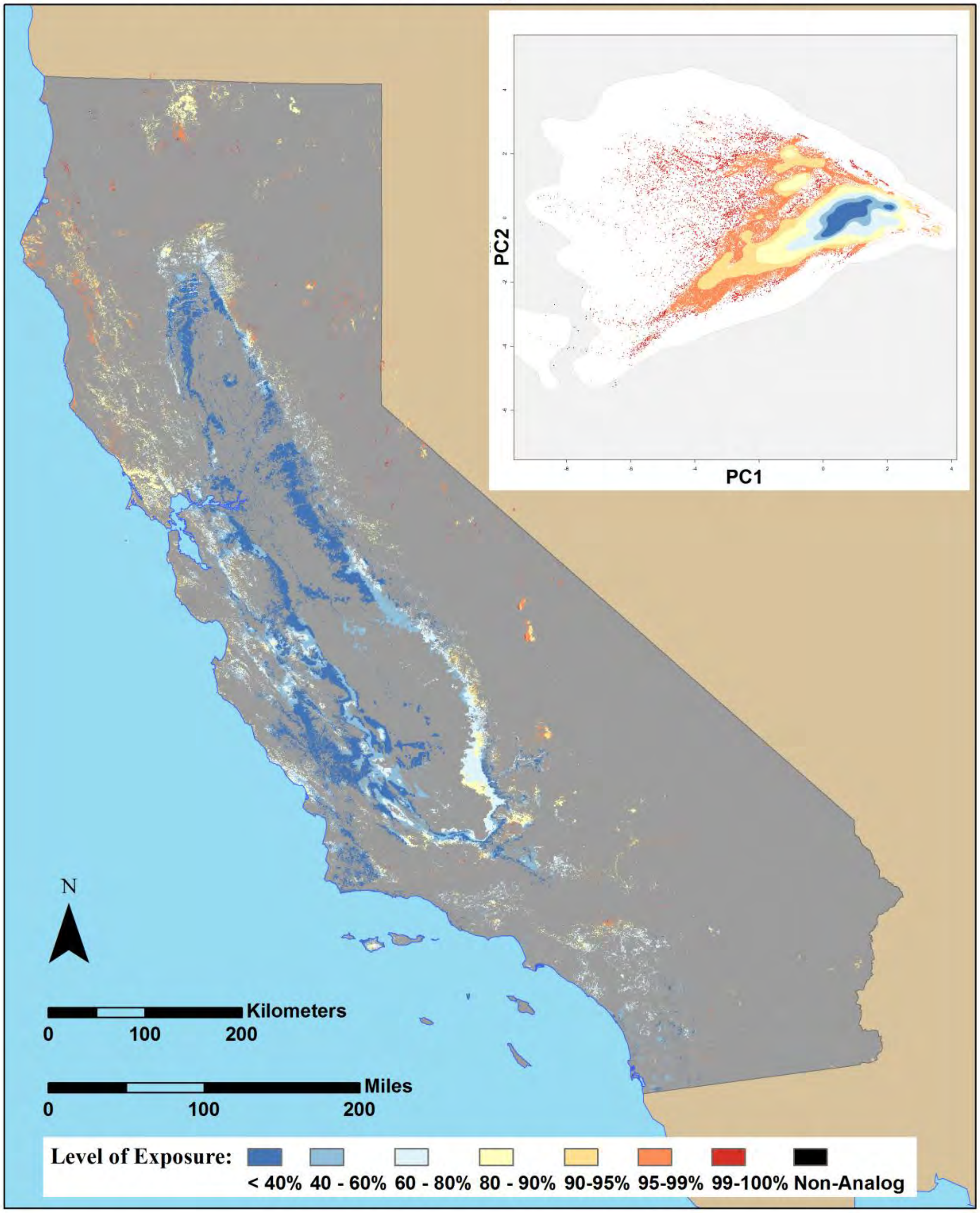


Figure 70. Map of Current Climate Suitability for Macrogroup 45. The 2015 mapped extent of macrogroup 45, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 45 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 40). The overall or grand mean for macrogroup 45 was found to be 2.81 for sensitivity and adaptive capacity.

Table 40. Sensitivity and Adaptive Capacity Rankings for Macrogroup 45. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 45. The annuals and grass species listed by CDFW for this macrogroup have different characteristics, but most of the grasses were not quantified in the MCV life history tables, and are not represented here.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Avena & Bromus genera	4	2	4	3	5	2	1	5	3	**3.2**
Nassella pulchra	4	3	4	3	3	2	5	5	1	**3.3**
Eschscholzia californica	4	3	2	3	3	2	1	5	1	**2.7**
Lasthenia californica	4	3	1	3	3	2	1	3	5	**2.8**
Amsinckia menziesii	4	3	1	3	2	2	1	3	3	**2.4**
Plagiobothrys nothofulvus	4	3	1	3	2	2	1	3	3	**2.4**
Mean	**4.00**	**2.83**	**2.17**	**3.00**	**3.00**	**2.00**	**1.67**	**4.00**	**2.67**	
Grand Mean	**2.81**				**Mean**	**2.83**		**Mean**	**2.78**	

Projected Climate Exposure

The future climate exposure for macrogroup 45 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 71).

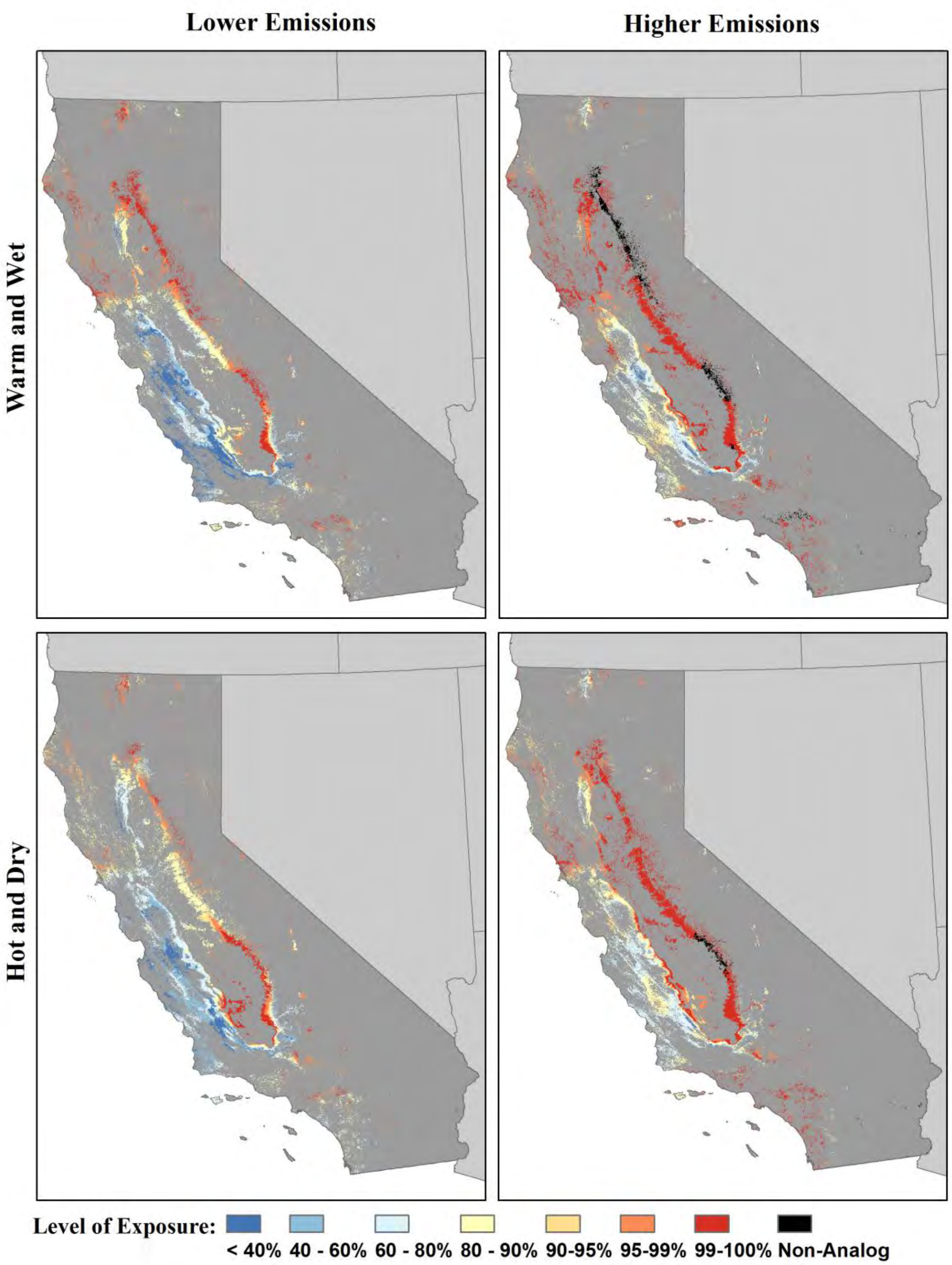


Figure 71. Maps of Projected Climate Exposure for Macrogroup 45. The climate exposure level for macrogroup 45 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 71 is derived from the PCA charts (Figure 72), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

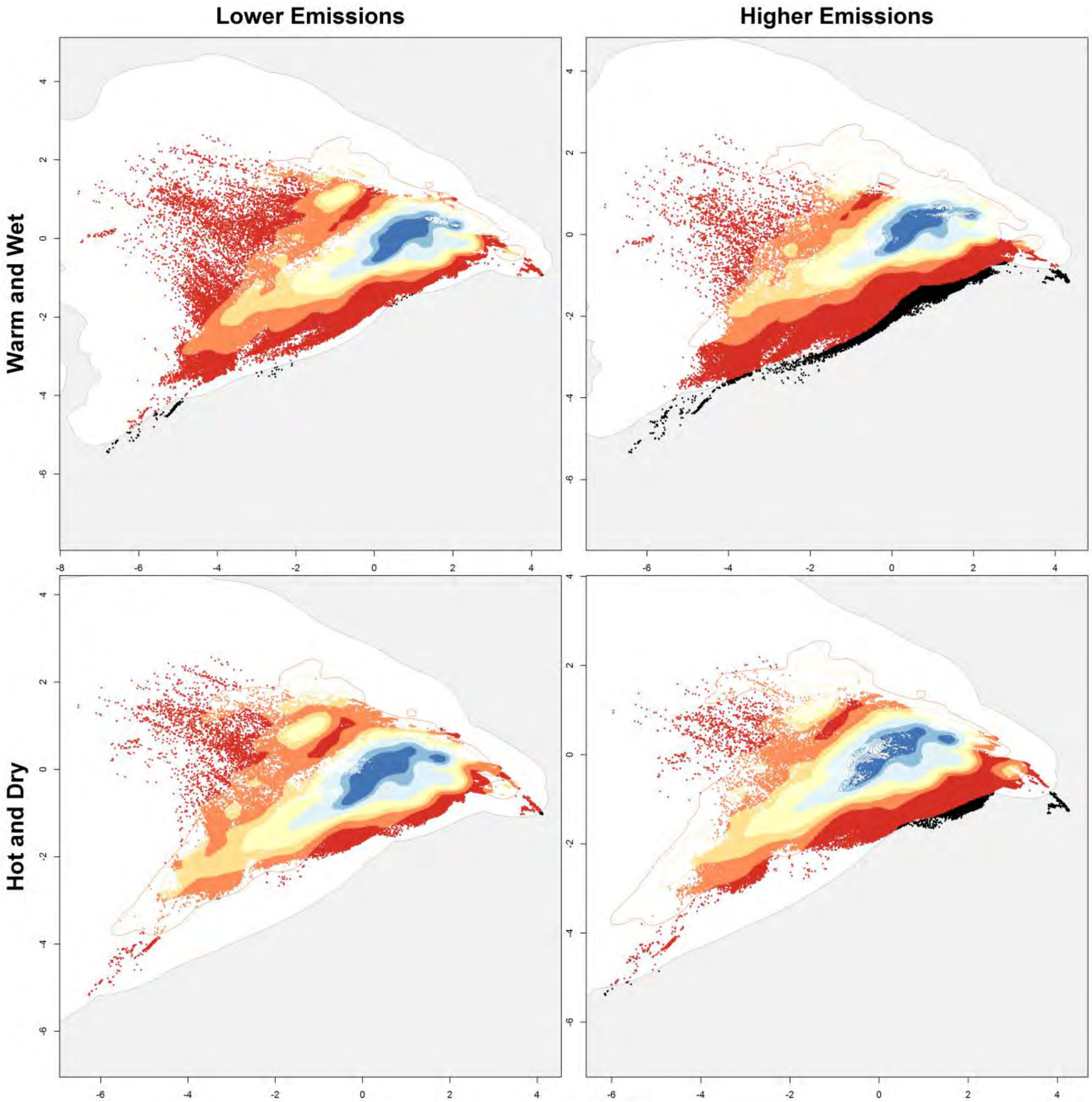


Figure 72. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 45. The PCA charts are two dimensional representations of climate exposure for macrogroup 45 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 41). In the current time period, macrogroup 45 occupies 44,866 km^2. By the end of the century, there will be between 8,276 km^2 (18%) and 21,663 km^2 (48%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 10,787 km^2 (24%) and 26,807 km^2 (60%) of this type will be climatically exposed by the end of century.

Table 41. Percentage of the Current Extent of Macrogroup 45 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	8,975	8,976	8,975	8,972	4,491	2,240	1,787	449	1
1980-2010 (%)	20.01	20.01	20.00	20.00	10.01	4.99	3.98	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	12.13	14.14	14.27	24.89	14.06	7.60	7.90	5.02	0.00
2040-2069 (%)	12.63	13.11	10.38	21.23	16.74	7.56	10.90	7.44	0.00
2070-2099 (%)	8.65	8.01	8.57	18.36	14.93	8.11	14.74	18.58	0.05
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	12.23	13.34	13.38	24.82	13.96	7.31	9.09	5.86	0.00
2040-2069 (%)	9.39	8.37	9.75	19.66	14.73	8.84	14.50	14.74	0.02
2070-2099 (%)	0.53	0.82	2.29	14.80	15.30	6.50	10.08	41.54	8.13
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	13.15	16.40	16.62	29.24	11.09	5.88	4.91	2.72	NA
2040-2069 (%)	10.69	12.21	12.75	29.96	15.22	7.06	7.95	4.16	NA
2070-2099 (%)	3.97	4.60	14.84	24.88	17.89	9.78	13.67	10.36	0.02
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	15.11	16.08	15.82	29.83	10.18	5.64	4.86	2.48	NA
2040-2069 (%)	3.80	8.82	13.84	26.89	18.44	8.66	11.06	8.48	0.02
2070-2099 (%)	0.20	0.39	1.26	20.73	16.43	7.56	12.54	39.11	1.77

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 45 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 73), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 110,537 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

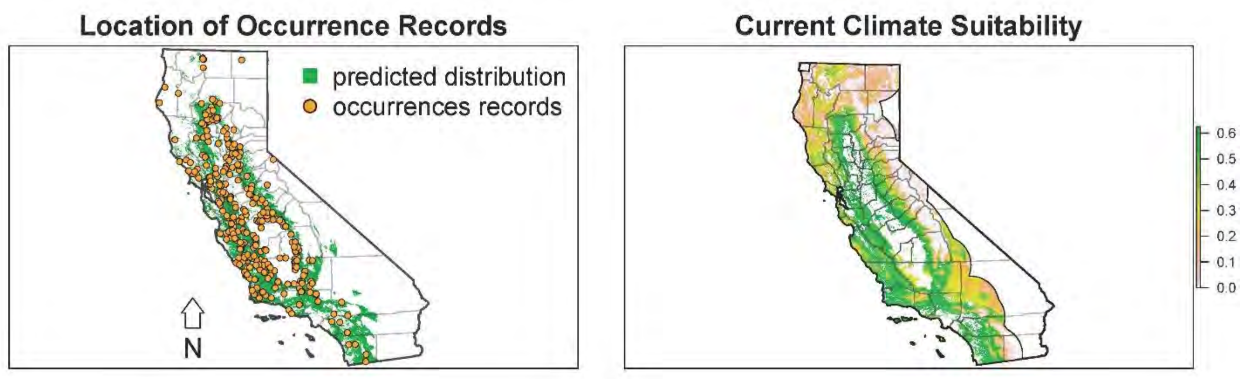


Figure 73. Map of Points Selected from the Extent of Macrogroup 45 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 45. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 45 (Figure 74). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 45, between 17,814 km^2 (16%) and 53,347 km^2 (48%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 57,190 km^2 (52%) and 92,723 km^2 (84%) will remain climatically suitable, and between 11,195 km^2 (10%) and 57,288 km^2 (52%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 42.

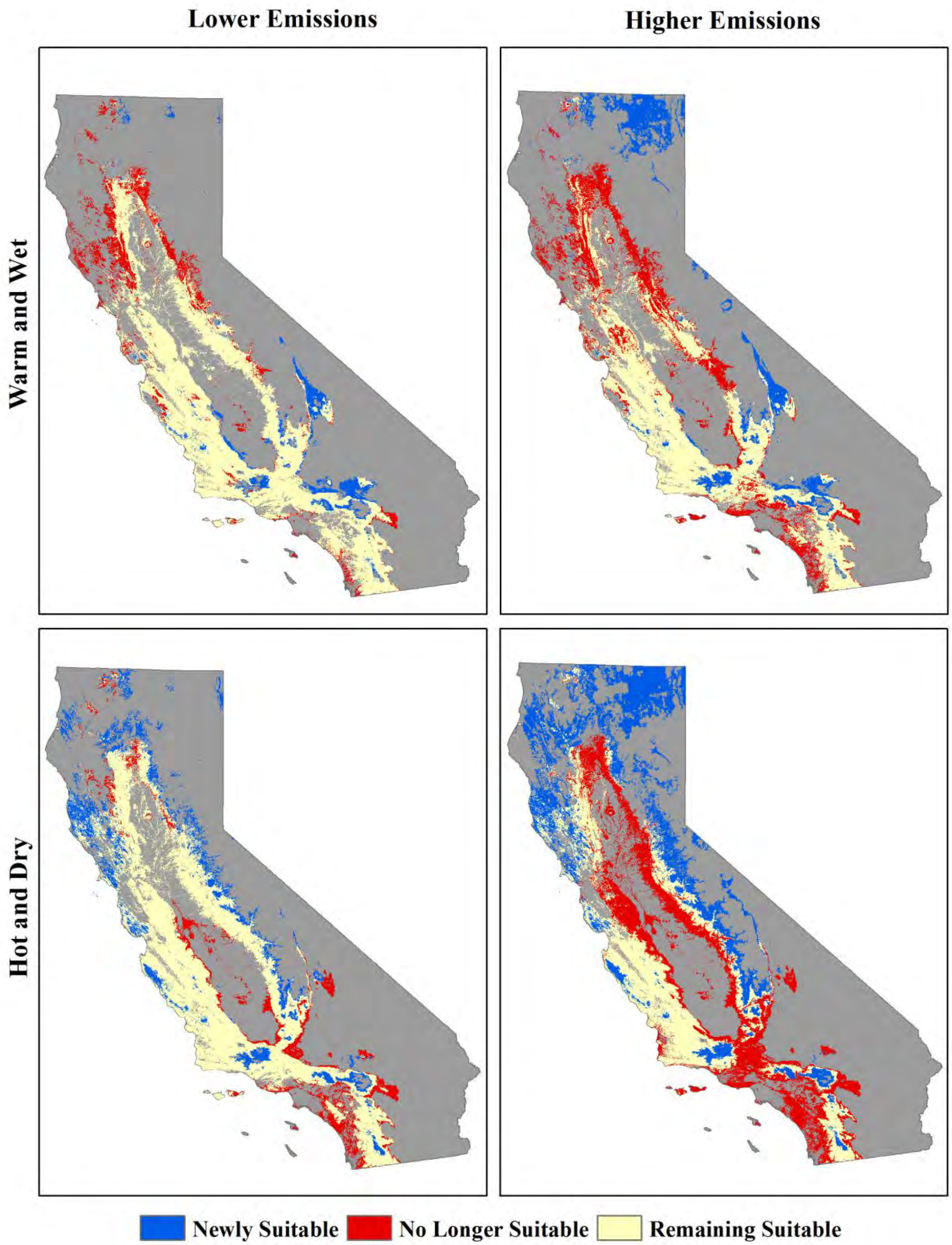


Figure 74. Maps of the Projected Climatically Suitable Range for Macrogroup 45. Maps showing the modeled climatically suitable range for macrogroup 45 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 42. Area of Projected Climatic Suitability for Macrogroup 45. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 45, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	19,585	90,951	11,195	18%	82%	10%
CNRM CM5 - RCP 8.5	37,931	72,606	22,989	34%	66%	21%
MIROC ESM - RCP 4.5	17,814	92,723	25,905	16%	84%	23%
MIROC ESM - RCP 8.5	53,347	57,190	57,288	48%	52%	52%

MG047: Western North American Montane-Subalpine Wet Shrubland and Wet Meadow [previously: Macrogroup Western Cordilleran Montane-Boreal Wet Meadow] Common Name: Mountain Riparian Scrub and Wet Meadow

This macrogroup contains montane meadow grasses, graminoids, and forbs and shrublands associated with meadows, riparian terraces, and seeps in the higher mountains of the state from the Peninsular and Transverse Ranges through the Sierra-Cascade Ranges and including the higher mountains of the Modoc Plateau, the Klamath Mountains and the high Inner North Coast Ranges. The vegetation tends to make small stands sorting ecologically based on moisture availability and on tolerance of disturbance. This concept joins both low riparian shrublands and associated wet meadows based on their overlap in ecologies and floristic composition.

Dominant and characteristic species in the wet meadow component of this macrogroup include many species of sedges (Carex), rushes (Juncus), and forbs such as goldenrod (Solidago), clover (Trifolium), iris, and corn lily (Veratrum). The montane riparian scrub component contains several species of willows including *Salix orestera*, *S. planifolia*, *S. Eastwoodiae*, *S. boothii*, and *S. lemmonnii*, along with scrub alders such as *Alnus tenuifolia* and *A. viridis*, and other riparian shrubs. This macrogroup is associated with sites that remain moist-to-wet well into the summer months, but do not stay saturated or have standing water for long periods through the summer growing season.

There is no single best WHR type. For the woody component, montane riparian (MRI) is closest although it would only refer to the shrubby thickets of willow, alder and other riparian deciduous shrubs of the higher mountains, and not the tree dominated stands of black cottonwood, aspen, or Oregon ash component of the MRI habitat. The herbaceous dominated stands in the macrogroup are best encompassed in the wet meadow (WTM) type.

Macrogroup 47 is comprised of approximately two WHR types for which we scored nine representative dominant species or representative genera. The statewide extent for the current time period cover 1,203 km^2, here classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 75). Using the current climate conditions for the extent of Macrogroup 47, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

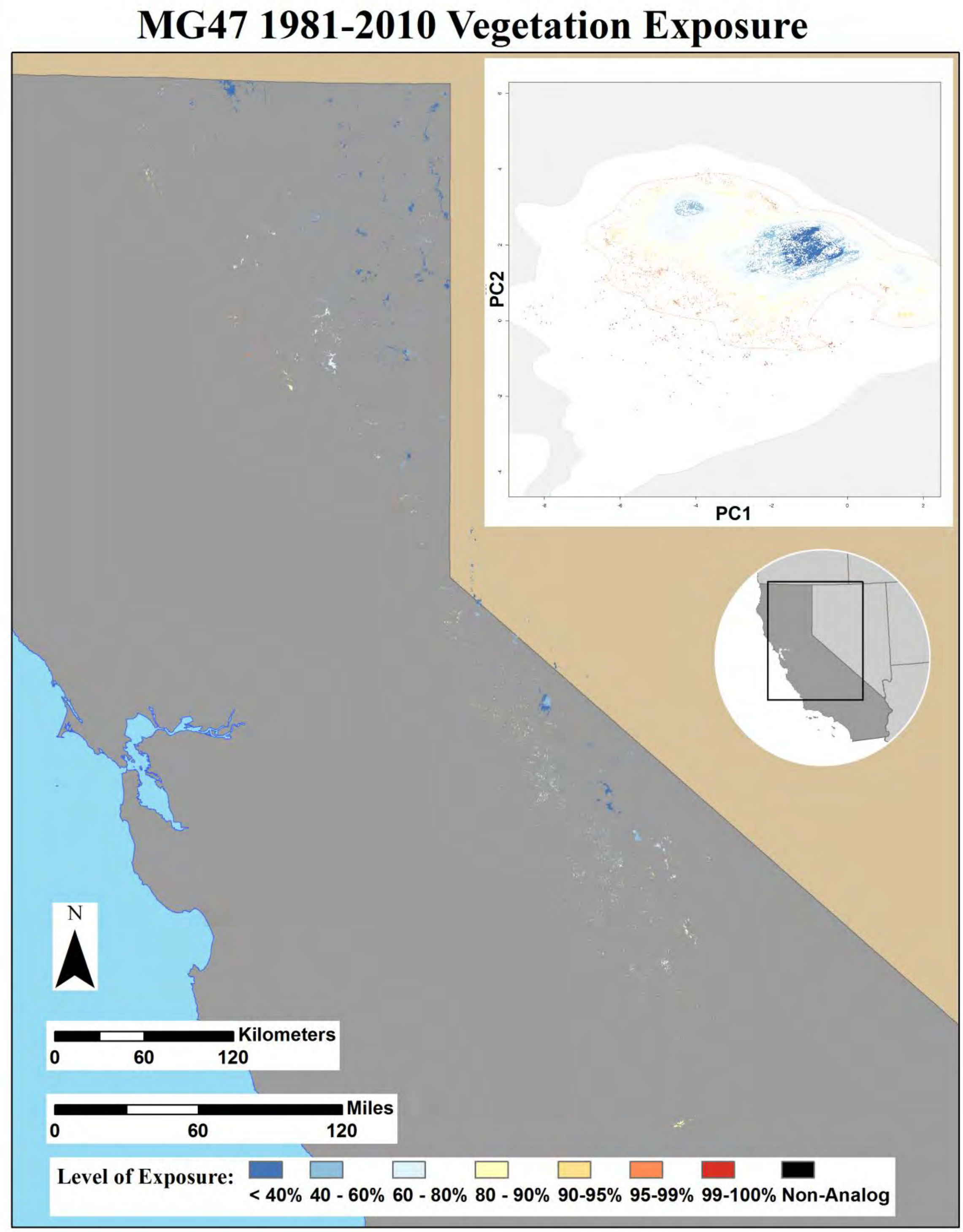


Figure 75. Map of Current Climate Suitability for Macrogroup 47. The 2015 mapped extent of macrogroup 47, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 47 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 43). The overall or grand mean for macrogroup 47 was found to be 2.97 for sensitivity and adaptive capacity.

Table 43. Sensitivity and Adaptive Capacity Rankings for Macrogroup 47. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 47. The score used for this macrogroup is selected from the second line, the genera-level scoring as most trees were included in MG034.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Populus trichocarpa	4	3	4	3	3	3	5	1	1	**3.0**
Alnus rhombifolia	3	2	4	3	3	2	5	4	1	**3.0**
Acer macrophylum	3	2	4	3	3	2	5	1	1	**2.7**
Fraxinus latifolia	2	3	4	1	3	3	5	4	5	**3.3**
Populus fremontii	4	3	3	3	5	3	3	5	1	**3.3**
Salix sp	3	2	4	3	5	3	5	3	1	**3.2**
Mean	**3.17**	**2.50**	**3.83**	**2.67**	**3.67**	**2.67**	**4.67**	**3.00**	**1.67**	
Grand Mean	**3.09**				**Mean**	**3.08**		**Mean**	**3.11**	
Species - WTM	2	1	3	3	2	2	4	2	2	**2.3**
Carex sp	3	2	3	3	2	4	3	2	2	**2.7**
Juncus sp	3	2	4	3	3	4	4	3	3	**3.2**
Danthonia sp	3	2	3	3	4	3	3	3	2	**2.9**
Mean	**3.00**	**2.20**	**3.60**	**2.80**	**3.30**	**2.90**	**4.20**	**2.80**	**1.90**	
Grand Mean	**2.97**				**Mean**	**2.97**		**Mean**	**2.97**	

Projected Climate Exposure

The future climate exposure for macrogroup 47 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 76).

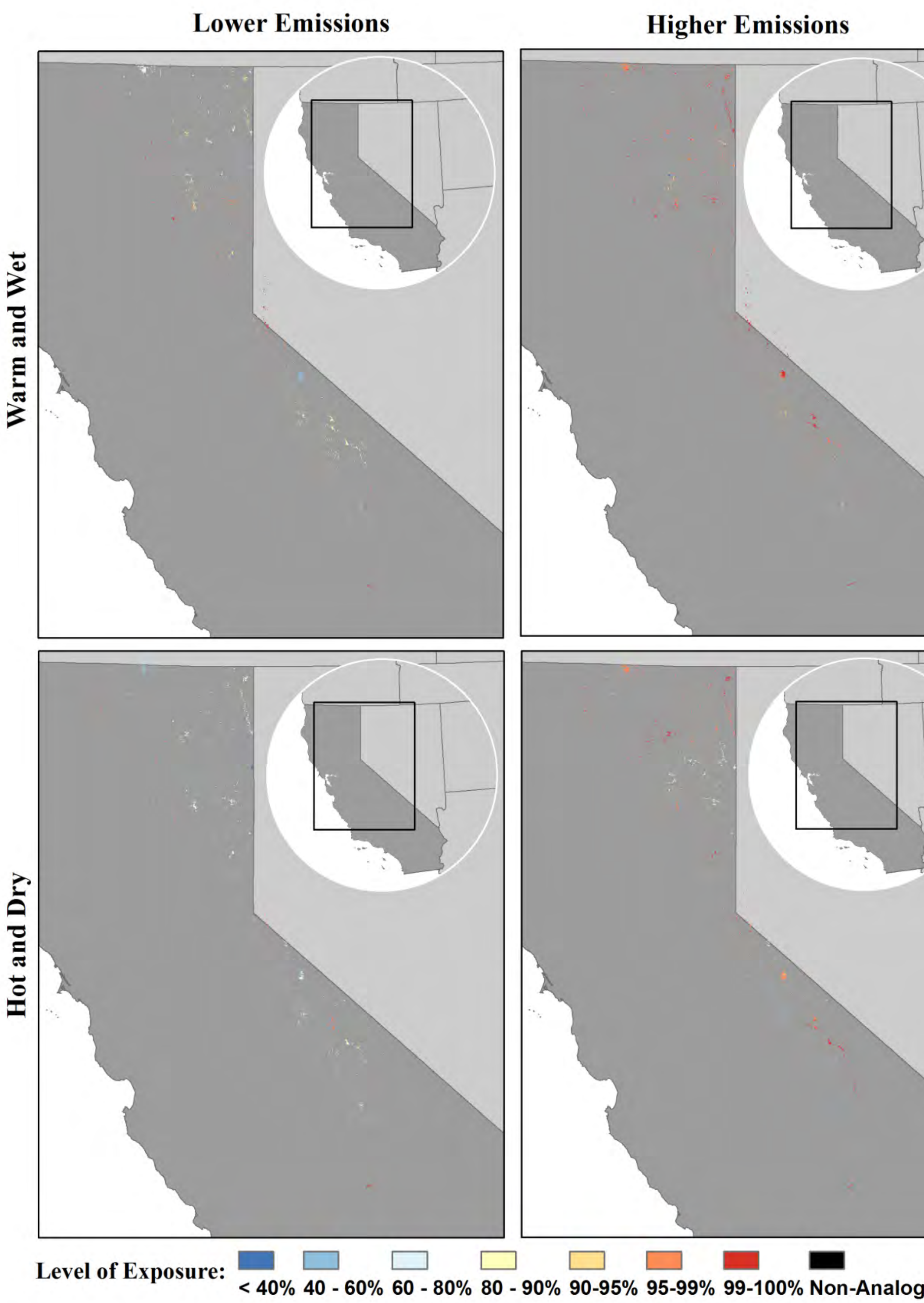


Figure 76. Maps of Projected Climate Exposure for Macrogroup 47. The climate exposure level for macrogroup 47 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 76 is derived from the PCA charts (Figure 77), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

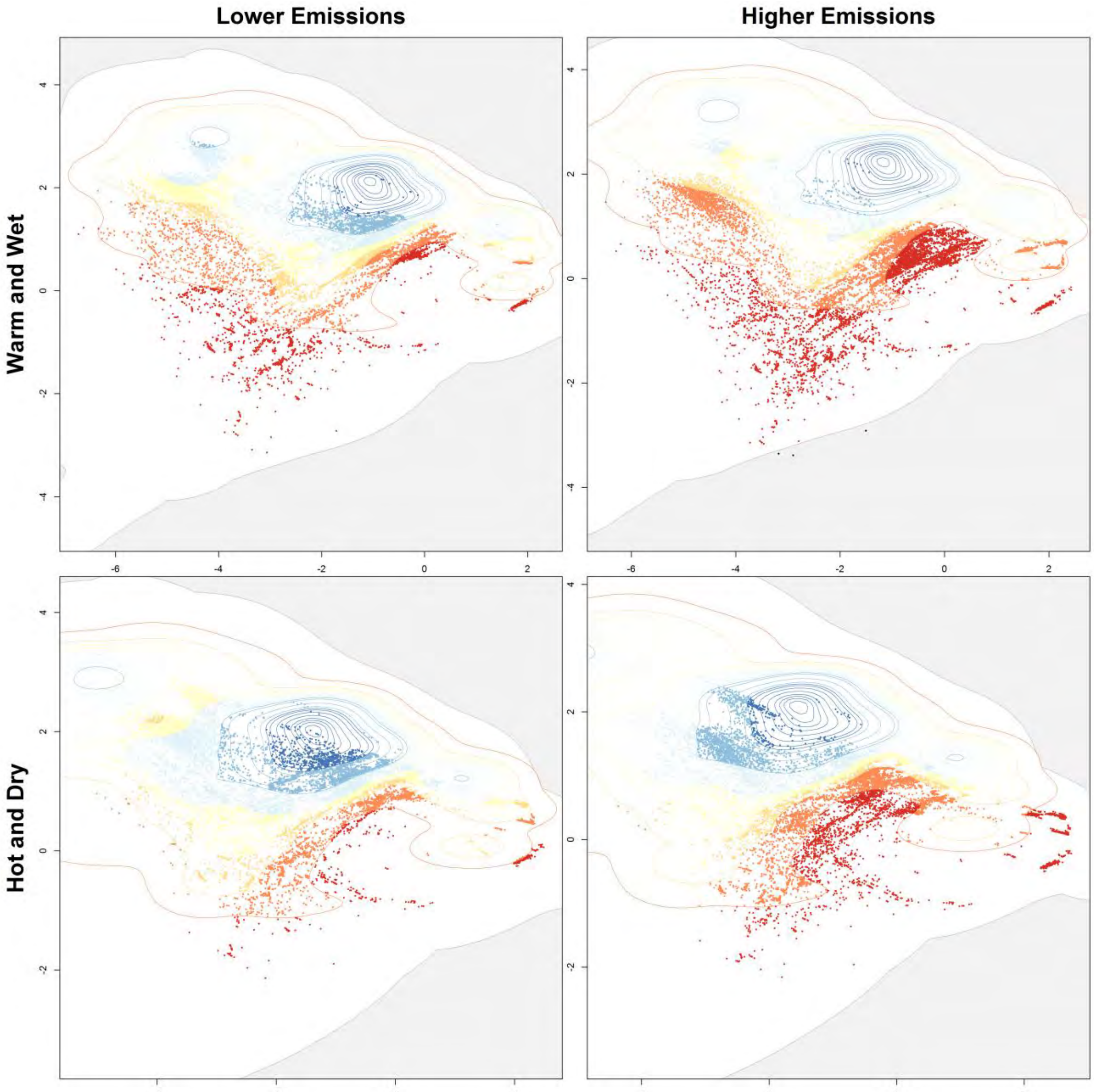


Figure 77. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 47. The PCA charts are two dimensional representations of climate exposure for macrogroup 47 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

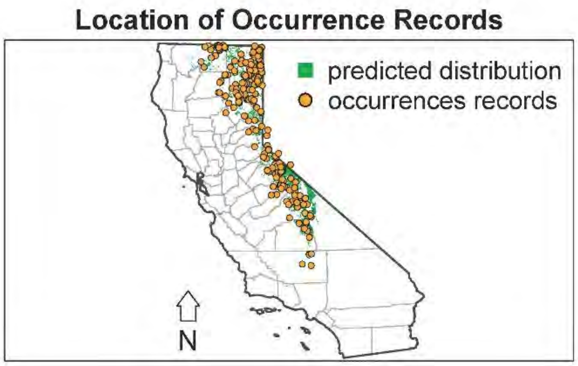
Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 44). In the current time period, macrogroup 47 occupies 1,203 km^2. By the end of the century, there will be between 32 km^2 (3%) and 657 km^2 (55%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 189 km^2 (16%) and 1,023 km^2 (85%) of this type will be climatically exposed by the end of century.

Table 44. Percentage of the Current Extent of Macrogroup 47 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	241	241	241	241	120	60	48	12	0
1980-2010 (%)	20.00	19.99	20.00	20.00	10.00	5.00	4.00	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.25	20.91	23.83	23.75	11.15	6.65	8.47	2.99	0.00
2040-2069 (%)	0.00	9.57	23.18	26.33	14.21	10.89	11.83	3.99	0.00
2070-2099 (%)	0.02	0.35	13.69	19.11	22.20	15.70	18.48	10.45	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	1.13	14.76	24.09	27.80	12.70	6.86	9.28	3.38	0.00
2040-2069 (%)	0.01	2.18	15.72	22.37	24.97	11.75	15.35	7.65	0.00
2070-2099 (%)	0.00	0.07	0.56	1.99	4.13	8.25	39.42	45.56	0.02
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	10.43	21.30	23.22	22.72	11.71	5.23	4.79	0.59	NA
2040-2069 (%)	2.28	13.38	25.25	26.29	18.60	7.58	5.66	0.95	NA
2070-2099 (%)	0.45	5.03	24.16	24.92	22.03	7.71	12.77	2.92	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	18.06	21.45	17.51	22.17	11.36	5.60	3.40	0.45	NA
2040-2069 (%)	0.38	8.03	22.27	32.00	16.22	6.16	13.27	1.67	0.00
2070-2099 (%)	0.04	1.41	10.29	8.95	13.73	7.05	36.44	22.09	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 47 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 78), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 28,005 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.



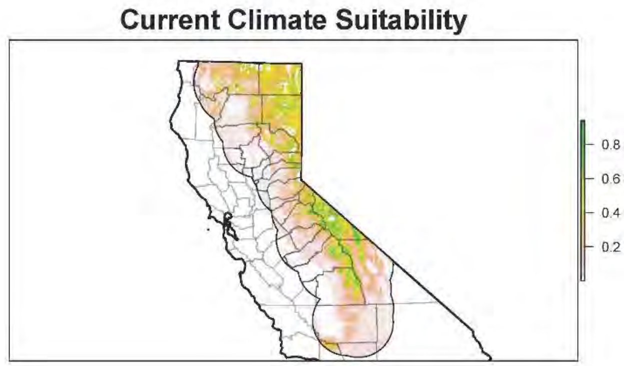


Figure 78. Map of Points Selected from the Extent of Macrogroup 47 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 47. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 47 (Figure 79). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 47, between 7,470 km^2 (27%) and 20,523 km^2 (73%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 7,482 km^2 (27%) and 20,535 km^2 (73%) will remain climatically suitable, and between 3,820 km^2 (14%) and 16,409 km^2 (59%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 45.

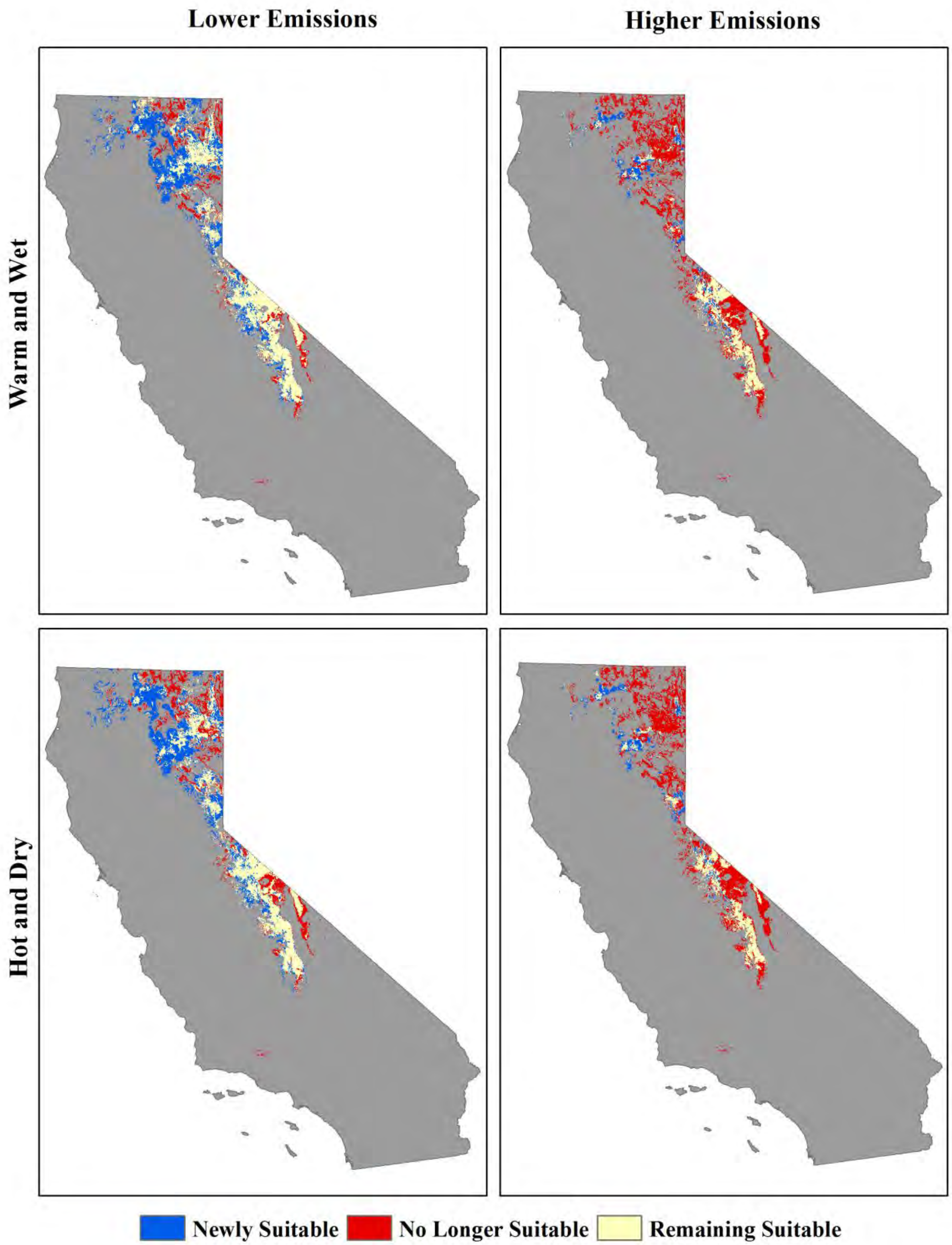


Figure 79. Maps of the Projected Climatically Suitable Range for Macrogroup 47. Maps showing the modeled climatically suitable range for macrogroup 47 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 45. Area of Projected Climatic Suitability for Macrogroup 47. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 47, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	7,470	20,535	16,409	27%	73%	59%
CNRM CM5 - RCP 8.5	19,364	8,642	3,996	69%	31%	14%
MIROC ESM - RCP 4.5	10,112	17,893	16,316	36%	64%	58%
MIROC ESM - RCP 8.5	20,523	7,482	3,820	73%	27%	14%

MG048: Macrogroup Western North American Temperate Grassland and Meadow
Common Name: Western Upland Grasslands

This macrogroup applies to vegetation dominated by grasses, which are typically not restricted to moisture conditions that are higher than the surrounding landscape (not seeps, riparian, or wet meadows). In general, these grasslands are also widespread outside of California in surrounding states with cool-temperate climatic conditions. This vegetation occurs in the hills and mountains of the north Coast Ranges, Klamath Mountains, lower montane Sierra Nevada, Modoc Plateau, Great Basin, and southward to the Transverse and Peninsular Ranges.

The vegetation included in this macrogroup includes native grasslands of Idaho fescue (*Festuca idahoensis*), Great Basin wild rye (*Elymus cinereus*), blue wild rye (*Elymus glaucus*), one-sided bluegrass (*Poa secunda*), etc. It also includes the non-native grasslands that are from cool temperate settings in Eurasia such as creeping bentgrass, velvet grass (*Holcus lanatus*), Kentucky bluegrass (*Poa pratensis*), and Harding grass (*Phalaris aquatica*). It also includes the cool-temperate annual non native cheat-grass (*Bromus tectorum*).

The best WHR fit is perennial grassland (PGS) at the macrogroup level, which would include coastal non-native perennial and native perennial upland grasslands. However, the annual cool upland grasses such as cheat-grass would be included in the annual grassland WHR habitat.

Macrogroup 48 is comprised of approximately one WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 178 km^2, shown classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 80). Using the current climate conditions for the extent of Macrogroup 48, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

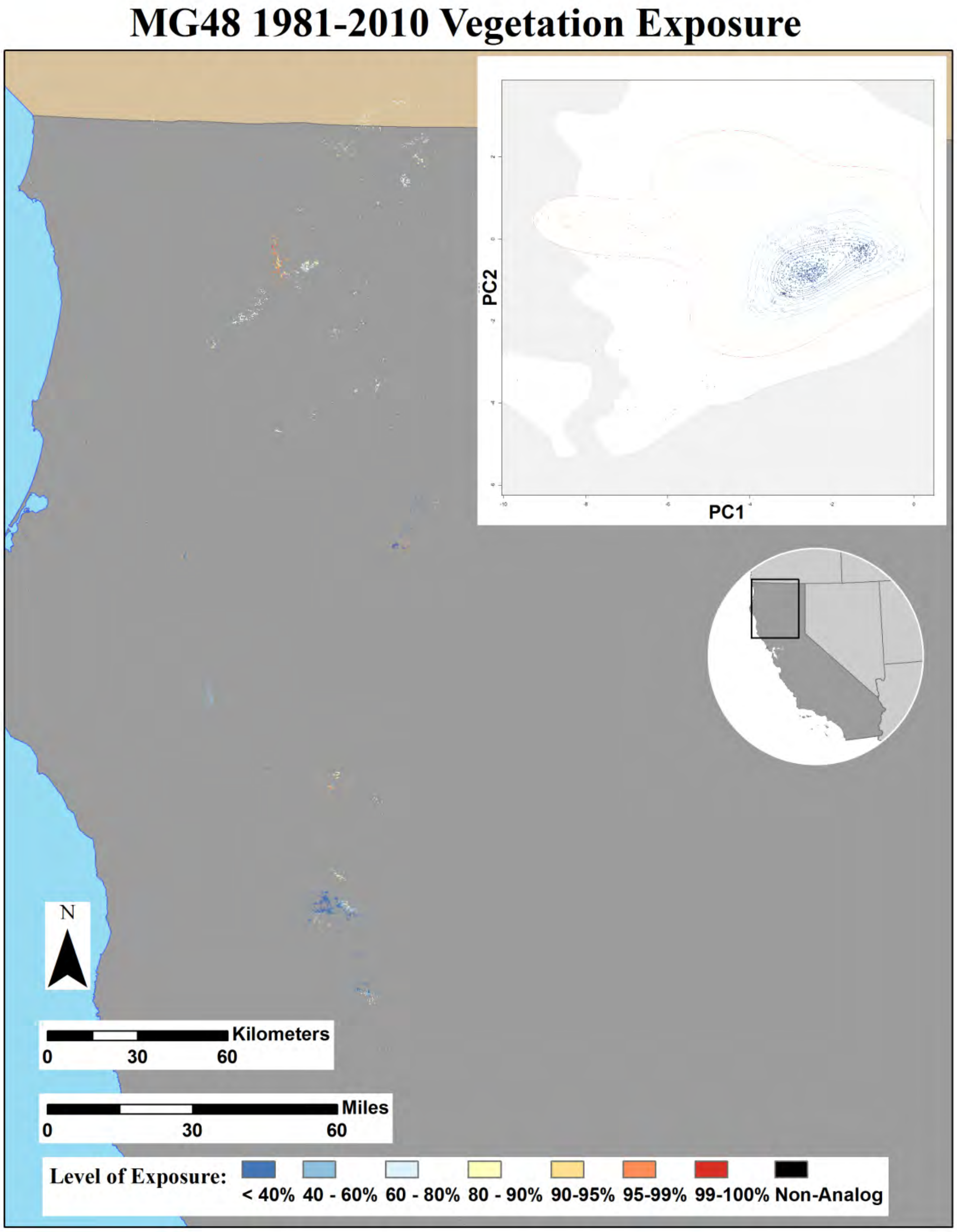


Figure 80. Map of Current Climate Suitability for Macrogroup 48. The 2015 mapped extent of macrogroup 48, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 48 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to

germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 46). The overall or grand mean for macrogroup 48 was found to be 2.58 for sensitivity and adaptive capacity.

Table 46. Sensitivity and Adaptive Capacity Rankings for Macrogroup 48. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 48.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
PGS - habitat level	3	3	4	3	3	3	4	3	3	**3.2**
Species										
Festuca idahoensis	3	2	1	3	2	1	1	3	3	**2.1**
Elymus glaucus	3	2	4	3	2	1	5	3	1	**2.7**
Poa secunda	3	2	1	3	4	1	1	3	3	**2.3**
Mean	**3.00**	**2.25**	**2.50**	**3.00**	**2.75**	**1.50**	**2.75**	**3.00**	**2.50**	
Grand Mean	**2.58**				**Mean**	**2.50**		**Mean**	**2.75**	

Projected Climate Exposure

The future climate exposure for macrogroup 48 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 81).

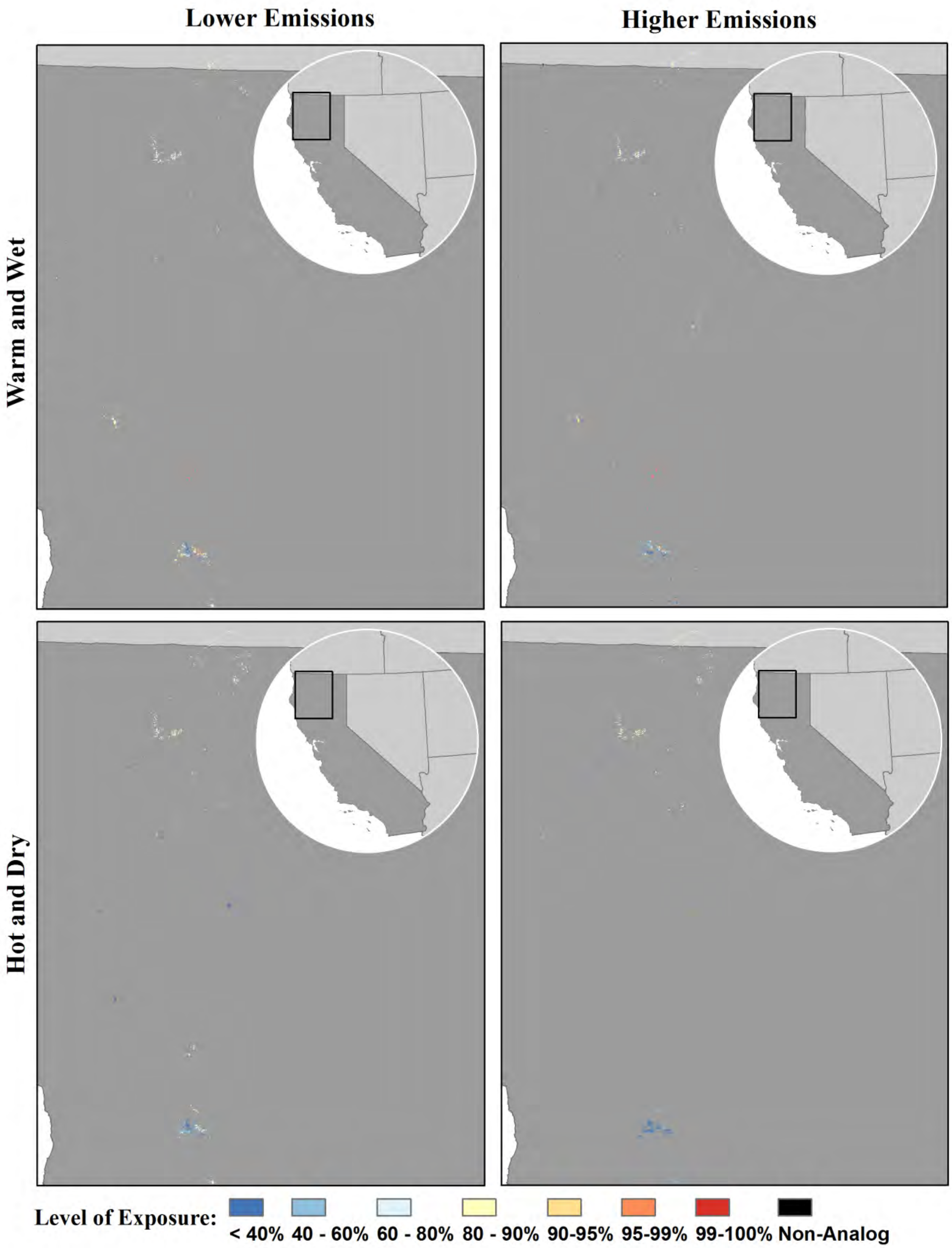


Figure 81. Maps of Projected Climate Exposure for Macrogroup 48. The climate exposure level for macrogroup 48 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 81 is derived from the PCA charts (Figure 82), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

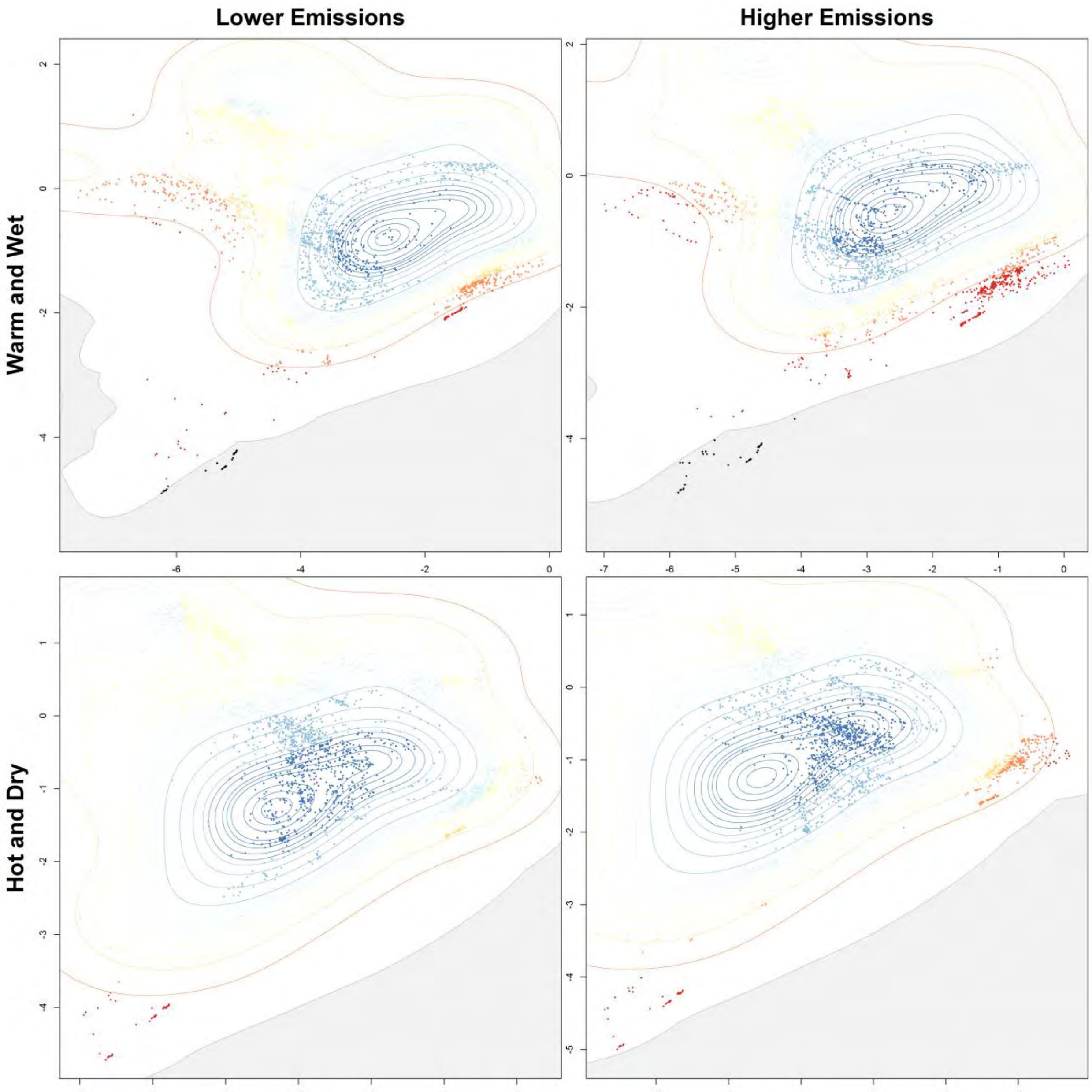


Figure 82. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 48. The PCA charts are two dimensional representations of climate exposure for macrogroup 48 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called “non-analog” conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 47). In the current time period, macrogroup 48 occupies 178 km^2. By the end of the century, there will be between 76 km^2 (43%) and 118 km^2 (67%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 4 km^2 (2%) and 47 km^2 (26%) of this type will be climatically exposed by the end of century.

Table 47. Percentage of the Current Extent of Macrogroup 48 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	36	35	36	36	18	9	7	2	0
1980-2010 (%)	20.06	19.81	20.06	20.02	10.05	5.00	3.98	0.98	0.04
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.58	4.27	16.65	36.59	25.35	7.71	4.68	2.17	0.00
2040-2069 (%)	4.27	6.19	19.48	32.12	25.96	5.17	4.63	2.17	0.00
2070-2099 (%)	1.76	5.41	22.93	12.59	30.19	7.71	14.48	3.53	1.39
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	2.21	3.40	17.43	31.75	28.51	9.80	4.72	2.17	0.00
2040-2069 (%)	3.94	6.15	25.14	17.56	32.28	6.77	6.03	1.56	0.57
2070-2099 (%)	5.09	10.54	24.08	11.12	16.65	6.23	7.63	16.74	1.93
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	4.14	5.25	30.19	32.08	22.81	2.71	0.86	1.97	NA
2040-2069 (%)	10.54	8.04	23.13	26.33	28.79	1.15	0.74	1.27	NA
2070-2099 (%)	9.68	15.18	19.28	22.40	28.63	2.67	0.33	1.85	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	3.32	4.18	29.00	29.45	28.84	2.13	1.31	1.76	NA
2040-2069 (%)	10.87	11.03	20.02	25.18	29.74	0.98	0.57	1.60	0.00
2070-2099 (%)	8.04	20.14	25.96	11.81	14.68	5.09	11.73	2.54	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 48 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 83), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 25,366 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

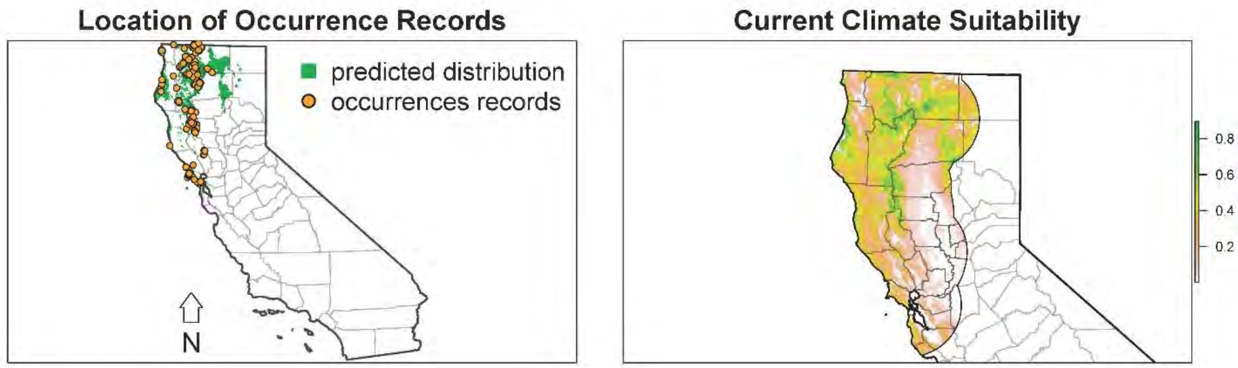


Figure 83. Map of Points Selected from the Extent of Macrogroup 48 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 48. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 48 (Figure 84). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 48, between 22,350 km^2 (88%) and 25,361 km^2 (100%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 6 km^2 (0%) and 3,016 km^2 (12%) will remain climatically suitable, and between 2 km^2 (0%) and 2,161 km^2 (9%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 48.

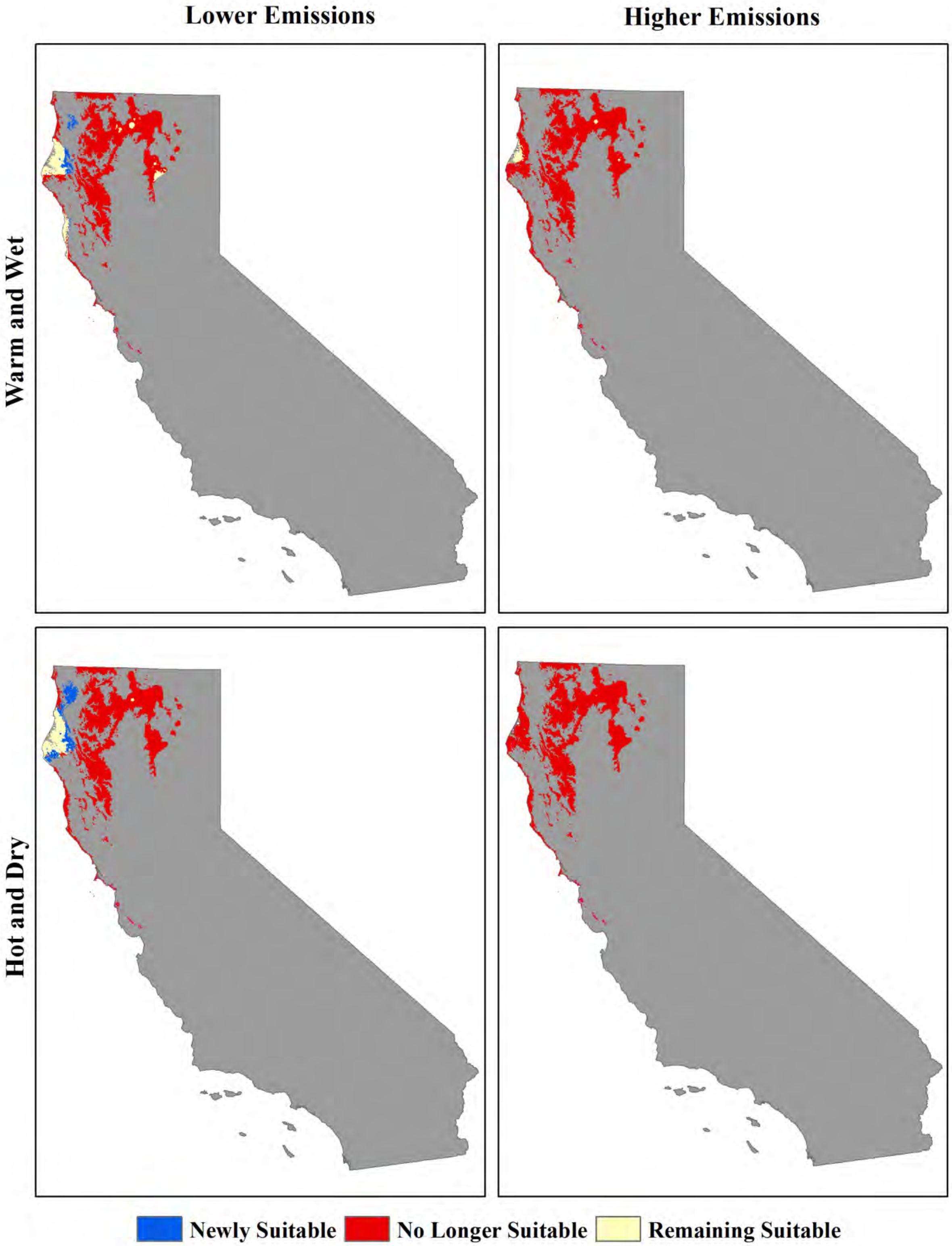


Figure 84. Maps of the Projected Climatically Suitable Range for Macrogroup 48. Maps showing the modeled climatically suitable range for macrogroup 48 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 48. Area of Projected Climatic Suitability for Macrogroup 48. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 48, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	22,350	3,016	922	88%	12%	4%
CNRM CM5 - RCP 8.5	24,765	601	2	98%	2%	0%
MIROC ESM - RCP 4.5	22,769	2,598	2,161	90%	10%	9%
MIROC ESM - RCP 8.5	25,361	6	3	100%	0%	0%

MG050: Macrogroup Vancouverian Lowland Grassland and Shrubland
Common Name: North Coast Deciduous Scrub and Terrace Prairie

This macrogroup includes a combination of grasses and shrubs, which tend to intermix in stands along the immediate coastal strip from central California to north of the Oregon border. Cool foggy summers and rainy winters, coupled with salty winds tend to preclude forest development along the immediate coast, but inland these stands only persist through regular disturbance such as clearing, grazing/browsing. Stands also commonly occur adjacent to upland Coastal Dune and Bluff Scrub. However, that macrogroup is characterized by more evergreen shrubs, which occur in well-drained exposed settings (exposed bluffs and dunes).

This macrogroup is dominated by mostly winter- deciduous shrubs in association with perennial cool-season grasses. Shrub indicators include: California blackberry (*Rubus ursinus*), thimbleberry (*Rubus parviflorus*), salmonberry (*Rubus spectabilis*), hazel (*Corylus cornuta*), and poison-oak (*Toxicodendron diversilobum*). Grasses include Pacific reedgrass (*Calamagrostis nutkatensis*), California oat-grass (*Danthonia californica*), red fescue, and tufted hair-grass (*Deschampsia cespitosa*). In most stands there is a combination of grasses and shrubs, but more regularly disturbed areas (grazed, salt-spray-blasted, etc.) tend to have grass dominance.

The closest WHR type for the grassy portions of this macrogroup is perennial grassland (PGS), while the shrublands are considered to be the WHR type coastal scrub.

Macrogroup 50 is comprised of approximately one WHR types for which we scored four representative dominant species. The statewide extent for the current time period cover 1,470 km^2, shown classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 85). Using the current climate conditions for the extent of Macrogroup 50, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

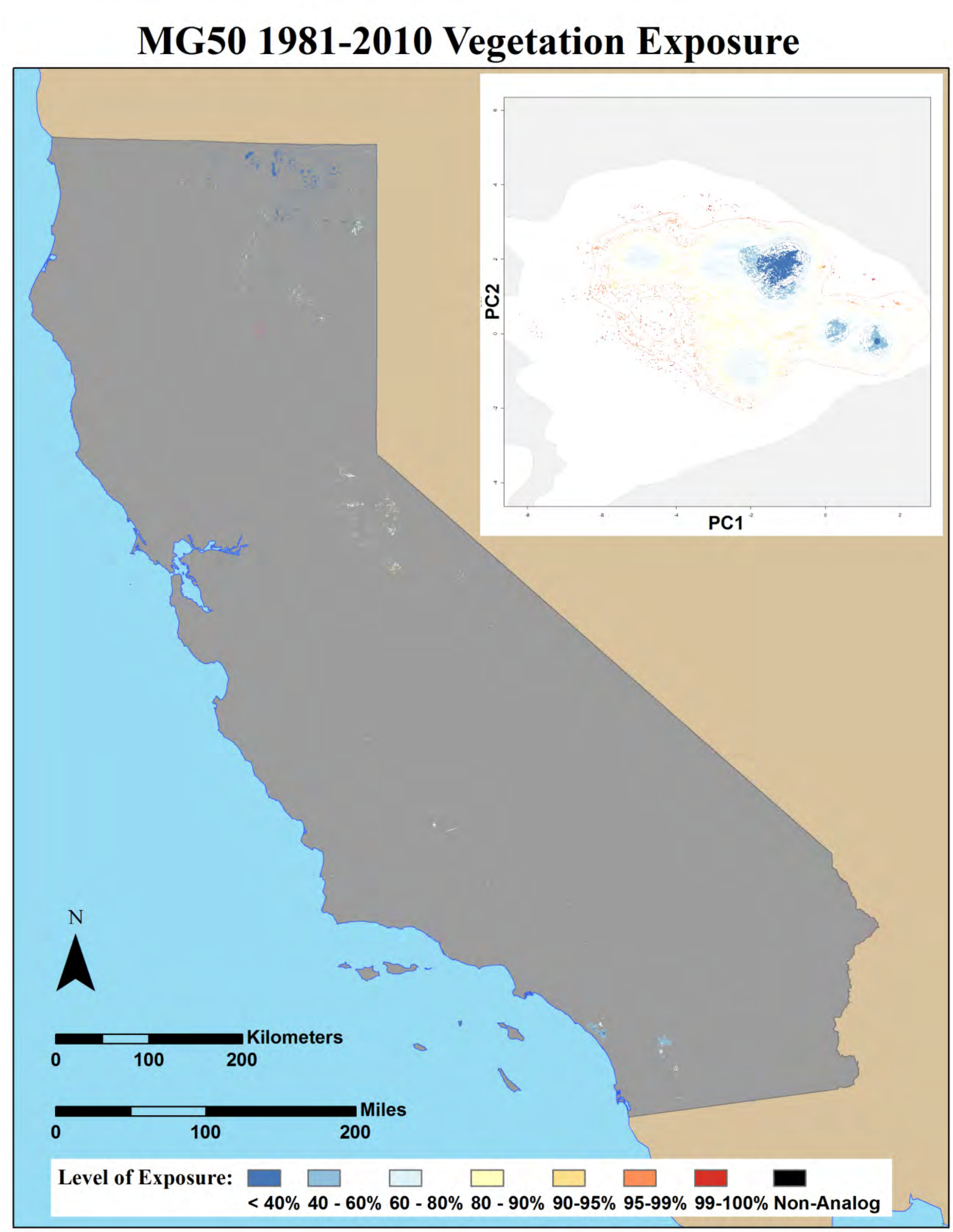


Figure 85. Map of Current Climate Suitability for Macrogroup 50. The 2015 mapped extent of macrogroup 50, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 50 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to

germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 49). The overall or grand mean for macrogroup 50 was found to be 2.97 for sensitivity and adaptive capacity.

Table 49. Sensitivity and Adaptive Capacity Rankings for Macrogroup 50. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 50.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Rubus ursinus	2	2	4	2	2	2	5	5	3	**3.0**
Rubus parviflorus	2	2	4	2	2	2	5	5	3	**3.0**
Toxicodendron diversilobum	2	2	4	3	2	3	5	5	1	**3.0**
Danthonia californica	3	2	4	3	4	1	5	3	1	**2.9**
Mean	**2.25**	**2.00**	**4.00**	**2.50**	**2.50**	**2.00**	**5.00**	**4.50**	**2.00**	
Grand Mean	**2.97**				**Mean**	**2.83**		**Mean**	**3.00**	

Projected Climate Exposure

The future climate exposure for macrogroup 50 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 86).

Figure 86. Maps of Projected Climate Exposure for Macrogroup 50. The climate exposure level for macrogroup 50 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 86 is derived from the PCA charts (Figure 87), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

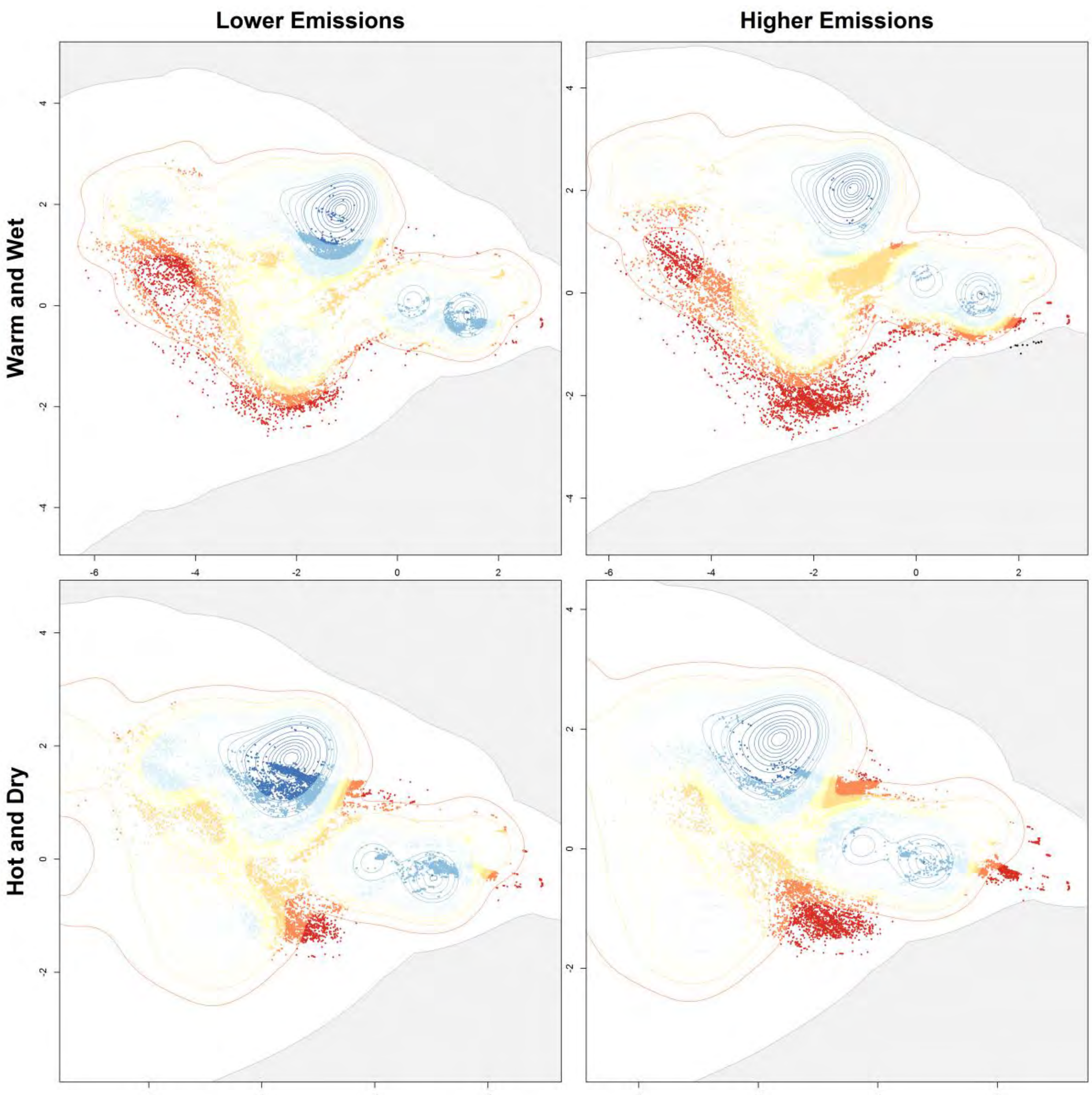


Figure 87. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 50. The PCA charts are two dimensional representations of climate exposure for macrogroup 50 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 50). In the current time period, macrogroup 50 occupies 1,470 km^2. By the end of the century, there will be between 99 km^2 (7%) and 875 km^2 (60%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 186 km^2 (13%) and 742 km^2 (50%) of this type will be climatically exposed by the end of century.

Table 50. Percentage of the Current Extent of Macrogroup 50 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	294	294	294	294	147	73	59	15	0
1980-2010 (%)	19.99	20.00	20.00	20.00	10.01	4.99	4.01	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	5.17	28.42	17.64	19.56	11.40	7.63	7.88	2.30	0.00
2040-2069 (%)	0.04	12.37	32.78	22.93	12.69	8.37	6.96	3.86	0.00
2070-2099 (%)	0.11	0.55	23.14	35.75	13.42	11.49	9.16	6.39	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.13	28.89	20.68	18.75	11.26	8.55	9.01	2.74	0.00
2040-2069 (%)	0.10	1.92	30.76	30.70	13.62	10.54	8.45	3.90	0.00
2070-2099 (%)	0.01	0.09	0.87	5.74	15.63	47.44	16.56	13.58	0.08
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	17.30	21.18	20.23	19.15	11.04	6.62	4.07	0.42	NA
2040-2069 (%)	2.21	12.11	29.46	22.88	15.87	11.89	3.70	1.87	NA
2070-2099 (%)	1.56	5.09	13.75	25.54	20.74	20.69	9.25	3.38	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	23.50	16.90	17.53	18.85	11.17	8.20	3.59	0.26	NA
2040-2069 (%)	1.27	7.03	19.03	29.92	18.75	14.49	6.60	2.91	0.00
2070-2099 (%)	0.00	0.49	4.32	12.82	17.05	14.83	32.48	18.01	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 50 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 88), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 62,197 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

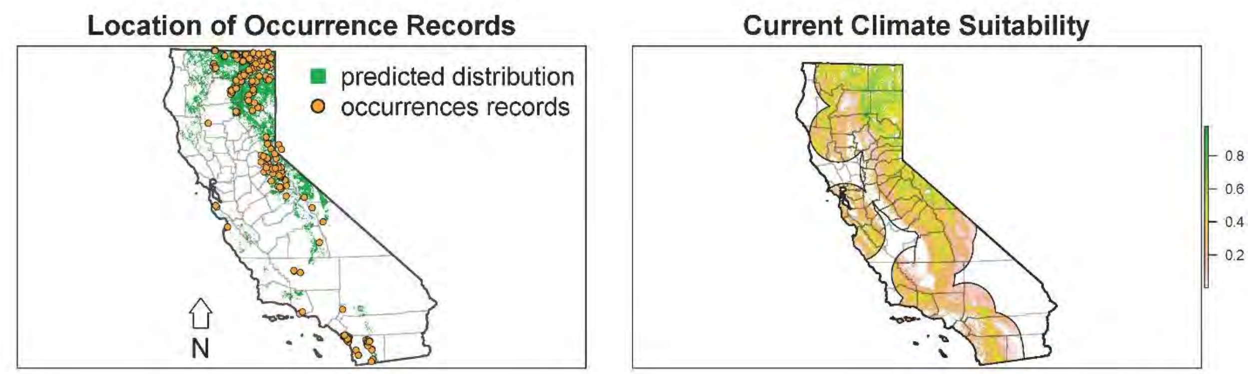


Figure 88. Map of Points Selected from the Extent of Macrogroup 50 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 50. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 50 (Figure 89). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 50, between 16,333 km^2 (26%) and 35,665 km^2 (57%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 26,532 km^2 (43%) and 45,864 km^2 (74%) will remain climatically suitable, and between 13,015 km^2 (21%) and 23,554 km^2 (38%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 51.

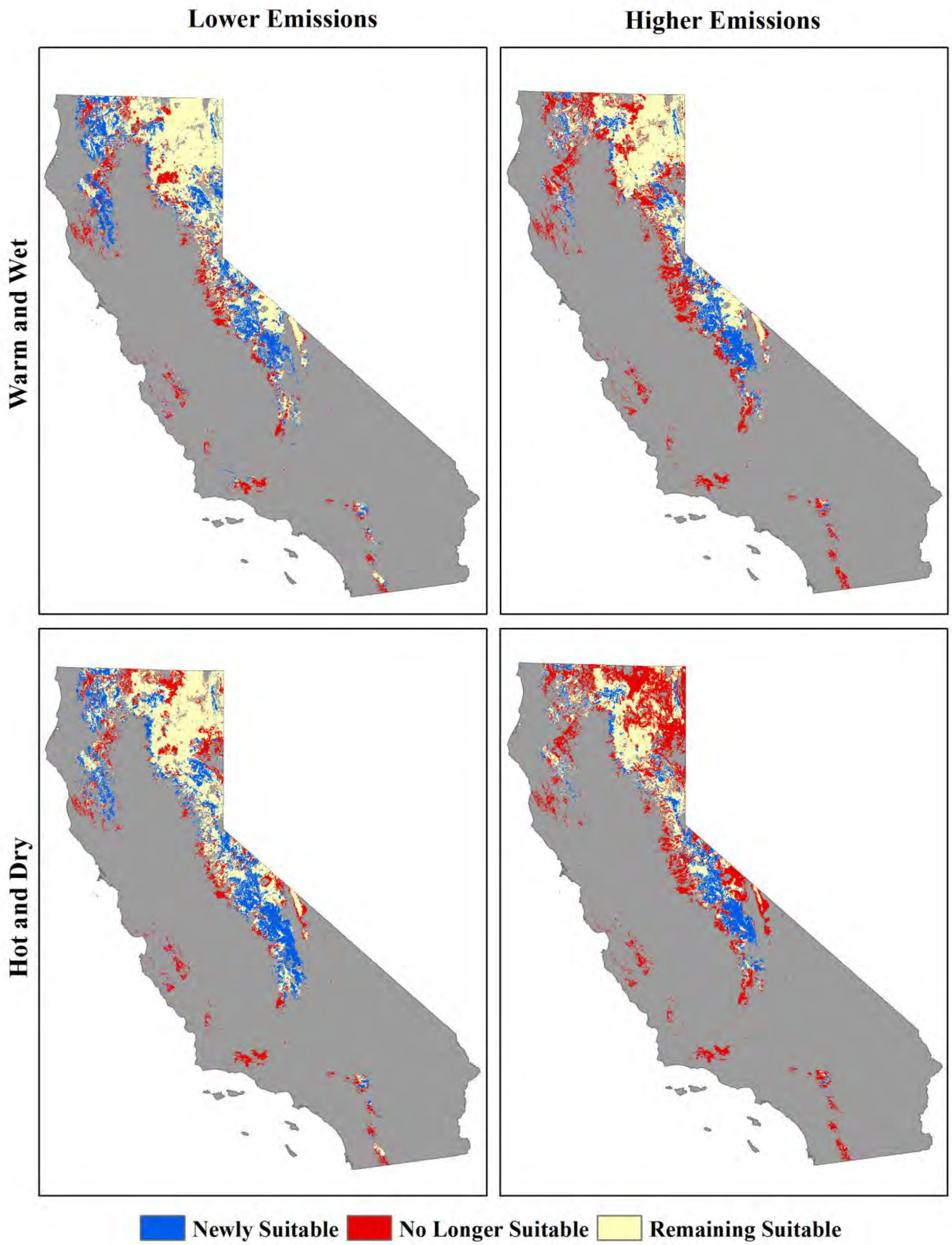


Figure 89. Maps of the Projected Climatically Suitable Range for Macrogroup 50. Maps showing the modeled climatically suitable range for macrogroup 50 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 51. Area of Projected Climatic Suitability for Macrogroup 50. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 50, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	16,333	45,864	21,095	26%	74%	34%
CNRM CM5 - RCP 8.5	25,006	37,191	14,297	40%	60%	23%
MIROC ESM - RCP 4.5	18,138	44,059	23,554	29%	71%	38%
MIROC ESM - RCP 8.5	35,665	26,532	13,015	57%	43%	21%

MG052 Cool Interior Chaparral Macrogroup [previously Macrogroup Western North American Cool/Montane Sclerophyllous Evergreen Scrub]
Common Name: Montane Chaparral

This macrogroup is characterized by sclerophyllous leaved shrubs with wider geographic range than California. Many occur throughout the western mountains to the Rockies. These are cold-adapted and occupy successional relationships to various coniferous forests on productive sites, or persist in rocky or other poor soil sites.

This macrogroup contains *Ceanothus cordulatus*, *C. velutinus*, *Arctostaphylos patula*, *A. nevadensis*, *Chrysolepis sempervirens*, and *Quercus vaccinifolia* dominated montane chaparrals. It does not include bittercherry (*Prunus emarginata*), ocean spray (*Holodiscus discolor*) or other taller winter deciduous shrub stands, which may occur near or adjacent to these evergreen stands

The single best WHR type at the macrogroup level is montane chaparral (MCP).

Macrogroup 52 is comprised of approximately one WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 6,257 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 90). Using the current climate conditions for the extent of Macrogroup 52, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

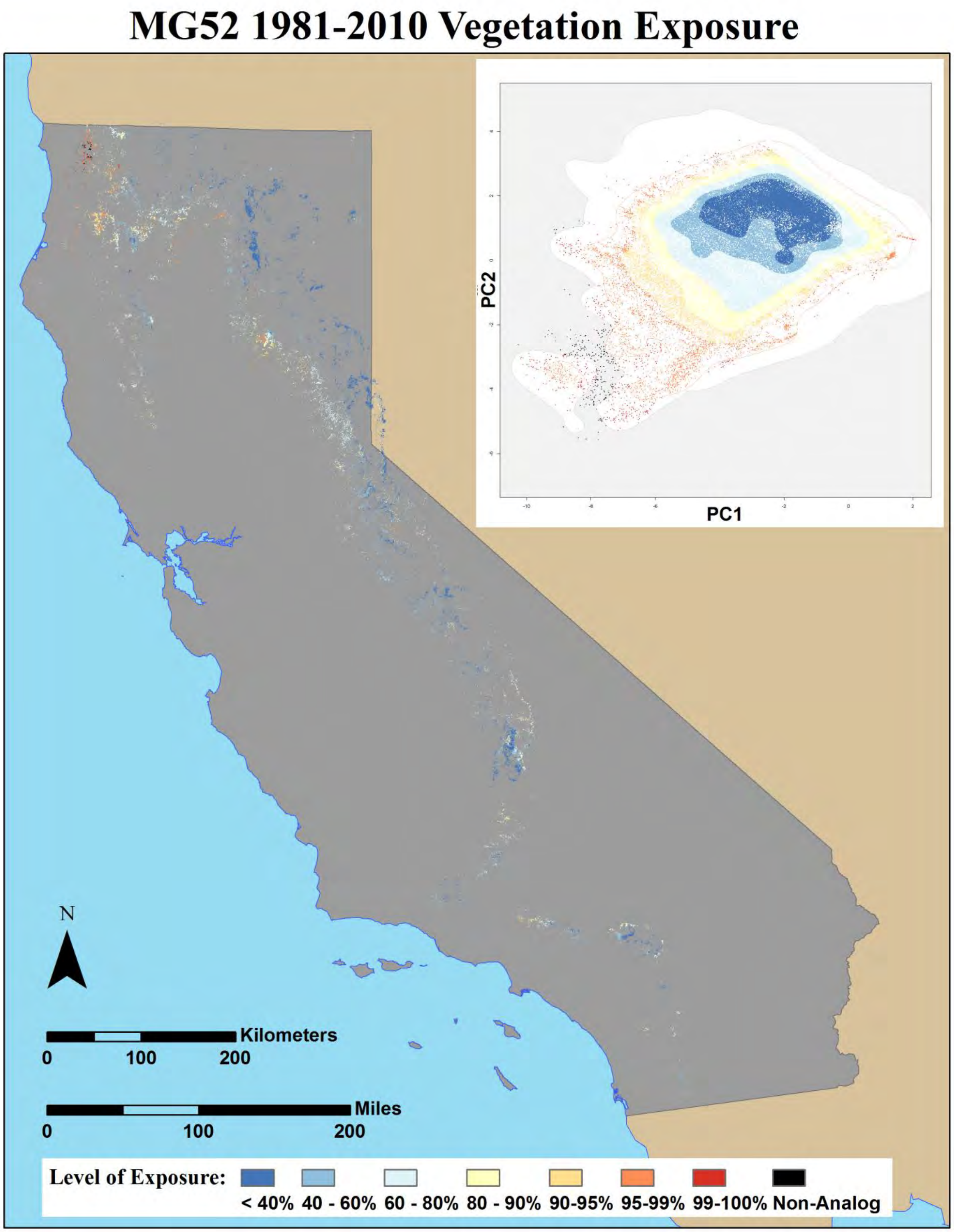


Figure 90. Map of Current Climate Suitability for Macrogroup 52. The 2015 mapped extent of macrogroup 52, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 52 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 52). The overall or grand mean for macrogroup 52 was found to be 2.96 for sensitivity and adaptive capacity.

Table 52. Sensitivity and Adaptive Capacity Rankings for Macrogroup 52. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 52.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Arctostaphylos patula	3	3	4	4	2	2	5	4	5	**3.6**
Ceanothus cordulatus	3	3	1	2	3	1	1	4	5	**2.7**
Chrysolepis sempervirens	2	3	4	3	2	2	5	1	3	**2.8**
Mean	**2.67**	**3.00**	**3.00**	**3.33**	**2.33**	**1.67**	**3.67**	**3.00**	**4.33**	
Grand Mean	**2.96**				**Mean**	**2.61**		**Mean**	**3.67**	

Projected Climate Exposure

The future climate exposure for macrogroup 52 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 91).

Figure 91. Maps of Projected Climate Exposure for Macrogroup 52. The climate exposure level for macrogroup 52 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 91 is derived from the PCA charts (Figure 92), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

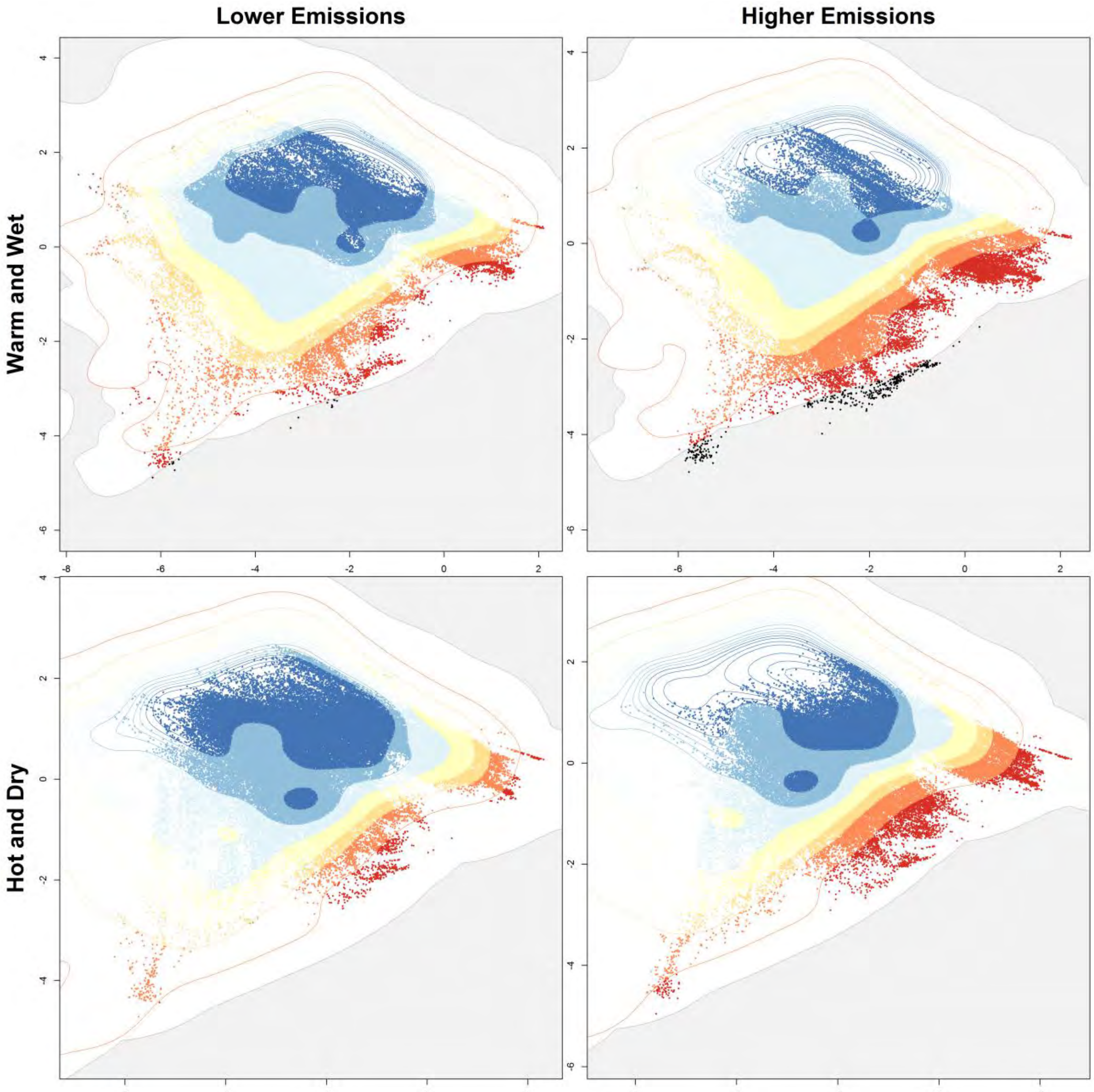


Figure 92. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 52. The PCA charts are two dimensional representations of climate exposure for macrogroup 52 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 53). In the current time period, macrogroup 52 occupies 6,257 km^2. By the end of the century, there will be between 3,706 km^2 (59%) and 5,392 km^2 (86%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 198 km^2 (3%) and 1,148 km^2 (18%) of this type will be climatically exposed by the end of century.

Table 53. Percentage of the Current Extent of Macrogroup 52 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1,252	1,251	1,251	1,252	626	313	251	45	17
1980-2010 (%)	20.00	19.99	19.99	20.00	10.00	5.00	4.01	0.72	0.27
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	11.50	26.25	24.40	24.07	7.74	3.12	2.44	0.48	0.00
2040-2069 (%)	10.51	24.68	28.22	23.51	6.88	2.70	2.96	0.55	0.00
2070-2099 (%)	7.27	15.51	30.77	24.97	10.87	4.51	4.53	1.54	0.02
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	10.57	24.43	26.70	24.59	8.00	2.98	2.32	0.41	0.00
2040-2069 (%)	8.82	18.24	30.01	24.79	9.32	3.79	3.90	1.14	0.00
2070-2099 (%)	1.69	6.10	19.76	31.69	14.30	8.11	11.42	6.48	0.45
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	17.31	35.28	25.60	15.31	4.56	1.06	0.84	0.04	NA
2040-2069 (%)	19.30	32.93	27.49	11.00	5.55	1.96	1.46	0.31	NA
2070-2099 (%)	15.96	28.36	29.46	12.39	7.25	3.41	2.39	0.78	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	18.87	36.88	25.67	12.45	4.32	0.96	0.83	0.02	NA
2040-2069 (%)	18.64	29.62	27.38	11.58	7.04	3.10	2.08	0.57	0.00
2070-2099 (%)	6.45	18.27	29.22	15.72	11.48	6.23	8.58	4.05	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 52 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 96), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 78,238 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

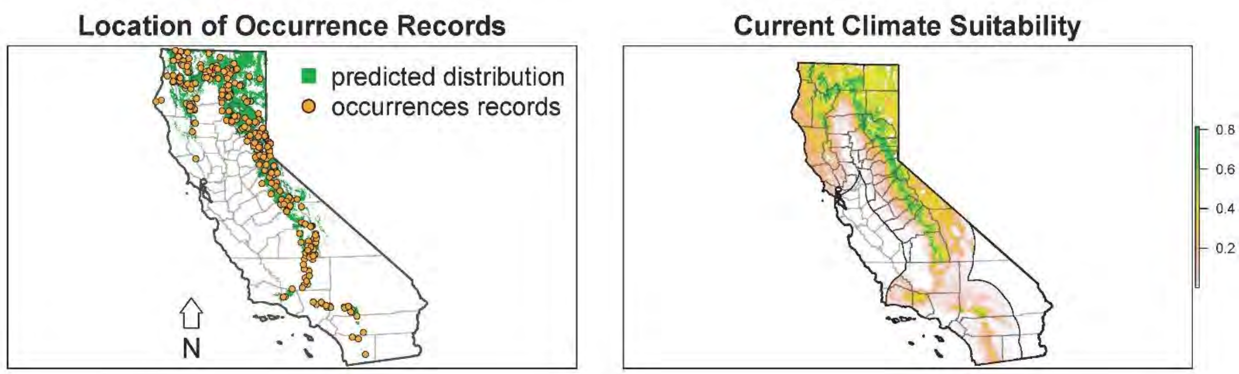


Figure 93. Map of Points Selected from the Extent of Macrogroup 52 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 52. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 52 (Figure 94). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 52, between 16,131 km^2 (21%) and 53,888 km^2 (69%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 24,350 km^2 (31%) and 62,107 km^2 (79%) will remain climatically suitable, and between 6,687 km^2 (9%) and 19,971 km^2 (26%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 54.

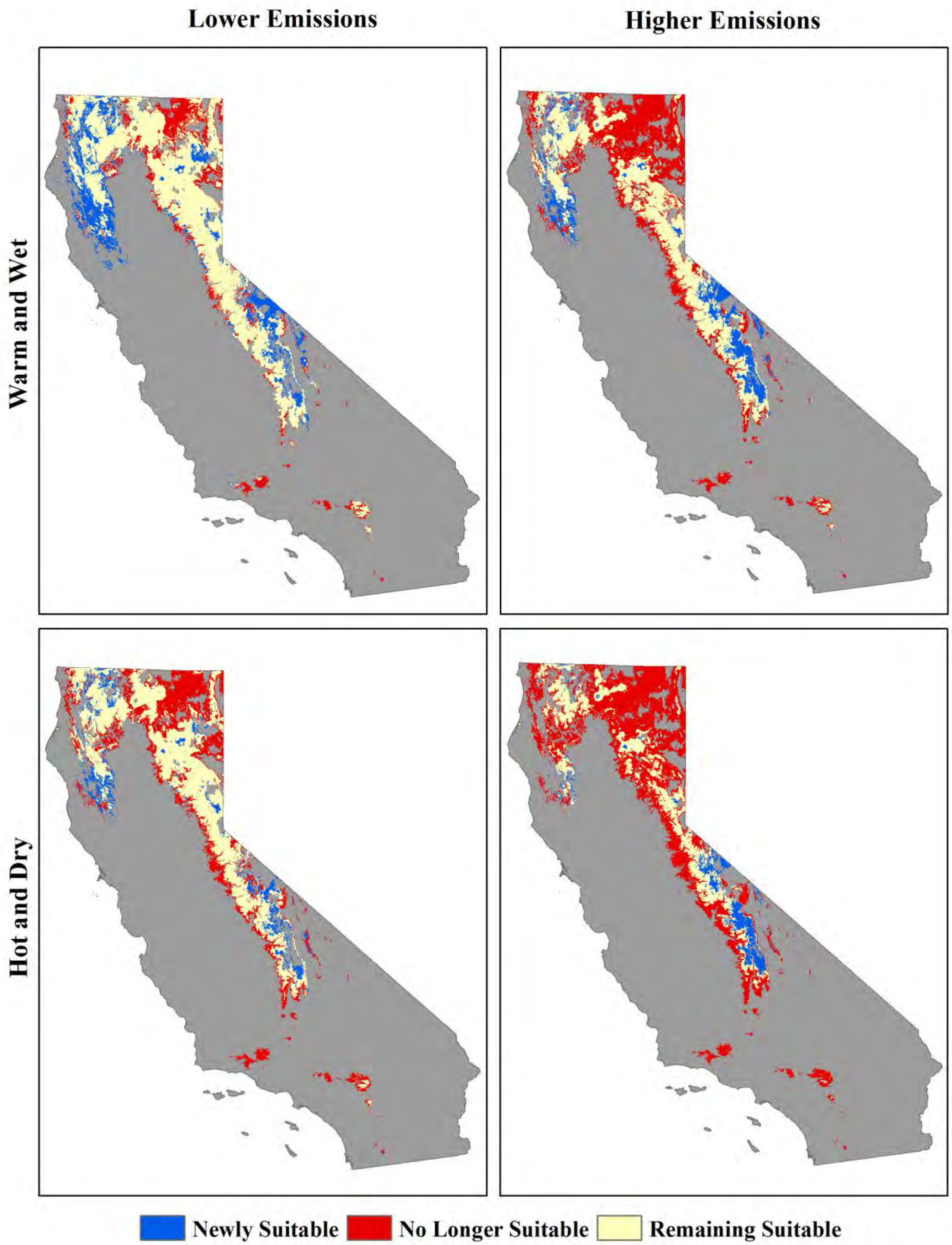


Figure 94. Maps of the Projected Climatically Suitable Range for Macrogroup 52. Maps showing the modeled climatically suitable range for macrogroup 52 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 54. Area of Projected Climatic Suitability for Macrogroup 52. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 52, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	16,131	62,107	19,971	21%	79%	26%
CNRM CM5 - RCP 8.5	37,029	41,209	13,102	47%	53%	17%
MIROC ESM - RCP 4.5	30,336	47,903	8,896	39%	61%	11%
MIROC ESM - RCP 8.5	53,888	24,350	6,687	69%	31%	9%

MG058: Macrogroup Vancouverian Coastal Dune and Bluff
Common Name: Coastal Dune and Bluff Scrub

Stands of coastal dune and bluff vegetation are limited to salty, rocky or sandy settings immediately adjacent to the open coast. Adaptations to salt spray, wind and shifting sands, result in several lifeforms including succulent or hairy leaves, long underground roots and stolons (adaptation to shifting sands), and good colonization of relatively unstable and sterile substrates.

Diagnostic species include the following shrubs: *Lupinus chamissonis*, *L. arboreus*, *Ambrosia chamissonis*, *Artemisia pycnocephala*, *Eriogonum latifolium*, etc. on coastal dunes and bluffs. Herbs such as live-forever (*Dudleya* spp.) and native succulents such as *Plantago maritima*, *Erigeron glauca*, (some non-native, some like ice-plant, *Carpobrotus* spp.) are present, and characteristic of some areas.

The single best WHR type is: coastal scrub (CSC), but that includes many south coastal sage scrub types, as well.

Macrogroup 58 is comprised of approximately one WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 400 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 95). Using the current climate conditions for the extent of Macrogroup 58, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

MG58 1981-2010 Vegetation Exposure

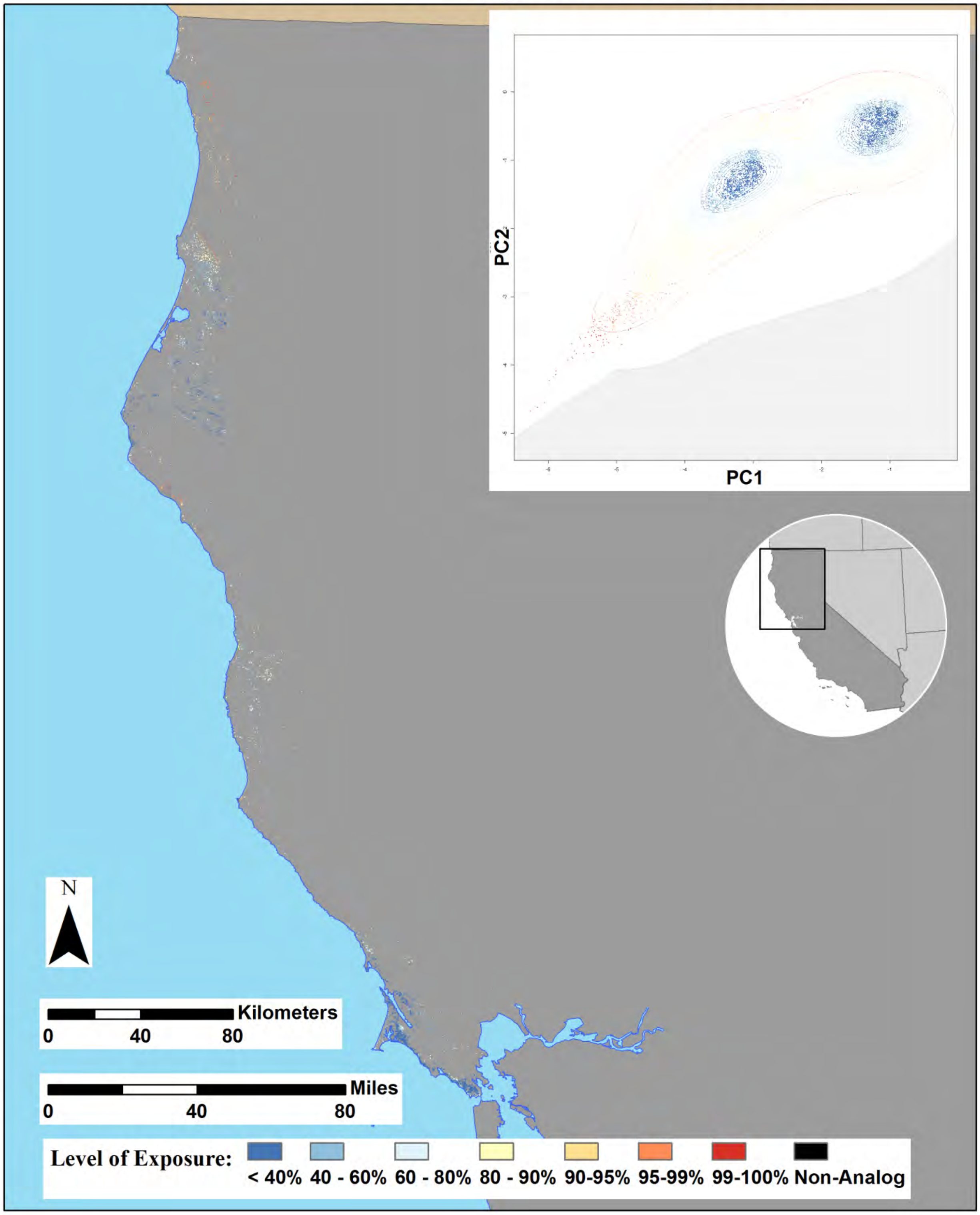


Figure 95. Map of Current Climate Suitability for Macrogroup 58. The 2015 mapped extent of macrogroup 58, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 58 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 55). The overall or grand mean for macrogroup 58 was found to be 2.41 for sensitivity and adaptive capacity.

Table 55. Sensitivity and Adaptive Capacity Rankings for Macrogroup 58. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 58. *Lupinus chamissonis* life history indicates underground structures, but does not specify sprouting after fire. *Ambrosia chamissonis* was not rated in the MCV life history tables, and *Plantago maritima* was used instead.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Lupinus chamissonis	3	3	2	3	3	3	1	2	5	**2.8**
Ambrosia chamissonis	3	2	1	2	3	2	2	1	1	**1.9**
Plantago maritima	3	2	1	3	3	2	1	3	5	**2.6**
Mean	**3.00**	**2.33**	**1.33**	**2.67**	**3.00**	**2.33**	**1.33**	**2.00**	**3.67**	
Grand Mean	**2.41**				**Mean**	**2.44**		**Mean**	**2.33**	

Projected Climate Exposure

The future climate exposure for macrogroup 58 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 96).

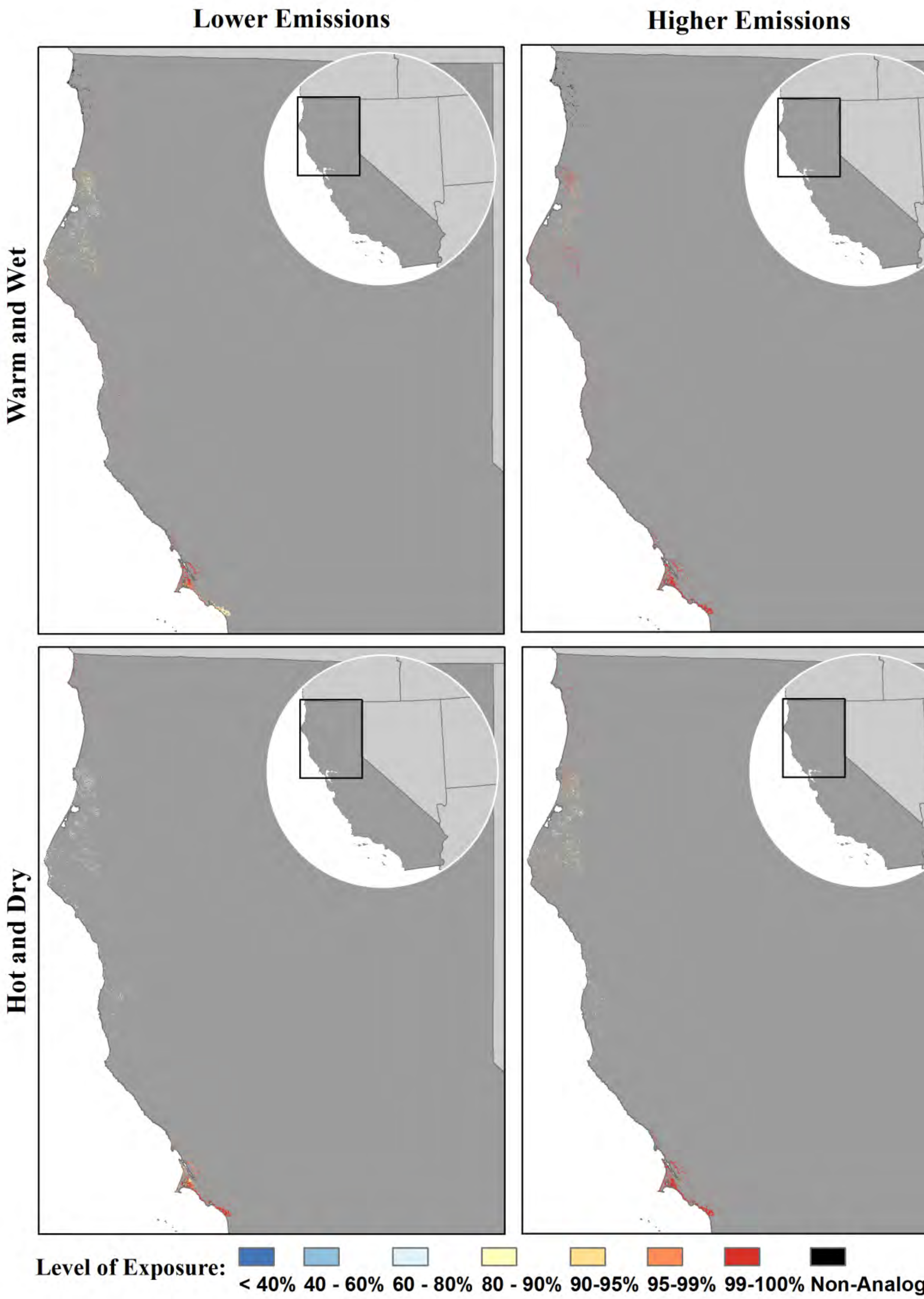


Figure 96. Maps of Projected Climate Exposure for Macrogroup 58. The climate exposure level for macrogroup 58 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 96 is derived from the PCA charts (Figure 97), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

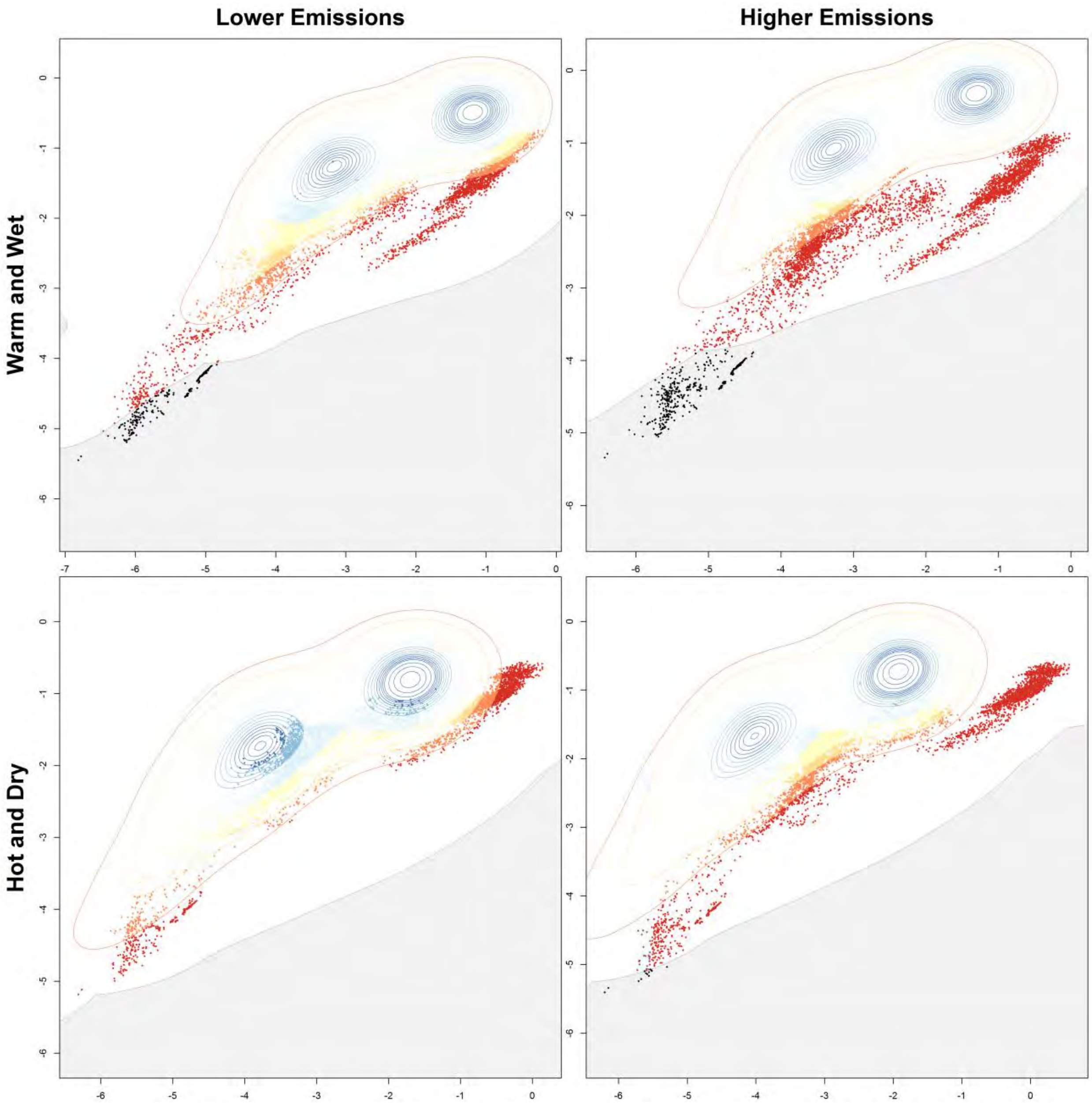


Figure 97. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 58. The PCA charts are two dimensional representations of climate exposure for macrogroup 58 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 56). In the current time period, macrogroup 58 occupies 400 km^2. By the end of the century, there will be between 0 km^2 (0%) and 163 km^2 (41%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 167 km^2 (42%) and 368 km^2 (92%) of this type will be climatically exposed by the end of century.

Table 56. Percentage of the Current Extent of Macrogroup 58 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	80	80	80	80	40	20	16	4	0
1980-2010 (%)	20.03	20.00	19.96	20.01	9.98	5.00	4.01	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.50	7.99	15.93	32.07	19.72	5.20	6.11	10.47	0.00
2040-2069 (%)	0.04	4.01	11.46	23.06	30.45	9.32	8.59	13.06	0.00
2070-2099 (%)	0.02	0.00	0.15	11.37	23.41	13.63	19.50	27.60	4.32
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.04	3.43	12.26	27.81	27.97	8.03	7.41	13.06	0.00
2040-2069 (%)	0.00	0.00	4.80	16.27	25.00	16.60	17.10	18.19	2.04
2070-2099 (%)	0.00	0.00	0.00	0.11	2.97	4.89	13.65	71.10	7.28
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	0.80	19.52	30.01	29.26	9.12	2.81	4.85	3.61	NA
2040-2069 (%)	1.50	9.21	19.34	21.95	12.53	6.42	16.66	12.39	NA
2070-2099 (%)	0.02	1.28	10.89	28.53	12.48	5.07	16.99	24.74	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	1.51	21.86	28.02	26.71	10.87	3.07	6.62	1.33	NA
2040-2069 (%)	1.06	4.49	16.91	26.44	9.30	5.31	11.95	24.54	0.00
2070-2099 (%)	0.00	0.00	0.13	3.69	20.11	12.19	13.01	50.65	0.24

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 58 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 98), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 38,407 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

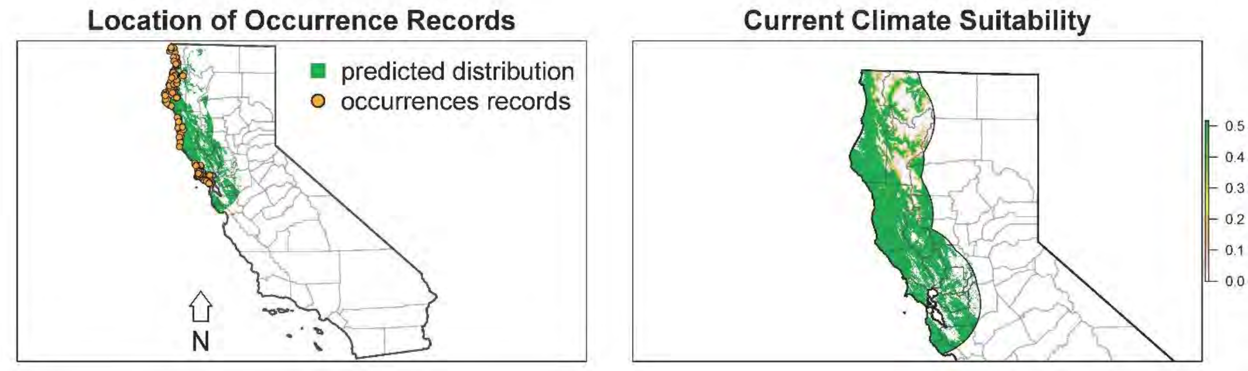


Figure 98. Map of Points Selected from the Extent of Macrogroup 58 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 58. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 58 (Figure 99). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 58, between 166 km^2 (0%) and 5,608 km^2 (15%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 32,799 km^2 (85%) and 38,241 km^2 (100%) will remain climatically suitable, and between 647 km^2 (2%) and 7,783 km^2 (20%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 57.

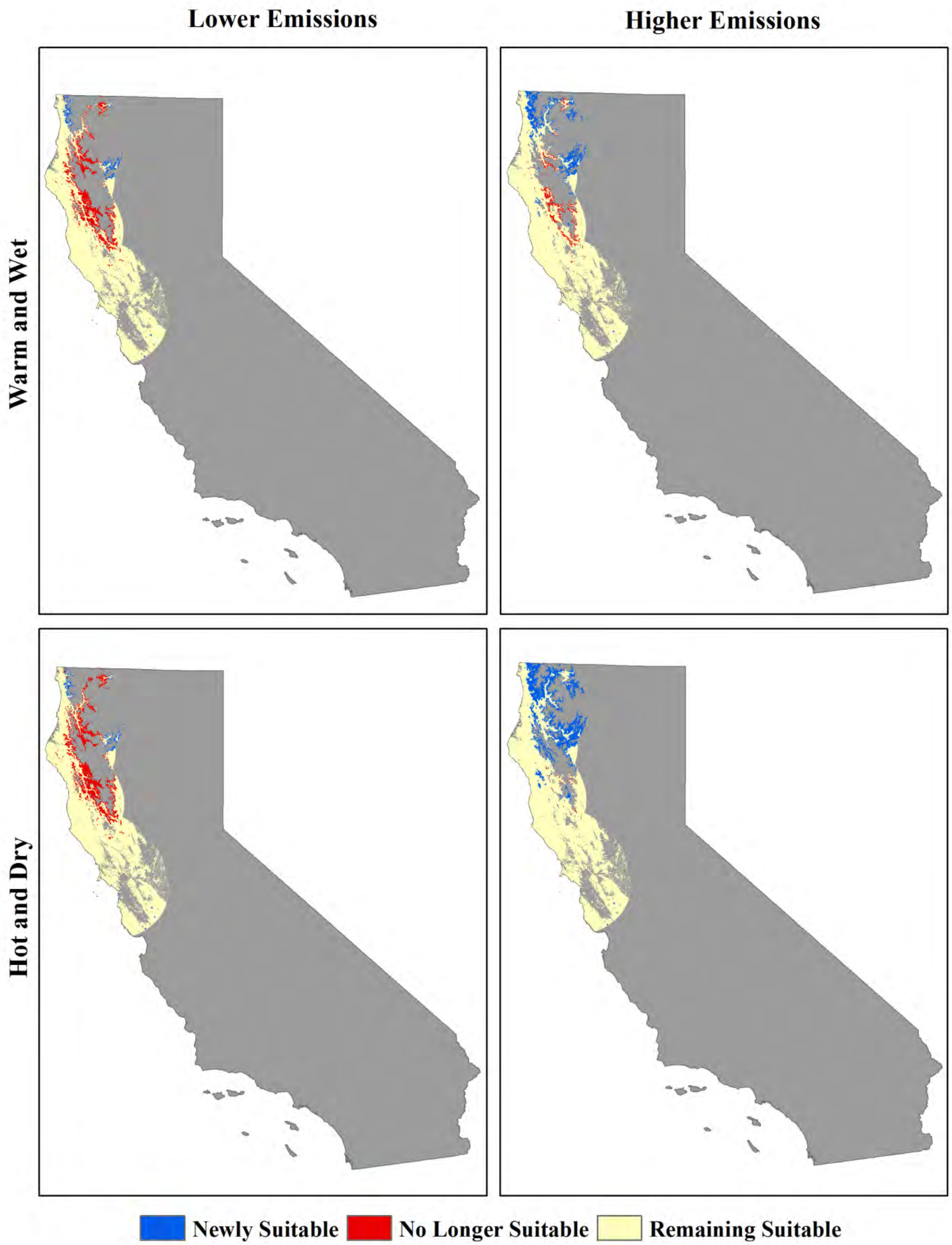


Figure 99. Maps of the Projected Climatically Suitable Range for Macrogroup 58. Maps showing the modeled climatically suitable range for macrogroup 58 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 57. Area of Projected Climatic Suitability for Macrogroup 58. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 58, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	4,760	33,646	1,027	12%	88%	3%
CNRM CM5 - RCP 8.5	1,688	36,719	3,681	4%	96%	10%
MIROC ESM - RCP 4.5	5,608	32,799	647	15%	85%	2%
MIROC ESM - RCP 8.5	166	38,241	7,783	0%	100%	20%

MG073: Macrogroup Western North American Freshwater Marsh
Common Name: Freshwater Marsh

Fresh water is present throughout all or most of the growing season, and species are widespread and tend to be tall emergent forms at lower elevations. But when water depth is > 1 m most vegetation is either anchored or floating hydrophytes (water lilies, duckweed, pondweed, etc.).

Tall bulrushes (*Schoenoplectus*), cattails, common reed (*Phragmites*), and several sedge (*Carex*) and other northwest coastal wetland species are typical and characteristic. If water is deeper, vegetation is dominated by anchored or floating hydrophytes (water lilies, duckweed, pondweed, burr reed, etc.).

Fresh emergent wetland (FEW) is the best single fit for WHR type at the macrogroup level.

Macrogroup 73 is comprised of approximately one WHR types for which we scored two representative dominant genera. The statewide extent for the current time period cover 1,284 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 100). Using the current climate conditions for the extent of Macrogroup 73, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

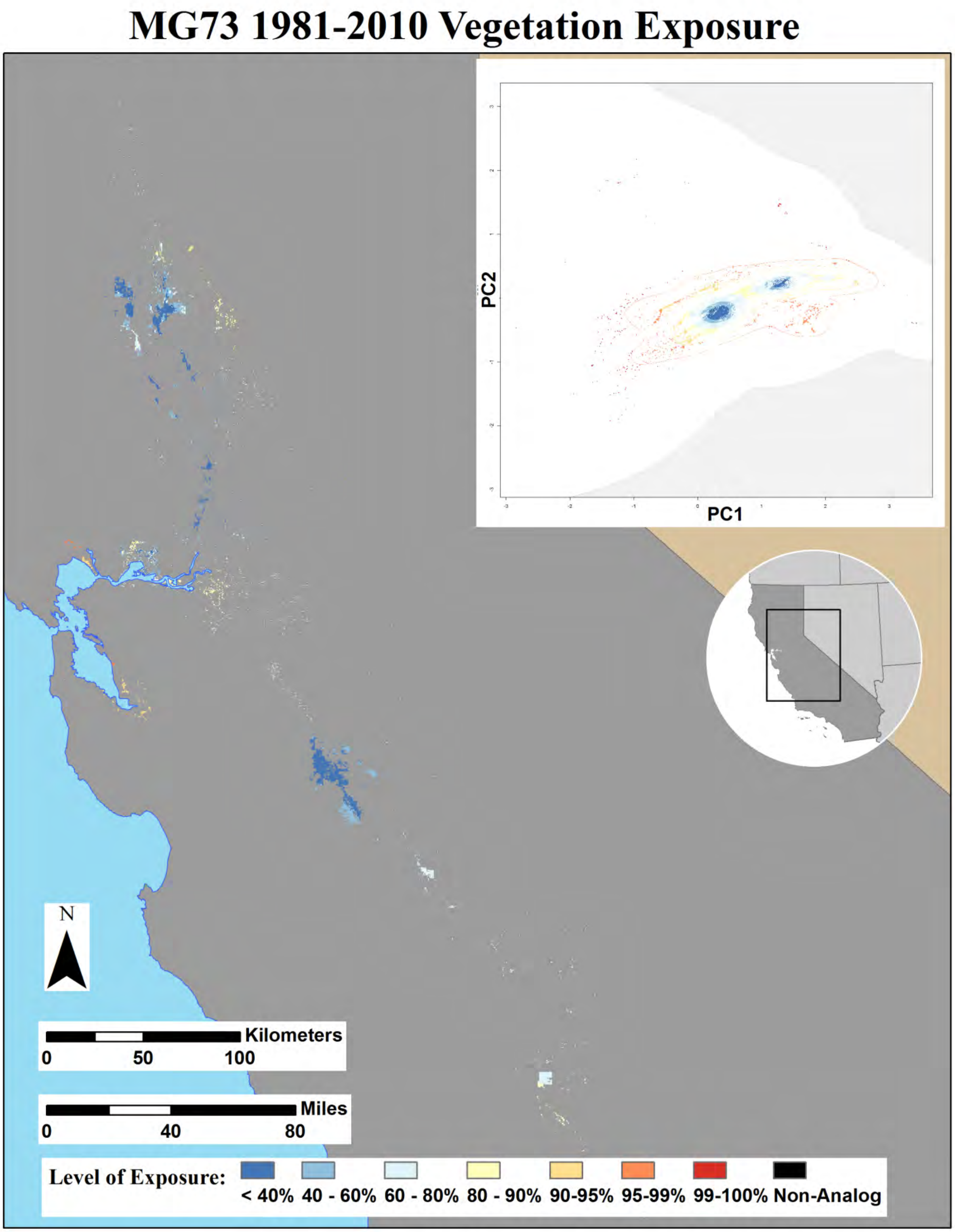


Figure 100. Map of Current Climate Suitability for Macrogroup 73. The 2015 mapped extent of macrogroup 73, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 73 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 58). The overall or grand mean for macrogroup 73 was found to be 3.00 for sensitivity and adaptive capacity.

Table 58. Sensitivity and Adaptive Capacity Rankings for Macrogroup 73. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 73.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Eleocharis sp	2	2	4	2	3	1	5	1	5	**2.8**
Schoenoplectus sp	2	2	4	2	3	1	5	5	5	**3.2**
Mean	**2.00**	**2.00**	**4.00**	**2.00**	**3.00**	**1.00**	**5.00**	**3.00**	**5.00**	
Grand Mean	**3.00**				**Mean**	**2.33**		**Mean**	**4.33**	

Projected Climate Exposure

The future climate exposure for macrogroup 73 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 101).

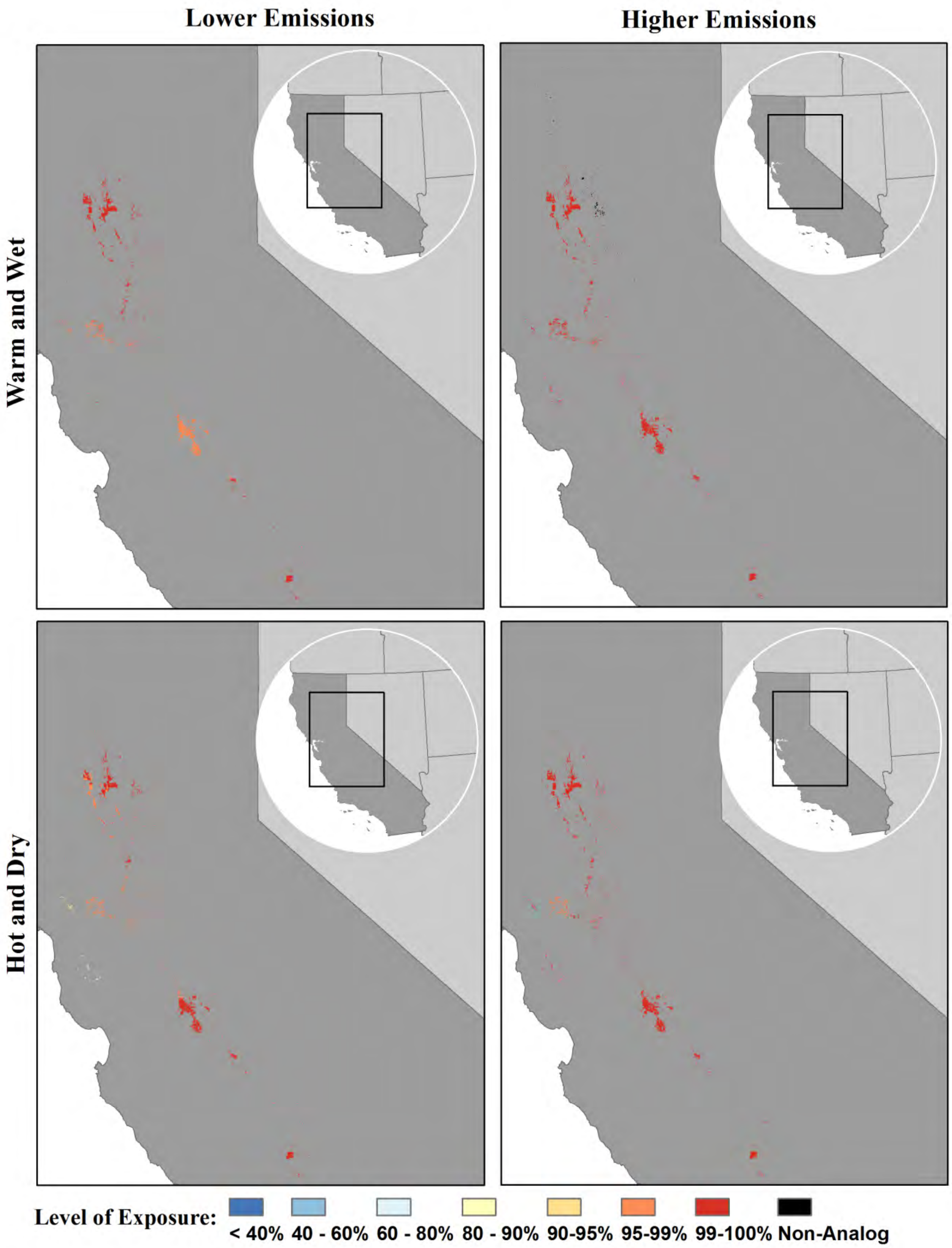


Figure 101. Maps of Projected Climate Exposure for Macrogroup 73. The climate exposure level for macrogroup 73 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 101 is derived from the PCA charts (Figure 102), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

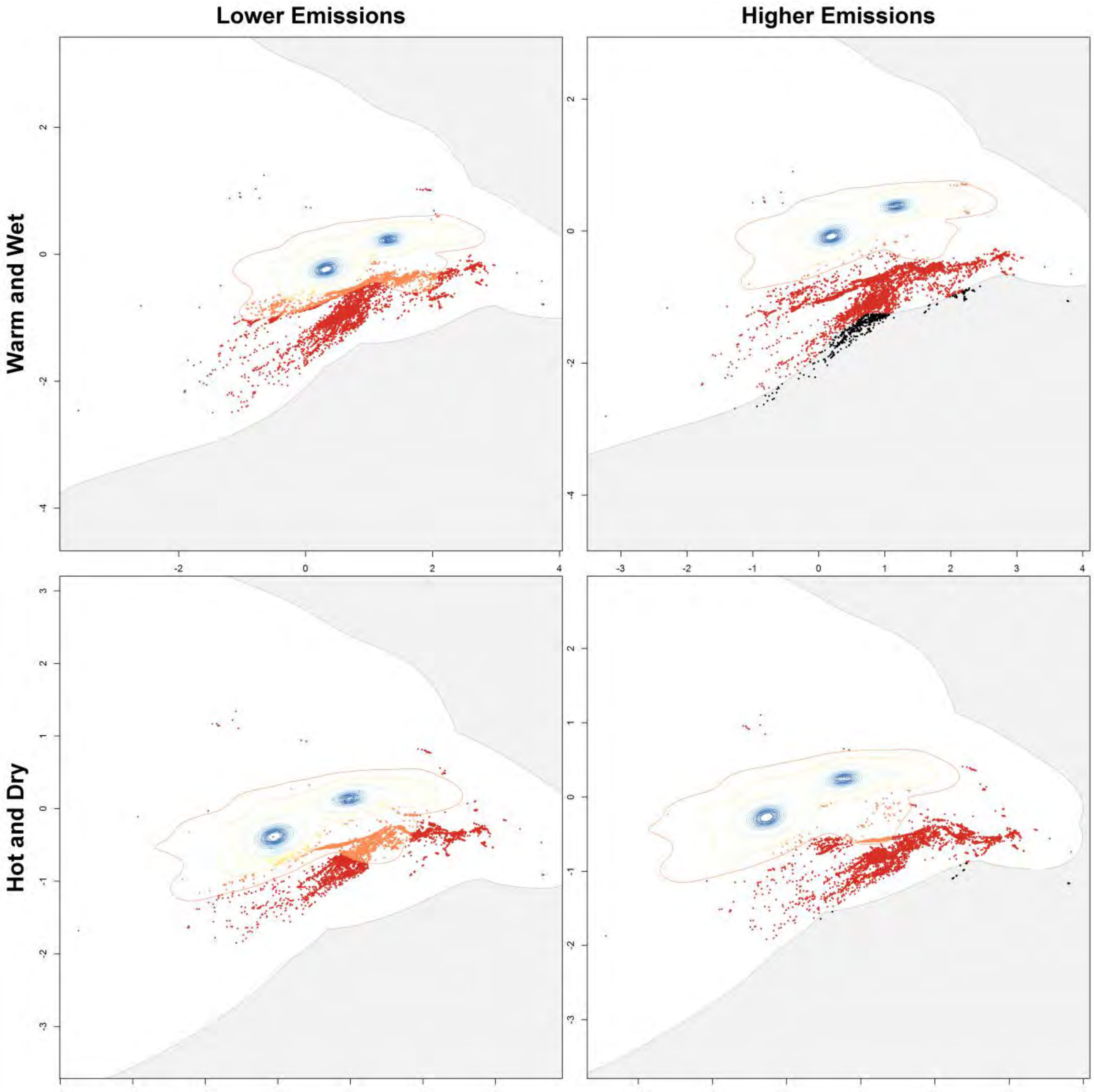


Figure 102. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 73. The PCA charts are two dimensional representations of climate exposure for macrogroup 73 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 59). In the current time period, macrogroup 73 occupies 1,284 km^2. By the end of the century, there will be between 0 km^2 (0%) and 15 km^2 (1%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,237 km^2 (96%) and 1,283 km^2 (100%) of this type will be climatically exposed by the end of century.

Table 59. Percentage of the Current Extent of Macrogroup 73 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	257	257	257	257	128	64	51	13	0
1980-2010 (%)	20.02	20.01	20.01	20.02	10.00	4.96	3.99	0.98	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	0.01	1.70	2.64	4.62	4.93	15.82	55.55	14.74	0.00
2040-2069 (%)	0.03	0.02	0.06	1.89	4.67	5.90	45.74	41.68	0.00
2070-2099 (%)	0.03	0.01	0.01	0.15	0.15	0.37	40.39	58.88	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.03	0.02	2.19	5.47	3.53	10.98	60.07	17.72	0.00
2040-2069 (%)	0.03	0.01	0.01	0.20	0.27	2.11	42.63	54.73	0.00
2070-2099 (%)	0.00	0.00	0.00	0.00	0.01	0.02	0.34	94.95	4.70
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	1.95	1.68	2.23	20.50	20.03	32.10	19.09	2.43	NA
2040-2069 (%)	1.12	0.72	1.16	0.52	0.48	1.41	69.83	24.76	NA
2070-2099 (%)	0.01	0.03	0.05	1.04	1.08	1.39	32.98	63.41	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	0.79	1.11	3.84	23.83	19.19	28.24	19.58	3.42	NA
2040-2069 (%)	0.12	0.10	0.52	2.13	0.64	0.36	50.52	45.61	0.00
2070-2099 (%)	0.00	0.00	0.00	0.01	0.01	0.02	7.62	92.22	0.12

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 73 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 103), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 45,005 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

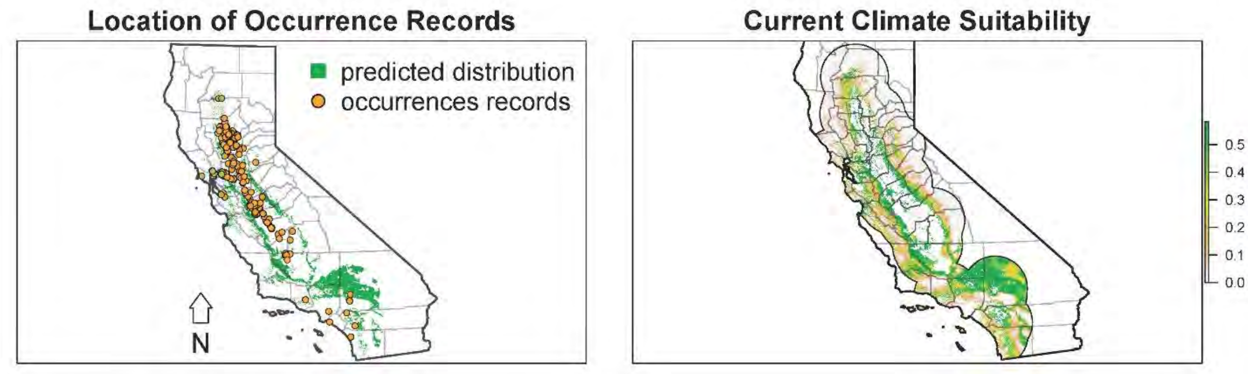


Figure 103. Map of Points Selected from the Extent of Macrogroup 73 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 73. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 73 (Figure 104). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 73, between 32,080 km^2 (71%) and 43,561 km^2 (97%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 1,444 km^2 (3%) and 12,925 km^2 (29%) will remain climatically suitable, and between 3,943 km^2 (9%) and 24,164 km^2 (54%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 60.

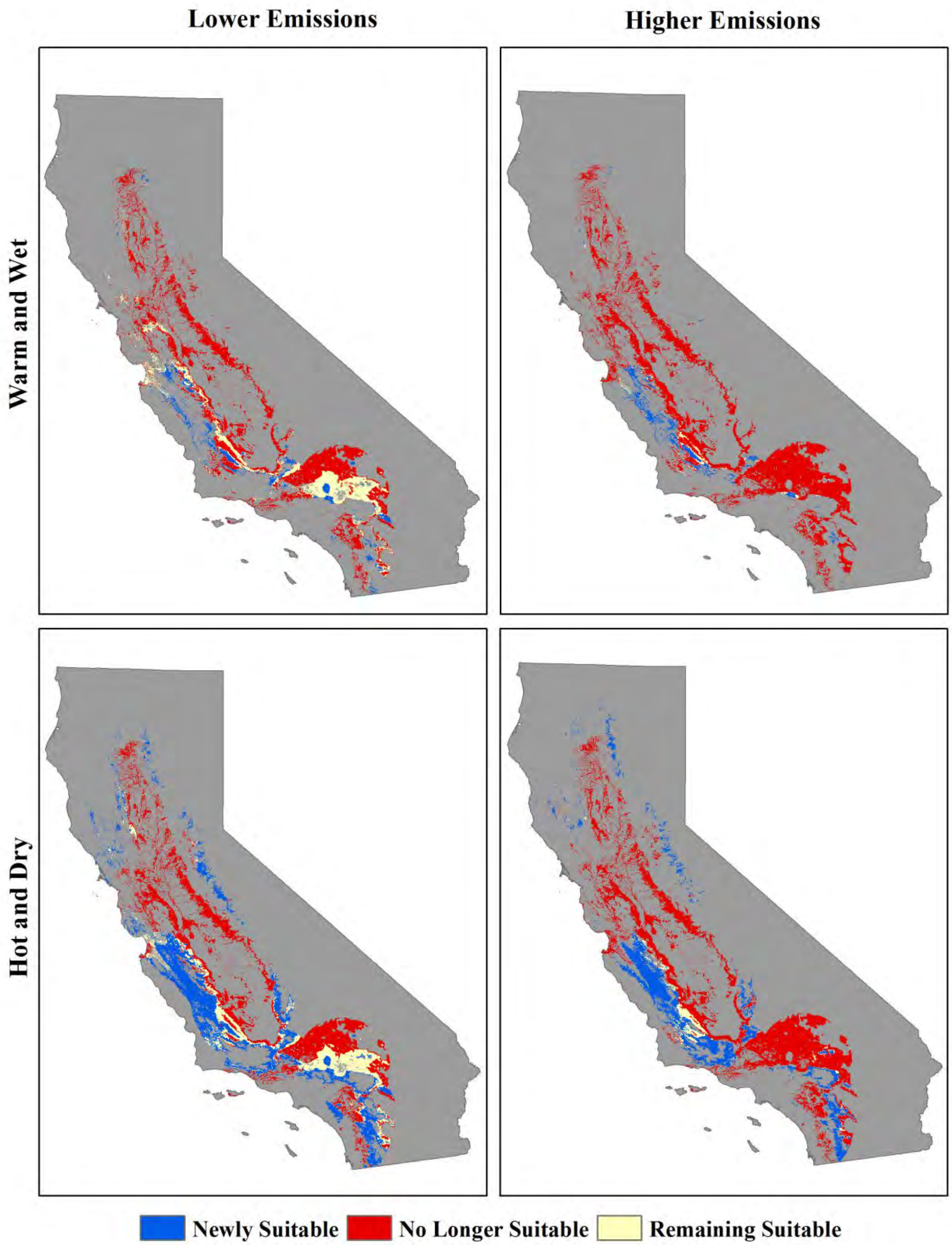


Figure 104. Maps of the Projected Climatically Suitable Range for Macrogroup 73. Maps showing the modeled climatically suitable range for macrogroup 73 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 60. Area of Projected Climatic Suitability for Macrogroup 73. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 73, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	33,411	11,594	4,914	74%	26%	11%
CNRM CM5 - RCP 8.5	43,561	1,444	3,943	97%	3%	9%
MIROC ESM - RCP 4.5	32,080	12,925	24,164	71%	29%	54%
MIROC ESM - RCP 8.5	41,915	3,090	17,337	93%	7%	39%

MG075: Macrogroup Western North America Wet Meadow and Low Shrub
Common Name: Wet Mountain Meadow

Wet meadows are typical of low lying sites in the mountains and in some lower elevation valleys and depressions. Saturated soil or standing water through the growing season are key characteristics. Long-persisting standing water tends to convert sites to Macrogroup 73: Western North American Freshwater Marsh. Many wet meadow vegetation types occur in the mountainous areas of the state where cool snowy winters and short growing seasons prevail. However, there is a warmer winter lower elevation analog, and also one with invasive exotic species. This macrogroup is widespread throughout the state wherever freshwater meadows and seeps occur.

Species from several habitats are representative of this group. From the Western Cordilleran Montane-Boreal Summer-Saturated Meadow macrogroup (online as MG 168[25]), these species include: *Bistorta bistortoides*, *Mimulus primuloides*, *Camassia quamash*, *Carex* (*aquatilis, lenticularis*), *Carex nigricans*, *Carex scopulorum*, *Carex simulata*, *Carex* (*utriculata, vesicaria*), *Eleocharis quinqueflora*, *Glyceria* (*elata*, *striata*), *Glyceria occidentalis*, *Oxypolis occidentalis*, *Senecio triangularis*, and *Torreyochloa pallida*. From Californian Warm Temperate Marsh/Seep habitats, species include *Carex barbarae*, *Carex densa*, *Carex nudata*, *Carex serratodens*, *Cirsium fontinale*, *Juncus arcticus* (var. *balticus*, *mexicana*), Juncus (*oxymeris*, *xiphioides*), *Leymus triticoides*, *Mimulus guttatus*, and *Muhlenbergia rigens*. And, from Naturalized Warm-Temperate Riparian and Wetland habitats, are included semi-natural stands of *Lepidium latifolium*, *Persicaria lapathifolia*, and *Xanthium strumarium*.

Wet meadow (WTM) is the single best WHR analog, but this macrogroup is very wet compared to Macrogroup 73: Western North American Freshwater Marsh.

Macrogroup 75 is comprised of approximately one WHR type which we scored by habitat, for four representative dominant species, and for two representative genera. The statewide extent for the current time period cover 84 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 105). Using the current climate conditions for the extent of Macrogroup 75, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

[25] http://www1.usgs.gov/csas/nvcs/nvcsGetUnitDetails?elementGlobalId=860608

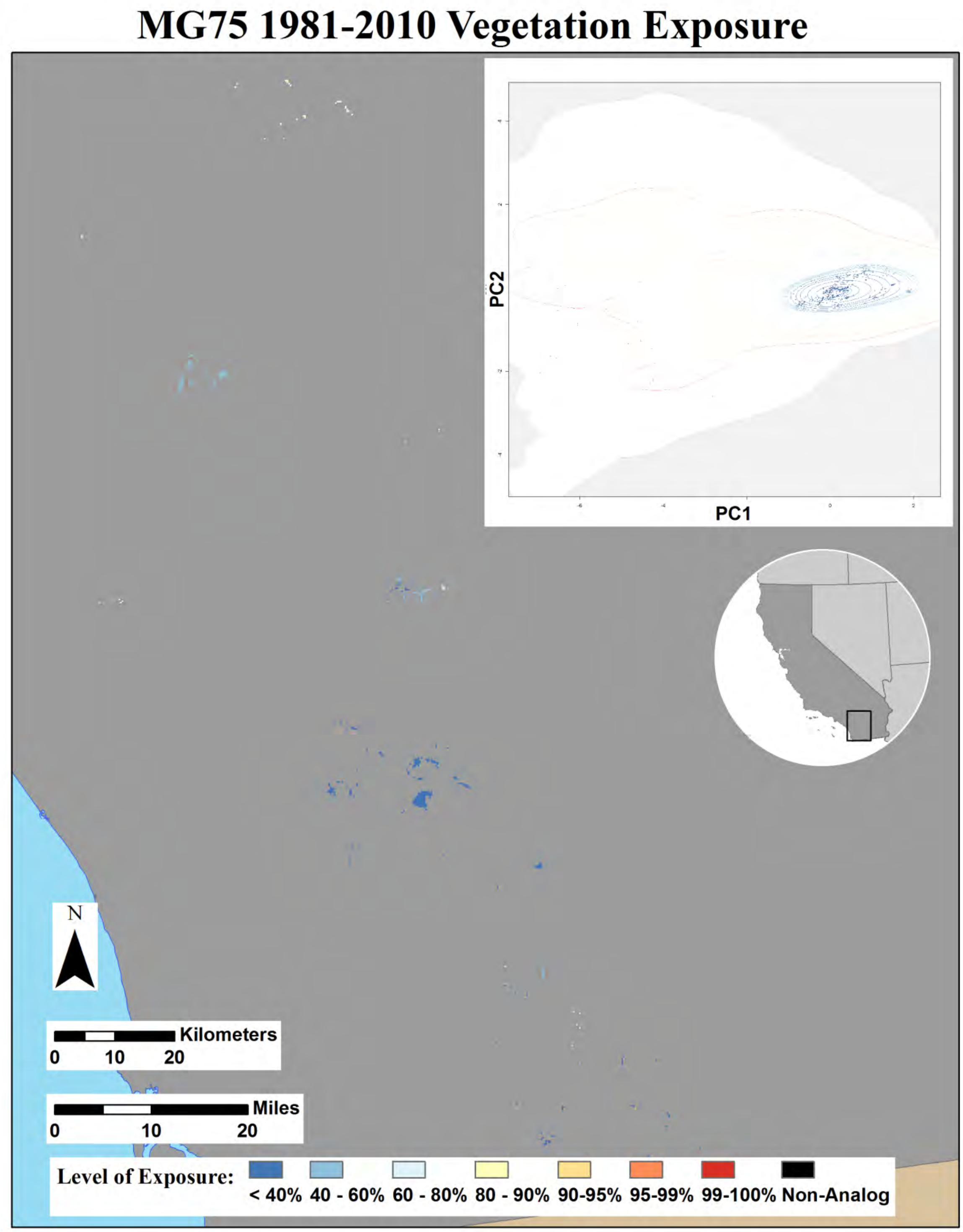


Figure 105. Map of Current Climate Suitability for Macrogroup 75. The 2015 mapped extent of macrogroup 75, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 75 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 61). The overall or grand mean for macrogroup 75 was found to be 2.21 for sensitivity and adaptive capacity.

Table 61. Sensitivity and Adaptive Capacity Rankings for Macrogroup 75. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 75. *Carex sp.* is represented by *C. scolulorum* and *C. simulata*; *Juncus sp.* is represented by *J. arcticus var. balticus*.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
WTM - habitat level	2	1	3	3	2	2	4	2	2	**2.3**
Species										
Bistorta bistortoides	2	1	1	3	2	1	1	1	1	**1.4**
Mimulus primuloides	2	1	1	3	2	1	1	1	1	**1.4**
Camassia quamash	2	1	4	3	3	2	5	3	1	**2.7**
Cirsium fontinale	3	2	1	3	3	2	1	1	1	**1.9**
Carex sp.	3	2	4	2	2	2	5	3	1	**2.7**
Juncus sp.	3	2	4	3	3	1	5	5	1	**3.0**
Mean	**2.43**	**1.43**	**2.57**	**2.86**	**2.43**	**1.57**	**3.14**	**2.29**	**1.14**	
Grand Mean	**2.21**				**Mean**	**2.21**		**Mean**	**2.19**	

Projected Climate Exposure

The future climate exposure for macrogroup 75 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 106).

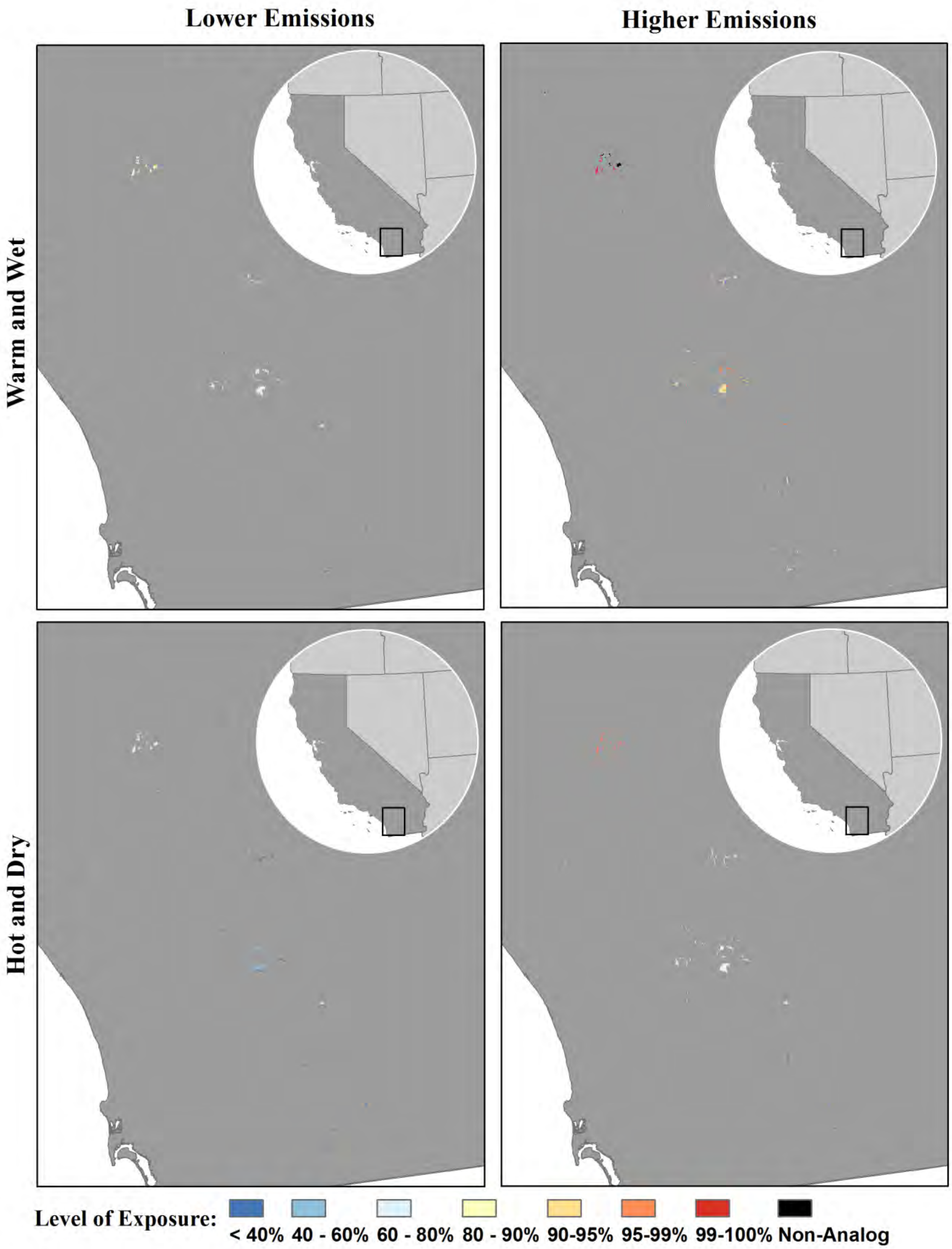


Figure 106. Maps of Projected Climate Exposure for Macrogroup 75. The climate exposure level for macrogroup 75 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 106 is derived from the PCA charts (Figure 107), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

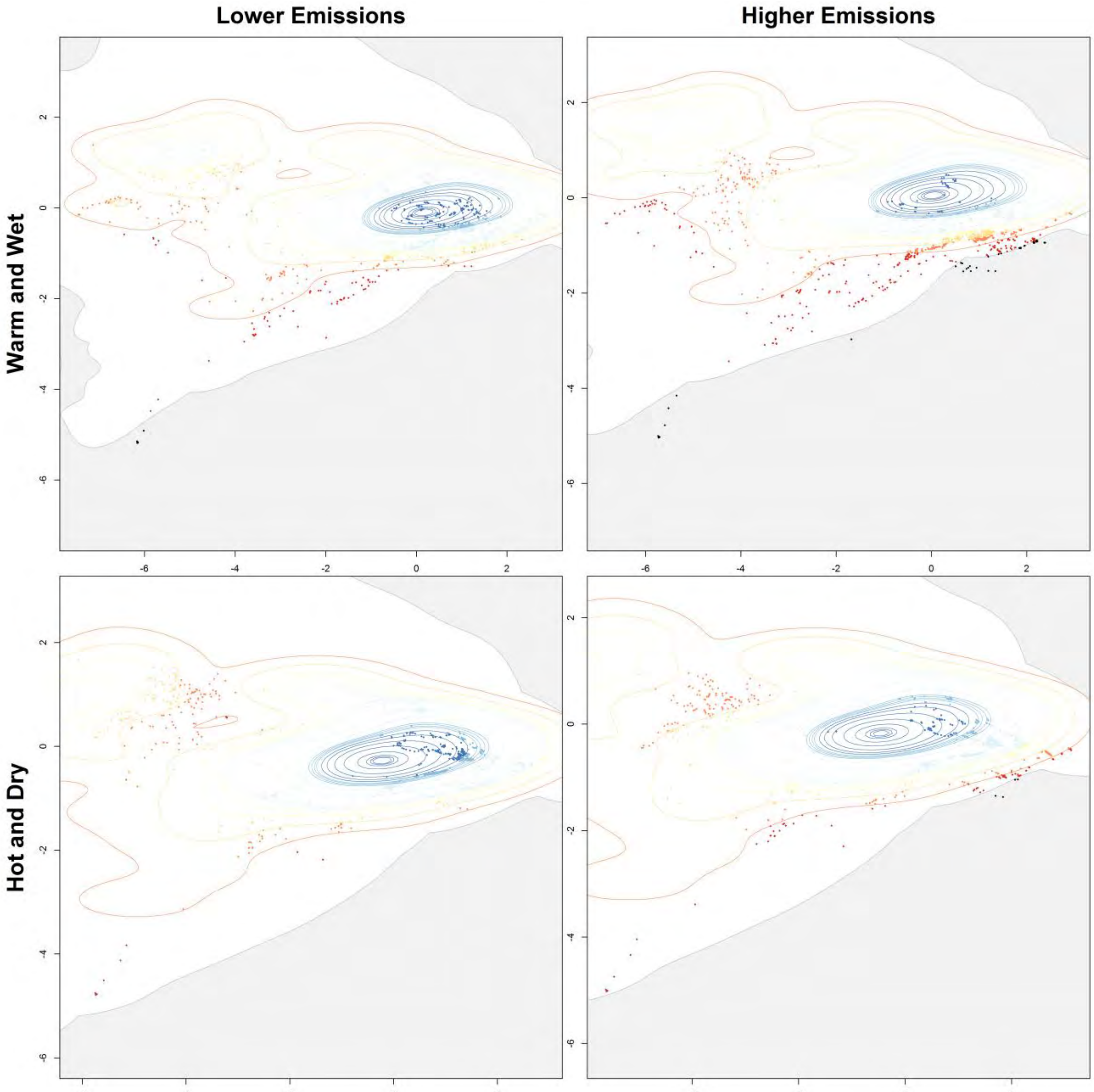


Figure 107. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 75. The PCA charts are two dimensional representations of climate exposure for macrogroup 75 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 62). In the current time period, macrogroup 75 occupies 84 km^2. By the end of the century, there will be between 15 km^2 (17%) and 65 km^2 (77%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 9 km^2 (11%) and 49 km^2 (58%) of this type will be climatically exposed by the end of century.

Table 62. Percentage of the Current Extent of Macrogroup 75 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	17	17	17	17	8	4	3	1	0
1980-2010 (%)	20.05	19.97	20.05	19.97	9.94	5.01	4.06	0.95	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	3.46	34.40	6.83	29.65	8.64	7.17	7.00	2.85	0.00
2040-2069 (%)	3.72	20.14	16.08	35.52	7.78	6.91	7.43	2.42	0.00
2070-2099 (%)	3.03	9.77	7.17	41.05	11.50	10.80	10.29	5.79	0.61
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	3.20	33.02	6.57	33.62	6.05	7.17	7.26	3.11	0.00
2040-2069 (%)	2.25	12.19	13.05	38.72	12.27	9.68	6.83	4.41	0.61
2070-2099 (%)	0.35	3.72	2.77	10.54	5.70	18.76	31.37	21.78	5.01
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	9.08	35.44	5.62	27.57	11.06	6.66	3.54	1.04	NA
2040-2069 (%)	0.09	42.09	10.37	27.40	5.19	7.95	6.05	0.86	NA
2070-2099 (%)	0.00	14.95	28.78	32.84	4.58	8.04	9.51	1.30	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	8.82	35.44	6.14	28.00	10.29	7.17	3.03	1.12	NA
2040-2069 (%)	0.09	30.60	18.32	30.42	3.20	7.95	8.56	0.86	0.00
2070-2099 (%)	0.00	4.84	6.66	48.14	6.91	4.24	18.93	9.94	0.35

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 75 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 108), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 38,447 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

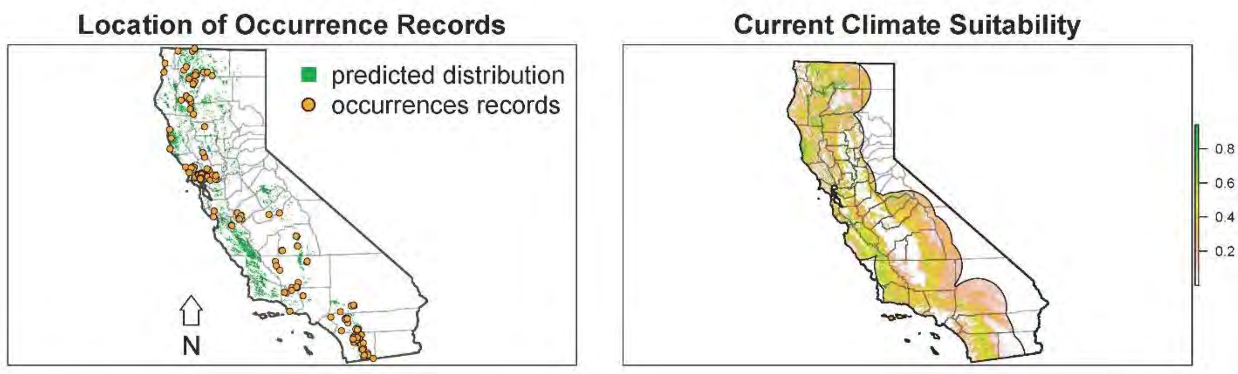


Figure 108. Map of Points Selected from the Extent of Macrogroup 75 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 75. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 75 (Figure 109). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 75, between 21,155 km^2 (55%) and 30,327 km^2 (79%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 8,120 km^2 (21%) and 17,292 km^2 (45%) will remain climatically suitable, and between 13,139 km^2 (34%) and 18,365 km^2 (48%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 63.

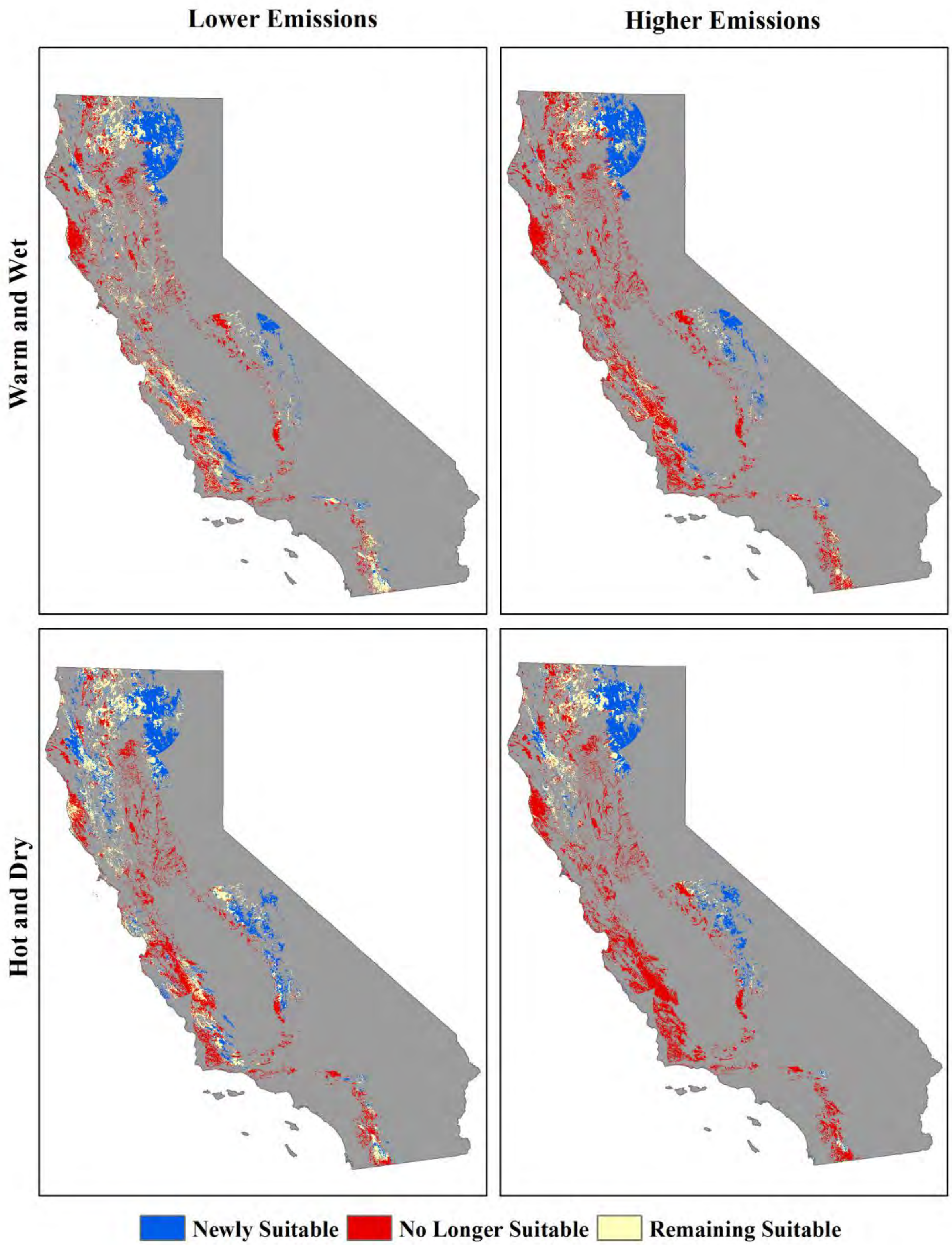


Figure 109. Maps of the Projected Climatically Suitable Range for Macrogroup 75. Maps showing the modeled climatically suitable range for macrogroup 75 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 63. Area of Projected Climatic Suitability for Macrogroup 75. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 75, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	22,072	16,375	14,275	57%	43%	37%
CNRM CM5 - RCP 8.5	30,327	8,120	13,142	79%	21%	34%
MIROC ESM - RCP 4.5	21,155	17,292	18,365	55%	45%	48%
MIROC ESM - RCP 8.5	29,101	9,346	13,139	76%	24%	34%

MG081: Macrogroup North American Pacific Coastal Salt Marsh
Common Name: Salt Marsh

Salt marshes are generally tied to coastal tidally-influenced wetlands in California. They have salinities similar to ocean water and do not develop the higher concentrations of salts characteristic of the Salt Marsh Meadow macrogroup. Many salt marsh species are widespread and species diversity is relatively low. Individual alliances within the macrogroup tend to sort out based on inundation frequencies and maximum water depths.

Representative species for this group come from two habitat types: Temperate Pacific Tidal Salt and Brackish Meadow, Western North American Disturbed Alkaline Marsh and Meadow. Species include: *Bolboschoenus maritimus*, *Distichlis spicata*, *Sarcocornia pacifica*, *Spartina* (*alterniflora*, *densiflora*), *Spartina foliosa*, *Sesuvium verrucosum*, *Atriplex prostrata*, and *Cotula coronopifolia*.

The single best WHR type: saline emergent wetland (SEW), although this concept also includes the Salt Meadows macrogroup.

Macrogroup 81 is comprised of approximately one WHR type for which we scored four representative dominant species. The statewide extent for the current time period cover 384 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 110). Using the current climate conditions for the extent of Macrogroup 81, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

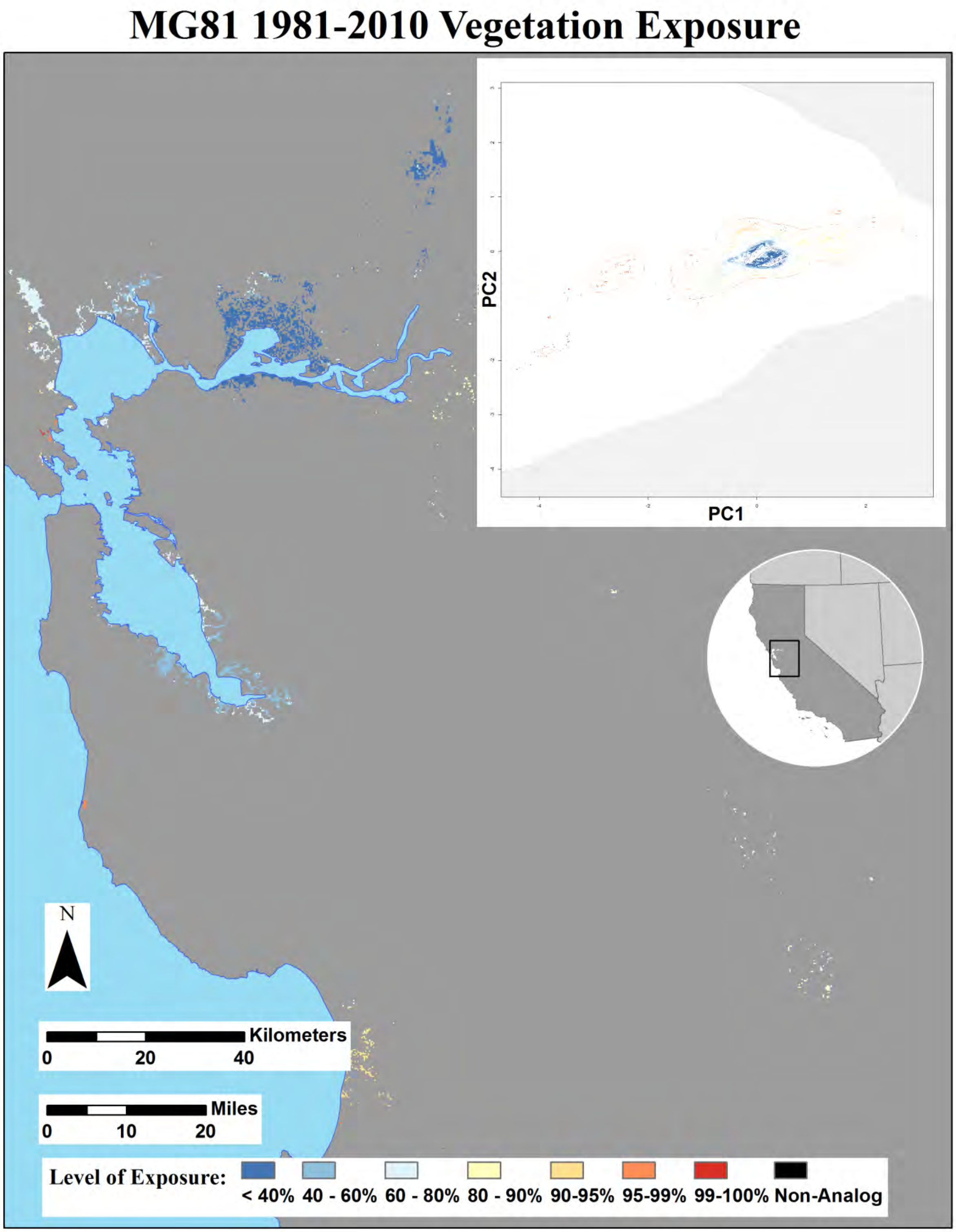


Figure 110. Map of Current Climate Suitability for Macrogroup 81. The 2015 mapped extent of macrogroup 81, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 81 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 64). The overall or grand mean for macrogroup 81 was found to be 3.00 for sensitivity and adaptive capacity.

Table 64. Sensitivity and Adaptive Capacity Rankings for Macrogroup 81. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 81. *Spartina sp.*is represented by *S. alterniflora*.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Distichlis spicata	4	2	4	3	5	2	5	5	4	**3.8**
*Bolboschoenus maritimus *(pacific bulrush)*	4	2	1	2	3	2	3	5	5	**3.0**
Spartina sp.	4	2	2	2	4	2	5	1	1	**2.6**
Sesuvium verrucosum	3	2	1	2	3	2	1	5	5	**2.7**
Mean	**3.75**	**2.00**	**2.00**	**2.25**	**3.75**	**2.00**	**3.50**	**4.00**	**3.75**	
Grand Mean	**3.00**				**Mean**	**2.63**		**Mean**	**3.75**	

Projected Climate Exposure

The future climate exposure for macrogroup 81 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 111).

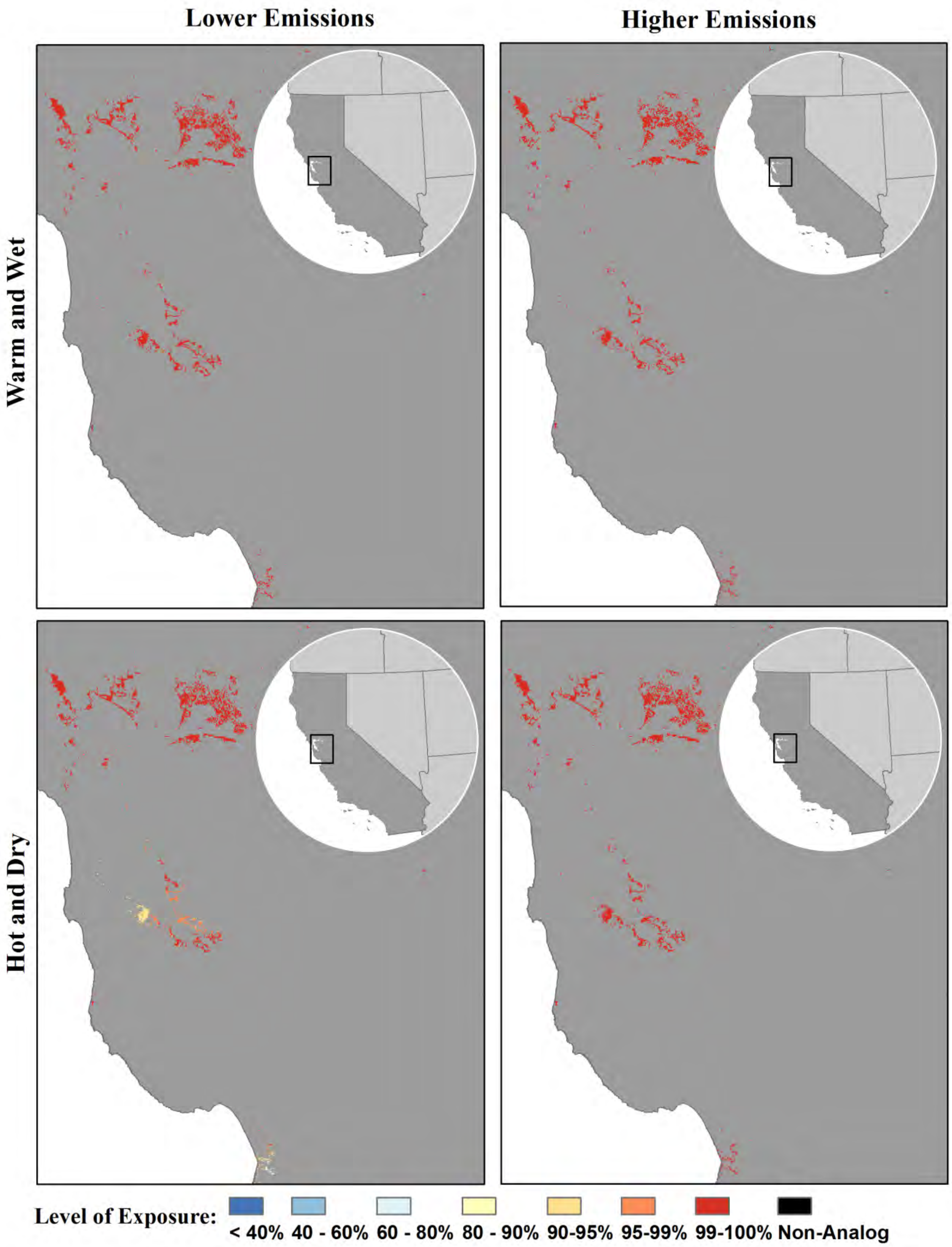


Figure 111. Maps of Projected Climate Exposure for Macrogroup 81, The climate exposure level for macrogroup 81 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 111 is derived from the PCA charts (Figure 112), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

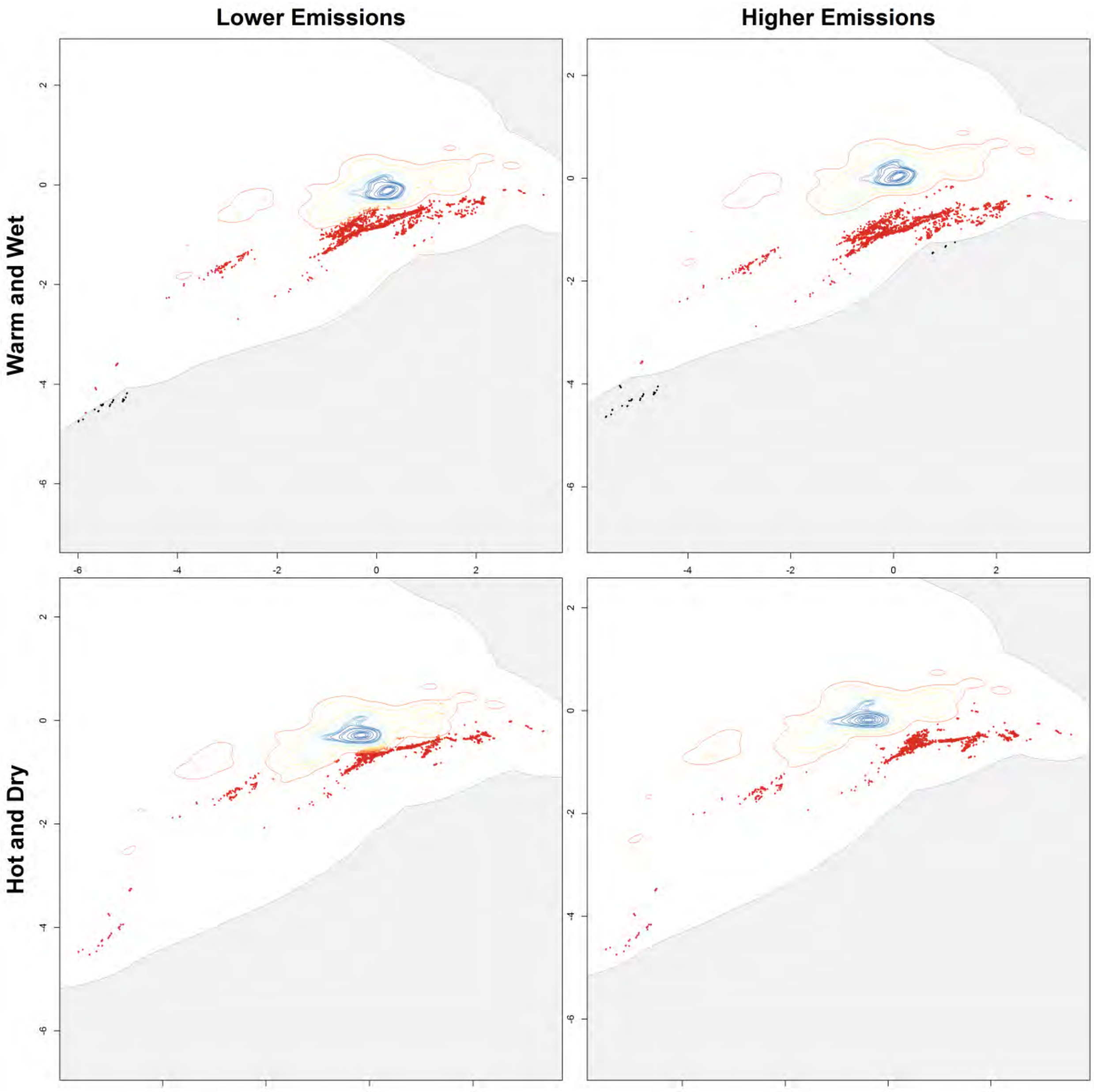


Figure 112. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 81. The PCA charts are two dimensional representations of climate exposure for macrogroup 81 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 65). In the current time period, macrogroup 81 occupies 384 km^2. By the end of the century, there will be between 0 km^2 (0%) and 4 km^2 (1%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 359 km^2 (93%) and 384 km^2 (100%) of this type will be climatically exposed by the end of century.

Table 65. Percentage of the Current Extent of Macrogroup 81 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	79	78	75	74	39	19	16	4	0
1980-2010 (%)	20.62	20.41	19.58	19.18	10.15	5.03	4.04	1.01	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	0.08	0.15	0.19	24.53	6.70	10.77	23.60	33.99	0.00
2040-2069 (%)	0.02	0.11	0.09	1.01	1.04	22.67	14.64	60.41	0.00
2070-2099 (%)	0.00	0.00	0.00	0.09	0.04	0.28	0.74	98.29	0.55
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.08	0.08	0.04	12.25	10.74	11.36	20.01	45.45	0.00
2040-2069 (%)	0.02	0.00	0.00	0.23	0.19	1.06	2.56	95.92	0.02
2070-2099 (%)	0.00	0.00	0.00	0.00	0.00	0.02	0.00	99.11	0.87
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	0.46	28.77	2.90	23.46	9.05	20.75	6.90	7.70	NA
2040-2069 (%)	4.53	13.41	1.80	12.20	1.97	8.12	31.53	26.44	NA
2070-2099 (%)	0.00	0.00	0.11	1.04	0.68	4.78	7.81	85.57	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	8.54	19.06	11.04	27.05	4.53	15.25	5.24	9.29	NA
2040-2069 (%)	0.00	1.67	6.77	10.03	3.02	10.81	10.74	56.96	0.00
2070-2099 (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 81 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 113), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 23,307 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

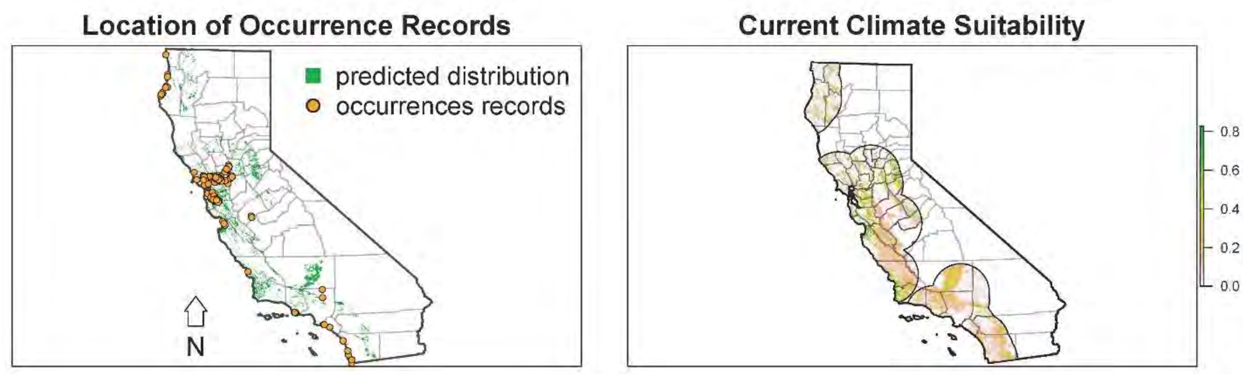


Figure 113. Map of Points Selected from the Extent of Macrogroup 81 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 81. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 81 (Figure 114). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 81, between 16,510 km^2 (71%) and 21,496 km^2 (92%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 3,455 km^2 (15%) and 6,797 km^2 (29%) will remain climatically suitable, and between 499 km^2 (2%) and 2,486 km^2 (11%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 66.

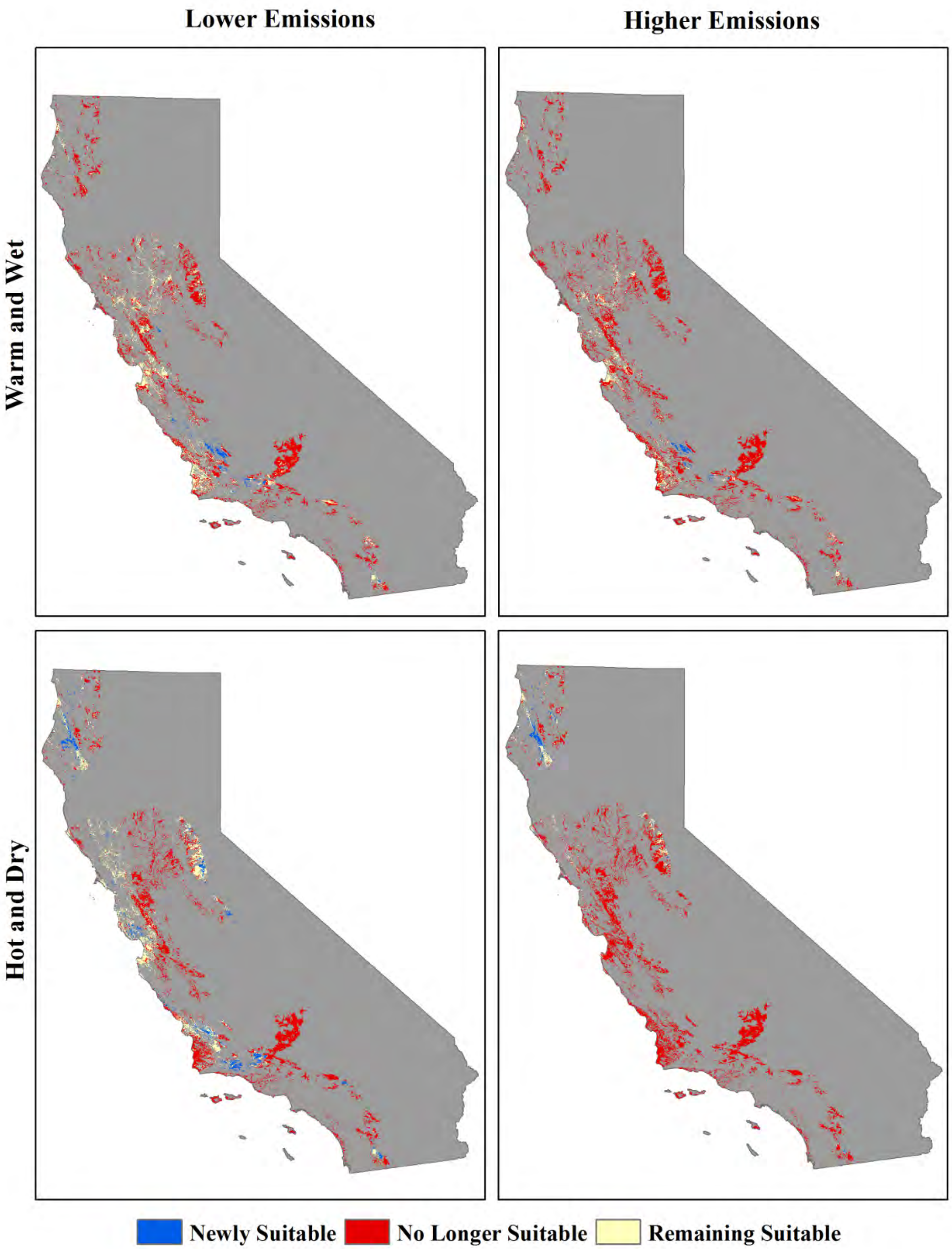


Figure 114. Maps of the Projected Climatically Suitable Range for Macrogroup 81. Maps showing the modeled climatically suitable range for macrogroup 81 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 66. Area of Projected Climatic Suitability for Macrogroup 81. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 81, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	16,884	6,423	940	72%	28%	4%
CNRM CM5 - RCP 8.5	19,852	3,455	499	85%	15%	2%
MIROC ESM - RCP 4.5	16,510	6,797	2,486	71%	29%	11%
MIROC ESM - RCP 8.5	21,496	1,811	674	92%	8%	3%

MG088: Macrogroup Mojavean–Sonoran Desert Scrub
Common Name: Mojave and Sonoran Desert Scrub

This is an upland desert scrub found on hill slopes and alluvial fans throughout the arid Southwest where winter temperatures are not as cold as in the Great Basin Desert and summer temperatures are very hot. The Mojave has frost and occasional winter snows while the Sonoran rarely has any frost. The warmer Sonoran desert tends to have more summer rain, and more distinctive emergent arborescent species, such as saguaro, ocotillo, and the Mojave is cooler with fewer large cacti and large thorny trees, but has Joshua trees and other Yucca species.

Creosote bush (*Larrea tridentata*) is the most diagnostic shrub of this macrogroup. The following trees or large shrubs are diagnostic, but are localized: ocotillo, Joshua-tree (*Yucca brevifolia*), and saguaro. Other widespread diagnostic shrubs include brittlebush (*Encelia farinosa*), burrobush (*Ambrosia dumosa*), among many others. The perennial desert grasses such as big galletta (*Pleuraphis rigida*) and desert needle grass (*Stipa speciosa*) also are considered part of this macrogroup.

WHR considers all hot desert scrub as desert scrub habitat, which includes all of the upland vegetation within this macrogroup. The WHR desert scrub is a broader concept which also includes some of the cool desert saltbush such as shadscale (*Atriplex confertifolia*). Mojavean desert wash vegetation is considered a part of the desert wash macrogroup. The single best WHR type is desert scrub (DSC), but this also includes desert succulent scrub (DSS), another WHR type that is mostly association or alliance level selection within this macrogroup. Note that this macrogroup includes Joshua tree, although it is a separate WHR type.

Macrogroup 88 is comprised of approximately three WHR types for which we scored five representative dominant species. The statewide extent for the current time period cover 83,193 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 115). Using the current climate conditions for the extent of Macrogroup 88, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

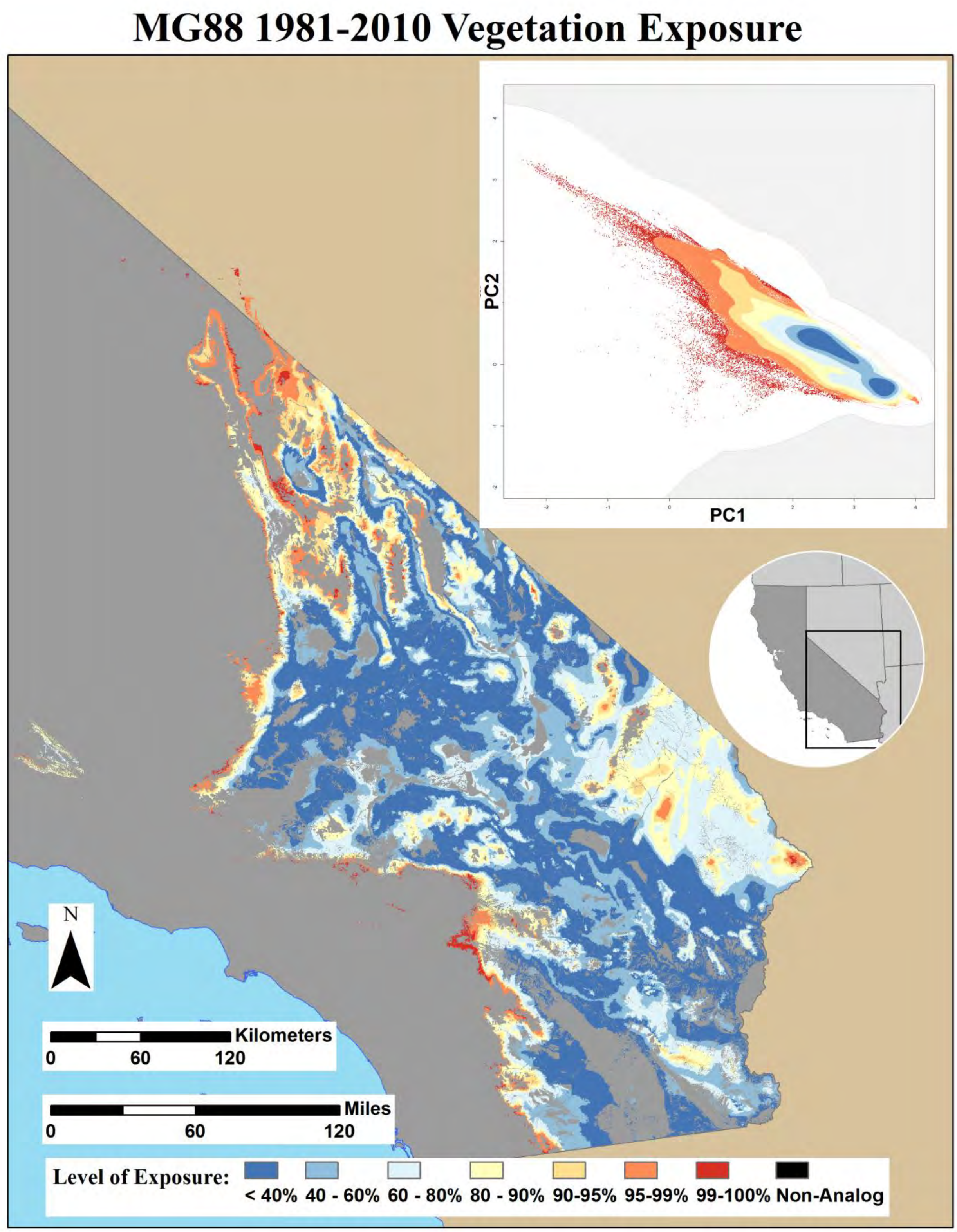


Figure 115. Map of Current Climate Suitability for Macrogroup 88. The 2015 mapped extent of macrogroup 88, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 88 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 67). The overall or grand mean for macrogroup 88 was found to be 2.84 for sensitivity and adaptive capacity.

Table 67. Sensitivity and Adaptive Capacity Rankings for Macrogroup 88. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 88.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species – DSC, DSS	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Larrea tridentata	5	5	1	4	4	5	1	3	3	**3.4**
Encelia farinosa	4	4	1	3	3	2	1	5	1	**2.7**
Ambrosia dumosa	4	4	2	3	2	2	1	5	3	**2.9**
Pleuraphis rigida	3	3	4	3	4	2	5	1	1	**2.9**
Yucca brevifolia	3	3	2	2	2	4	1	1	3	**2.3**
Mean	**3.80**	**3.80**	**2.00**	**3.00**	**3.00**	**3.00**	**1.80**	**3.00**	**2.20**	
Grand Mean	**2.84**				**Mean**	**3.10**		**Mean**	**2.33**	

Projected Climate Exposure

The future climate exposure for macrogroup 88 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 116).

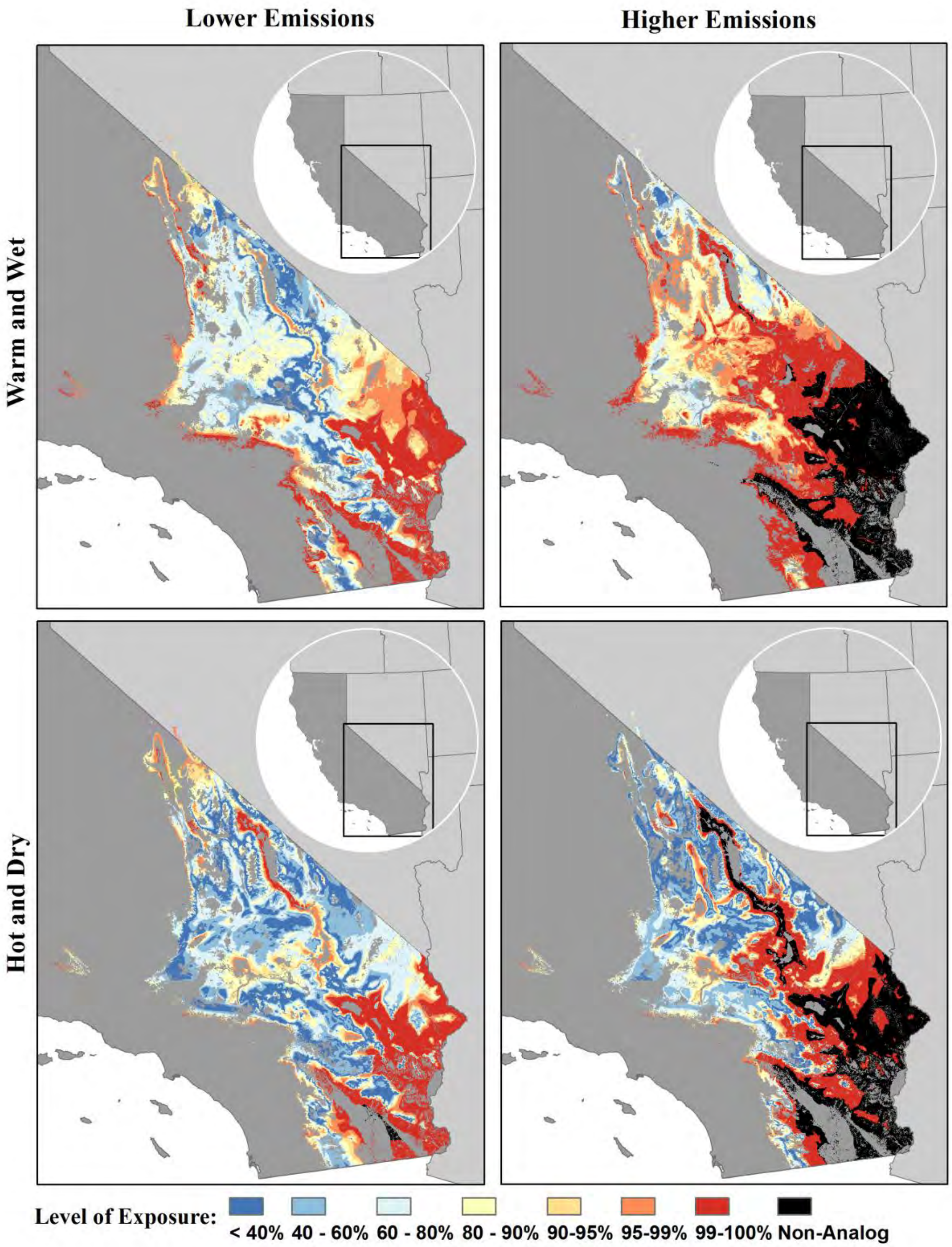


Figure 116. Maps of Projected Climate Exposure for Macrogroup 88. The climate exposure level for macrogroup 88 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 116 is derived from the PCA charts (Figure 117), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

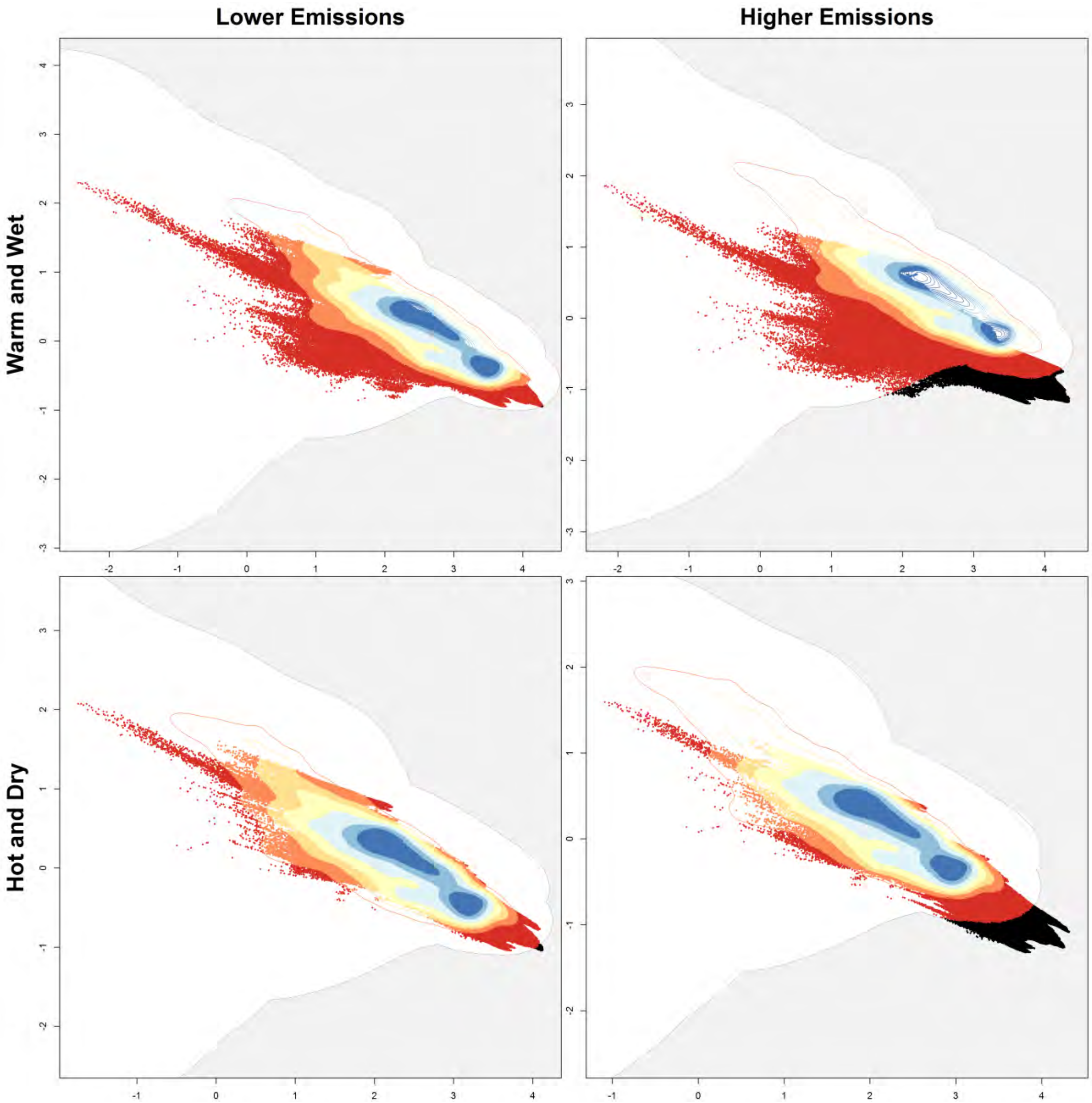


Figure 117. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 88. The PCA charts are two dimensional representations of climate exposure for macrogroup 88 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 68). In the current time period, macrogroup 88 occupies 83,193 km^2. By the end of the century, there will be between 7,421 km^2 (9%) and 49,157 km^2 (59%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 19,285 km^2 (23%) and 58,613 km^2 (70%) of this type will be climatically exposed by the end of century.

Table 68. Percentage of the Current Extent of Macrogroup 88 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	16,633	16,646	16,640	16,638	8,322	4,146	3,343	824	0
1980-2010 (%)	19.99	20.01	20.00	20.00	10.00	4.98	4.02	0.99	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	4.54	8.54	22.82	27.42	14.22	9.94	7.72	4.81	0.00
2040-2069 (%)	4.96	8.11	17.82	25.62	13.90	10.48	8.41	10.69	0.00
2070-2099 (%)	4.73	4.76	9.99	25.21	15.97	8.49	9.92	20.93	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	4.44	7.26	21.28	27.98	15.11	10.37	7.91	5.63	0.00
2040-2069 (%)	5.10	6.83	17.82	23.23	12.12	8.65	7.42	18.81	0.01
2070-2099 (%)	0.23	0.45	1.26	6.99	11.23	9.40	12.10	30.28	28.07
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	14.27	18.60	20.79	19.97	12.13	6.92	5.88	1.44	NA
2040-2069 (%)	8.97	17.42	18.81	17.53	11.63	5.92	6.82	12.90	NA
2070-2099 (%)	6.87	11.95	19.64	20.62	11.31	6.42	6.01	16.86	0.31
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	14.30	15.69	23.77	21.83	12.42	6.55	4.28	1.16	NA
2040-2069 (%)	6.83	11.43	19.99	20.26	10.96	6.44	6.02	17.90	0.17
2070-2099 (%)	4.87	9.10	14.35	11.84	8.42	4.12	4.92	19.08	23.30

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 88 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 118), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 105,377 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

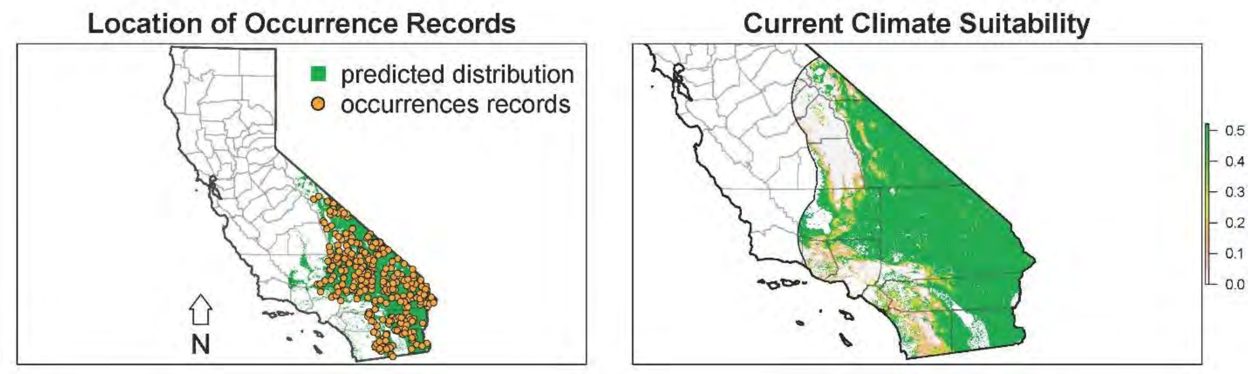


Figure 118. Map of Points Selected from the Extent of Macrogroup 88 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 88. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 88 (Figure 119). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 88, between 27 km^2 (0%) and 23,543 km^2 (22%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 81,835 km^2 (78%) and 105,351 km^2 (100%) will remain climatically suitable, and between 1,594 km^2 (2%) and 24,276 km^2 (23%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 69.

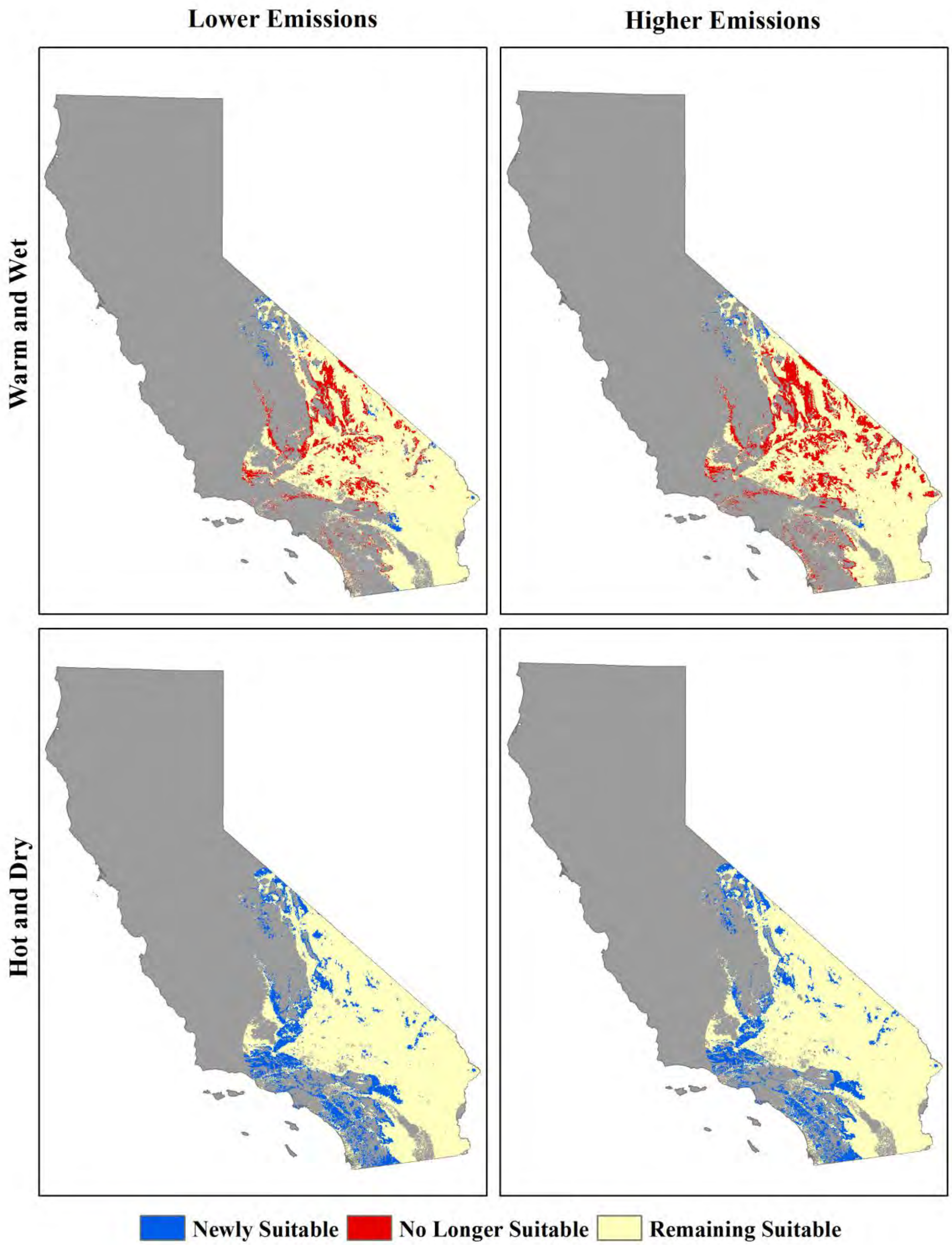


Figure 119. Maps of the Projected Climatically Suitable Range for Macrogroup 88. Maps showing the modeled climatically suitable range for macrogroup 88 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 69. Area of Projected Climatic Suitability for Macrogroup 88. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 88, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	14,372	91,005	2,632	14%	86%	2%
CNRM CM5 - RCP 8.5	23,543	81,835	1,594	22%	78%	2%
MIROC ESM - RCP 4.5	27	105,351	24,276	0%	100%	23%
MIROC ESM - RCP 8.5	77	105,300	22,654	0%	100%	21%

MG092: North American Warm-Desert Xero-Riparian Macrogroup [previously: Macrogroup Madrean Warm Semi-Desert Wash Woodland/Scrub] Common Name: Desert Wash Woodland and Scrub

This macrogroup includes the warm desert washes of the Sonoran and Colorado Desert. These have trees and large shrubs associated with them while the cooler Mojave Desert has fewer trees but several shrub species. Stands vary depending upon subsurface water availability, minimum winter temperature, and intensity and frequency of flooding.

This macrogroup includes vegetation of desert washes such as catclaw acacia (*Acacia greggii*), desert lavender (*Condea emoryi*), cheesebush (*Ambrosia salsola*), desert willow (*Chilopsis linearis*), and black stem rabbitbrush (*Ericameria paniculata*). It also includes the taller microphyll woodland species such as ironwood (*Olneya tesota*), smoke tree (*Psorothamnus spinosus*), and blue palo verde (*Parkinsonia florida*).

The single best WHR type is desert wash (DSW). Blue palo verde (*Parkinsonia florida*) ironwood (*Olneya tesota*), and smoke tree (*Psorothamnus spinosus*) are indicators of the desert wash habitat. (In this case WHR is analogous to the Group Sonoran-Coloradan Semi-Desert Wash Woodland/Scrub, but does not include the cooler Mojave wash scrub, which is included within the desert wash concept of WHR.)

Macrogroup 92 is comprised of approximately one WHR type for which we scored five representative dominant species. The statewide extent for the current time period cover 3,719 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 120). Using the current climate conditions for the extent of Macrogroup 92, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

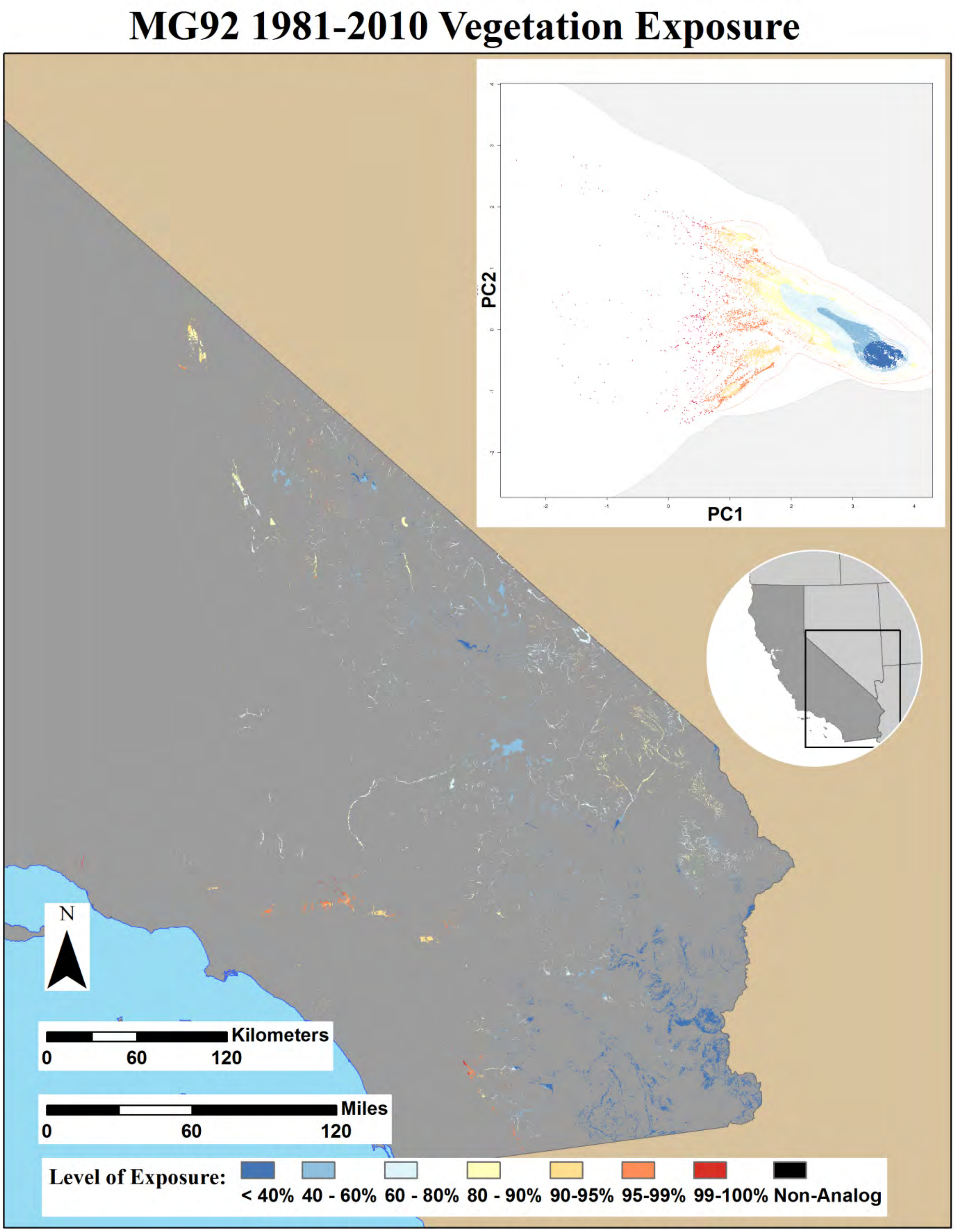


Figure 120. Map of Curent Climate Suitability for Macrogoup 92. The 2015 mapped extent of macrogroup 92, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 92 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 70). The overall or grand mean for macrogroup 92 was found to be 3.07 for sensitivity and adaptive capacity.

Table 70. Sensitivity and Adaptive Capacity rankings for Macrogroup 92. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 92. "Black stem rabbitbrush" was not found. Other named species had very limited distributions and thus were not included.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Acacia greggii	3	3	4	3	2	3	4	2	3	**3.0**
Ambrosia salsola	3	3	4	3	4	2	4	3	3	**3.2**
Chilopsis linearis	3	3	4	3	3	3	4	4	2	**3.2**
Parkinsonia florida	4	4	1	2	3	2	1	3	5	**2.8**
Psorothamnus spinosus	4	4	3	1	2	2	3	4	5	**3.1**
Mean	**3.40**	**3.40**	**3.20**	**2.40**	**2.80**	**2.40**	**3.20**	**3.20**	**3.60**	
Grand Mean	**3.07**				**Mean**	**2.93**		**Mean**	**3.33**	

Projected Climate Exposure

The future climate exposure for macrogroup 92 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 121).

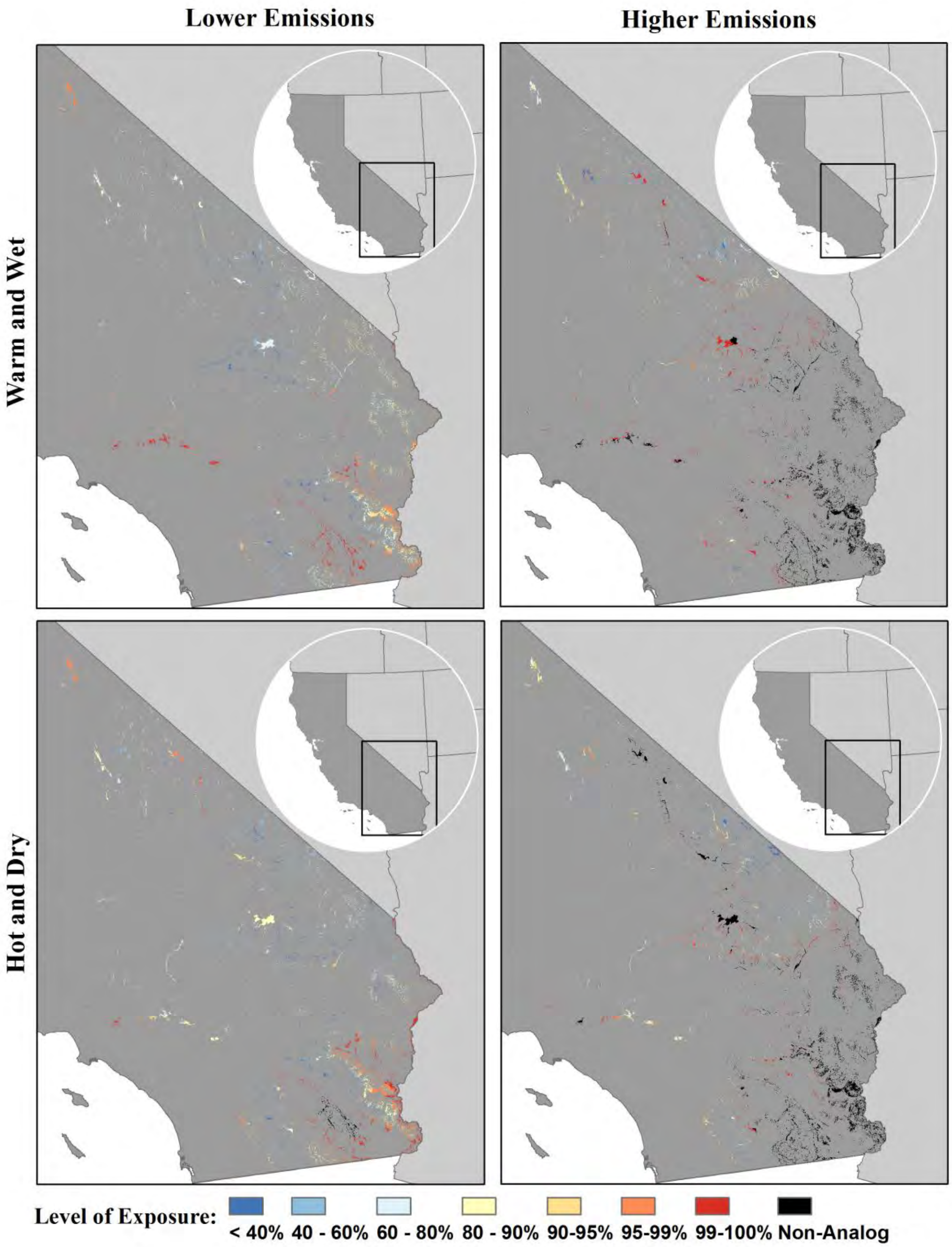


Figure 121. Maps of Projected Climate Exposure for Macrogroup 92. The climate exposure level for macrogroup 92 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 121 is derived from the PCA charts (Figure 122), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

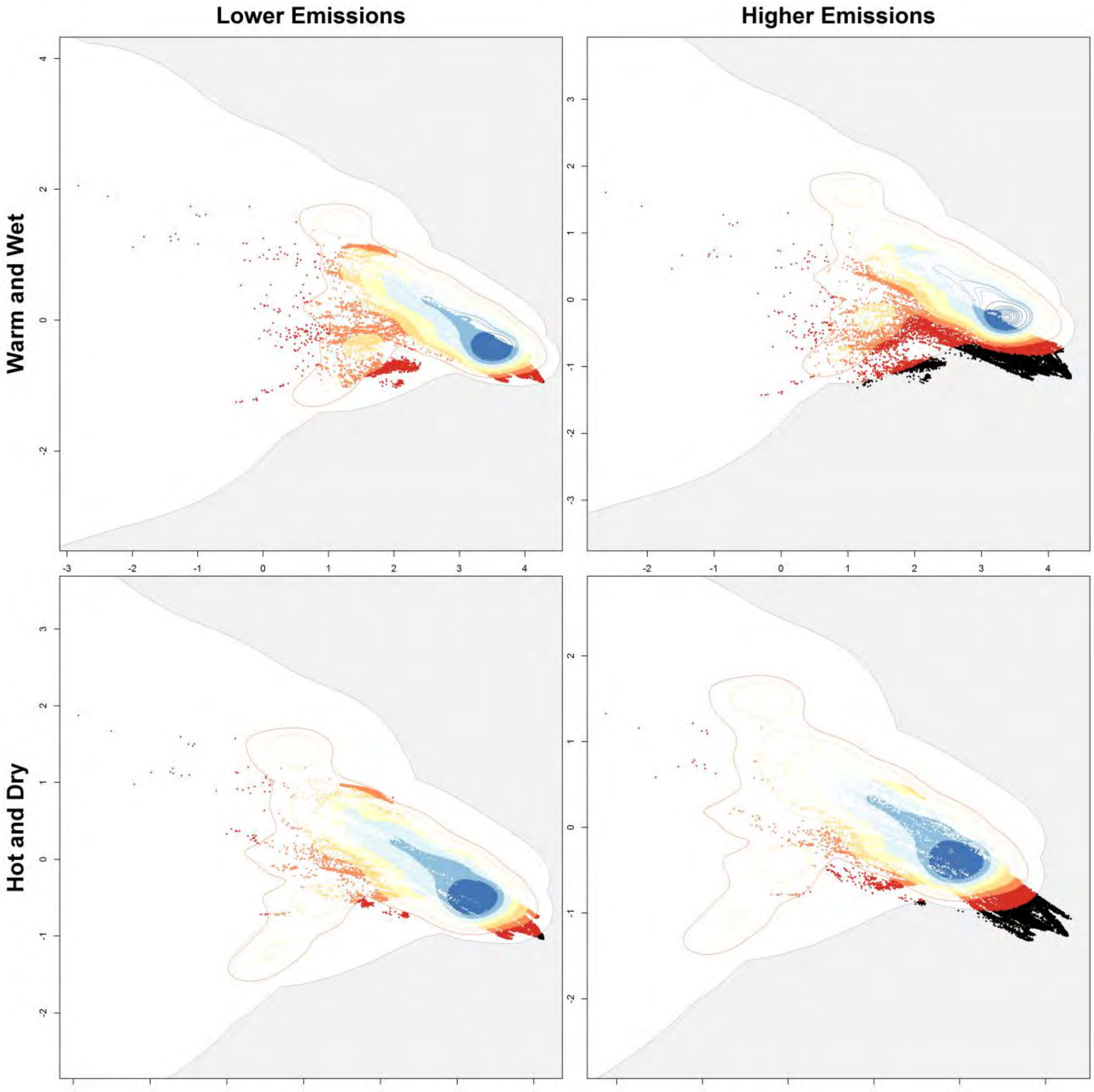


Figure 122. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 92. The PCA charts are two dimensional representations of climate exposure for macrogroup 92 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 71). In the current time period, macrogroup 92 occupies 3,719 km^2. By the end of the century, there will be between 475 km^2 (13%) and 1,650 km^2 (44%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,016 km^2 (27%) and 2,779 km^2 (75%) of this type will be climatically exposed by the end of century.

Table 71. Percentage of the Current Extent of Macrogroup 92 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	744	744	744	744	372	185	149	37	0
1980-2010 (%)	20.00	20.01	20.00	20.00	10.00	4.98	4.00	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	6.65	32.31	18.31	16.57	8.81	9.64	5.83	1.90	0.00
2040-2069 (%)	3.95	17.79	21.69	22.40	14.29	7.04	7.76	5.09	0.00
2070-2099 (%)	3.88	8.25	12.01	20.22	14.50	13.82	15.80	11.40	0.12
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	5.35	32.24	18.35	16.97	9.22	10.09	5.85	1.92	0.00
2040-2069 (%)	3.23	9.14	14.73	21.00	12.70	11.26	16.37	11.30	0.26
2070-2099 (%)	0.31	3.59	2.82	6.05	6.10	6.40	6.05	17.67	51.01
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	15.52	26.20	20.03	18.25	7.41	5.94	5.22	1.42	NA
2040-2069 (%)	3.65	10.69	21.85	18.70	15.25	14.99	7.95	6.93	NA
2070-2099 (%)	2.56	10.25	17.06	13.75	14.28	9.15	16.15	14.33	2.46
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	20.37	14.91	18.70	27.91	6.75	4.92	4.86	1.58	NA
2040-2069 (%)	2.31	10.30	16.43	13.51	12.86	13.52	17.10	12.12	1.85
2070-2099 (%)	2.03	6.79	7.05	7.22	5.93	5.68	5.13	9.72	50.45

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 92 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 123), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 55,927 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

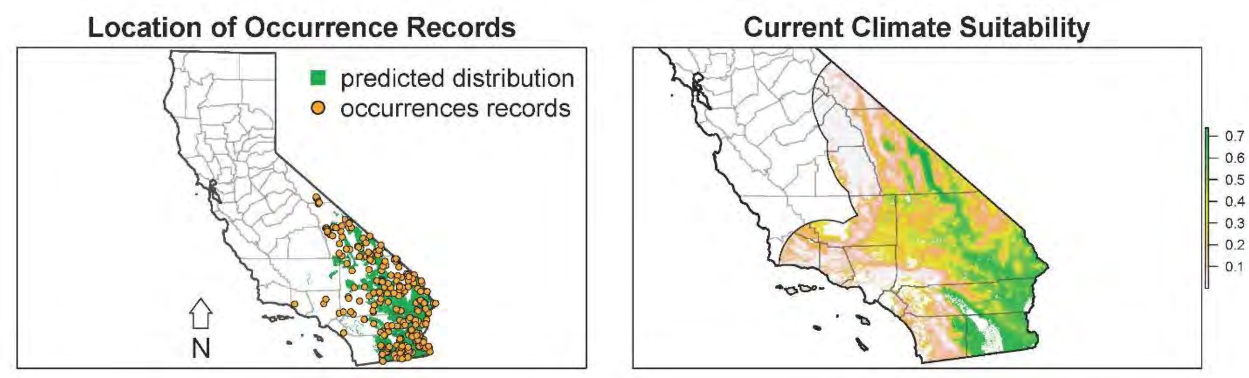


Figure 123. Map of Points Selected from the Extent of Macrogroup 92 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 92. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 92 (Figure 124). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 92, between 0 km^2 (0%) and 225 km^2 (0.4%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 55,781 km^2 (99.7%) and 55,927 km^2 (99.9%) will remain climatically suitable, and between 26,993 km^2 (48%) and 65,789 km^2 (118%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 72.

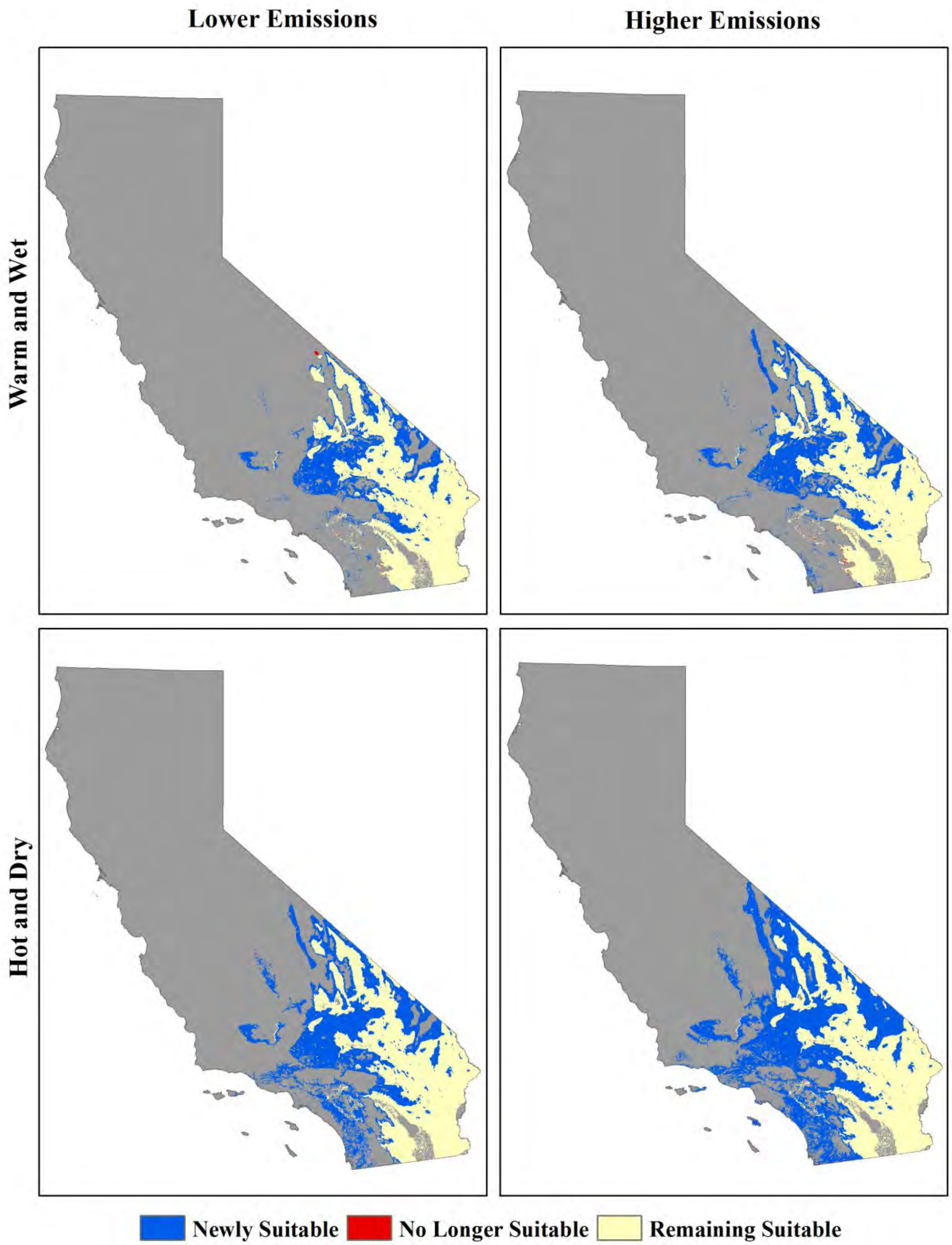


Figure 124. Maps of the Projected Climatically Suitable Range for Macrogroup 92. Maps showing the modeled climatically suitable range for macrogroup 92 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 72. Area of Projected Climatic Suitability for Macrogroup 92. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 92, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	146	55,781	26,993	0%	100%	48%
CNRM CM5 - RCP 8.5	225	55,702	33,051	0%	100%	59%
MIROC ESM - RCP 4.5	0	55,927	46,633	0%	100%	83%
MIROC ESM - RCP 8.5	0	55,927	65,789	0%	100%	118%

MG093: Great Basin Saltbush Scrub Macrogroup [previously: Macrogroup Western North American Cool Semi-Desert Shrubland, Shrub-Steppe]
Common Name: Shadscale-Saltbush Scrub

The shrubby cool desert saltbush species often form distinct bands above closed basins and below extensive sagebrush belts in the Great Basin Desert. This macrogroup addresses those saltbush scrubs, which typically are not growing in strongly saline or alkaline soils, but do tolerate higher pH (alkalinity) and often finer soil texture than *Artemisia tridentata* and related taxa of sagebrush.

Shadscale (*Atriplex confertifolia*), allscale (*Atriplex polycarpa*), and four-wing saltbush (*A. canescens*) are the main vegetation alliance indicators occurring in California. These species are tolerant of a range of conditions, shadscale occurs from upland rocky calcium-rich soils, to fine textured playa edges, but most are uplands, especially in the northeastern part of the state. Allscale occurs in fine textured upland soils and in basins in the southern Great Basin, the Mojave and Sonoran deserts, and in the inner Coast Ranges and San Joaquin Valley. Four-wing saltbush occurs in sandy uplands and may tolerate the salty edges of sand dunes adjacent to playas in the Mojave Desert.

The best single fit to WHR is alkali desert scrub (ASC). However, also included in part in desert wash (DSW) and desert scrub (DSC) habitats.

Macrogroup 93 is comprised of approximately three WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 7,758 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 125). Using the current climate conditions for the extent of Macrogroup 93, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

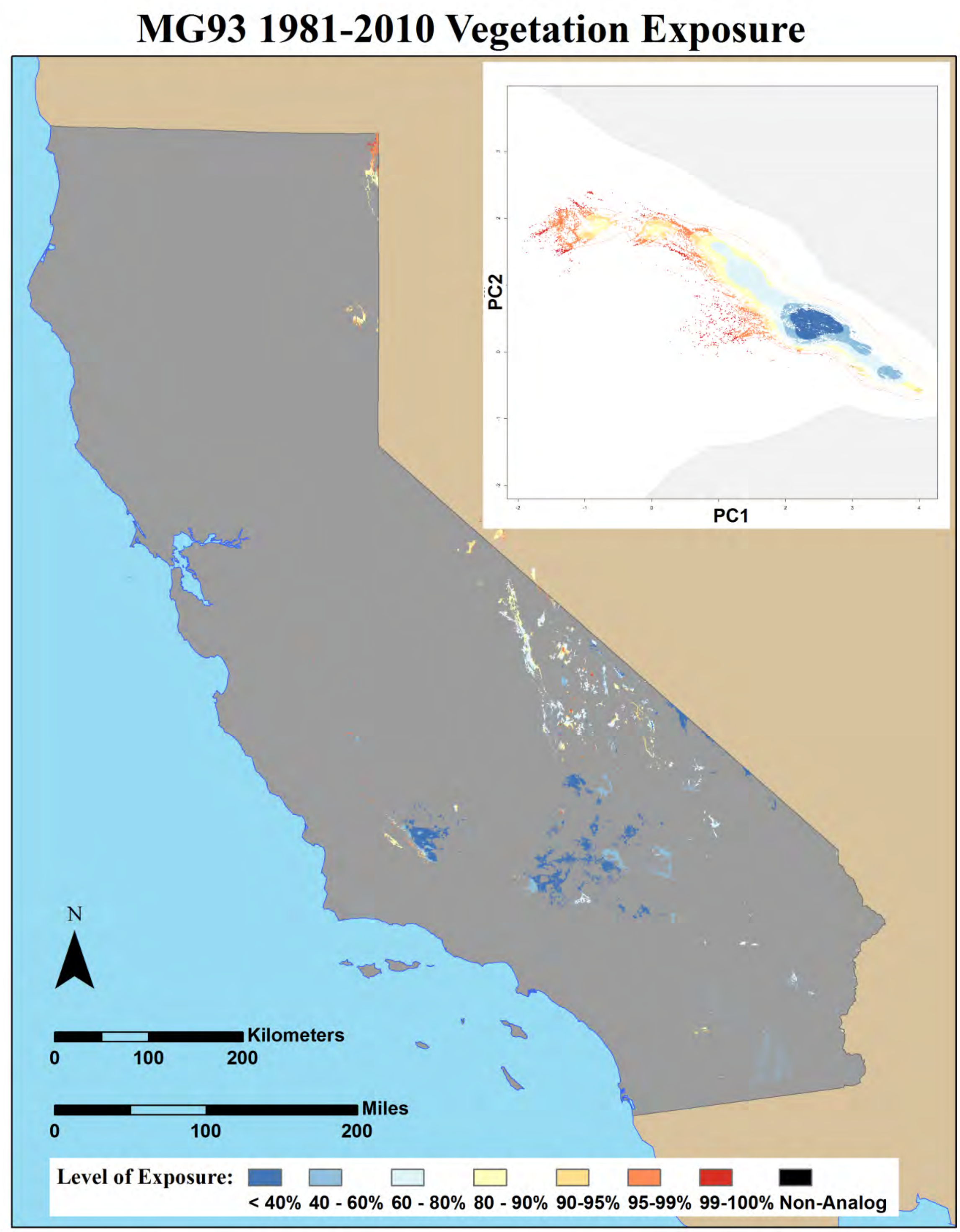


Figure 125. Map of Current Climate Suitability for Macrogroup 93. The 2015 mapped extent of macrogroup 93, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 93 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to

germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 73). The overall or grand mean for macrogroup 93 was found to be 3.11 for sensitivity and adaptive capacity.

Table 73. Sensitivity and Adaptive Capacity Rankings for Macrogroup 93. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 93.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Atriplex confertifolia	4	4	4	3	3	2	3	3	3	**3.2**
Atriplex canescens	4	4	4	2	3	2	5	3	3	**3.3**
Atriplex polycarpa	4	4	1	2	2	3	1	5	3	**2.8**
Mean	**4.00**	**4.00**	**3.00**	**2.33**	**2.67**	**2.33**	**3.00**	**3.67**	**3.00**	
Grand Mean	**3.11**				**Mean**	**3.06**		**Mean**	**3.22**	

Projected Climate Exposure

The future climate exposure for macrogroup 93 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 126).

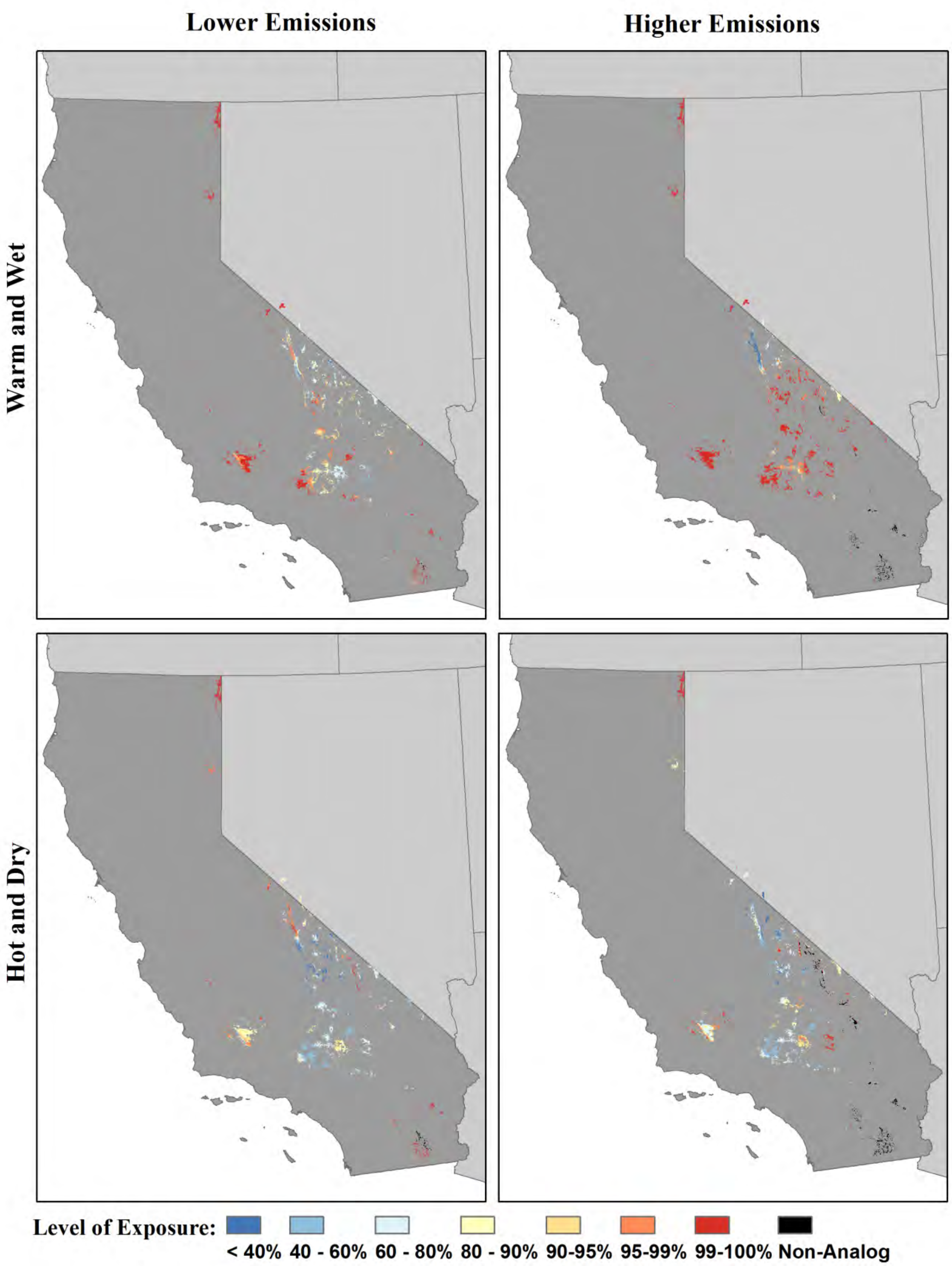


Figure 126. Maps of Projected Climate Exposure for Macrogroup 93. The climate exposure level for macrogroup 93 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 126 is derived from the PCA charts (Figure 127), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

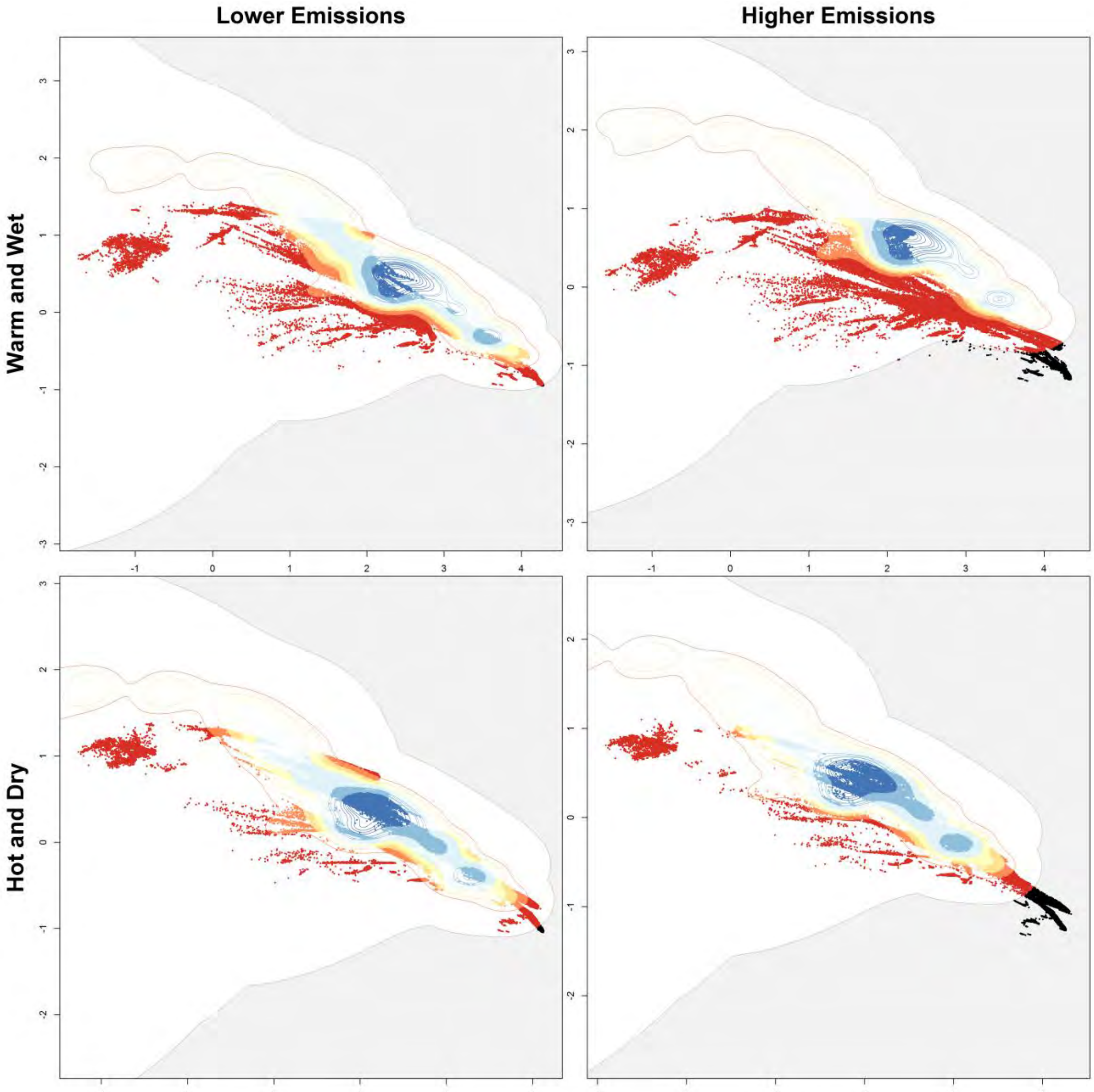


Figure 127. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 93. The PCA charts are two dimensional representations of climate exposure for macrogroup 93 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 74). In the current time period, macrogroup 93 occupies 7,758 km^2. By the end of the century, there will be between 669 km^2 (9%) and 4,291 km^2 (55%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,698 km^2 (22%) and 6,442 km^2 (83%) of this type will be climatically exposed by the end of century.

Table 74. Percentage of the Current Extent of Macrogroup 93 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1,552	1,551	1,552	1,552	776	388	310	78	0
1980-2010 (%)	20.00	20.00	20.00	20.01	10.00	5.00	3.99	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	0.96	6.34	16.43	27.08	13.39	9.87	9.73	16.21	0.00
2040-2069 (%)	0.24	1.89	10.17	30.02	19.43	10.84	7.35	20.06	0.00
2070-2099 (%)	0.34	0.75	6.32	19.66	11.01	13.41	14.99	33.28	0.25
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.68	5.85	18.53	25.12	14.57	8.76	8.97	17.52	0.00
2040-2069 (%)	0.48	1.29	10.01	25.18	14.96	10.10	10.03	27.59	0.36
2070-2099 (%)	3.05	1.10	2.06	2.41	4.07	4.27	10.99	65.11	6.93
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	7.24	17.21	23.80	23.32	7.65	5.60	8.69	6.49	NA
2040-2069 (%)	1.84	4.00	33.35	26.59	8.37	6.02	4.84	14.99	NA
2070-2099 (%)	5.88	2.75	21.49	25.20	13.29	9.52	8.33	12.24	1.31
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	6.28	17.31	20.41	26.92	9.48	6.58	8.57	4.44	NA
2040-2069 (%)	6.34	3.59	23.91	28.50	11.26	6.65	7.16	11.49	1.09
2070-2099 (%)	2.26	3.75	20.29	25.43	12.15	8.44	5.84	11.22	10.61

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 93 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 128), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 81,607 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

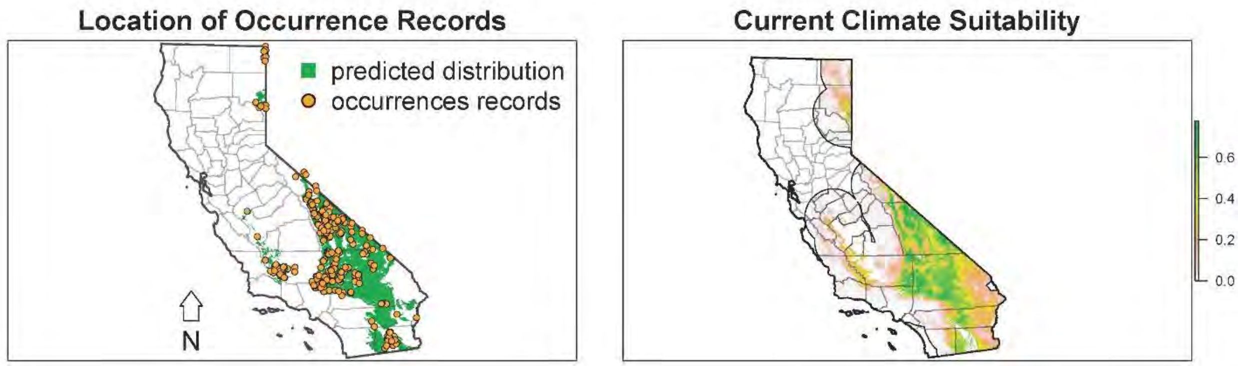


Figure 128. Map of Points Selected from the Extent of Macrogroup 93 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 93. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 93 (Figure 129). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 93, between 12,026 km^2 (15%) and 78,847 km^2 (97%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 2,760 km^2 (3%) and 69,580 km^2 (85%) will remain climatically suitable, and between 2 km^2 (0%) and 10,040km^2 (12%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 75.

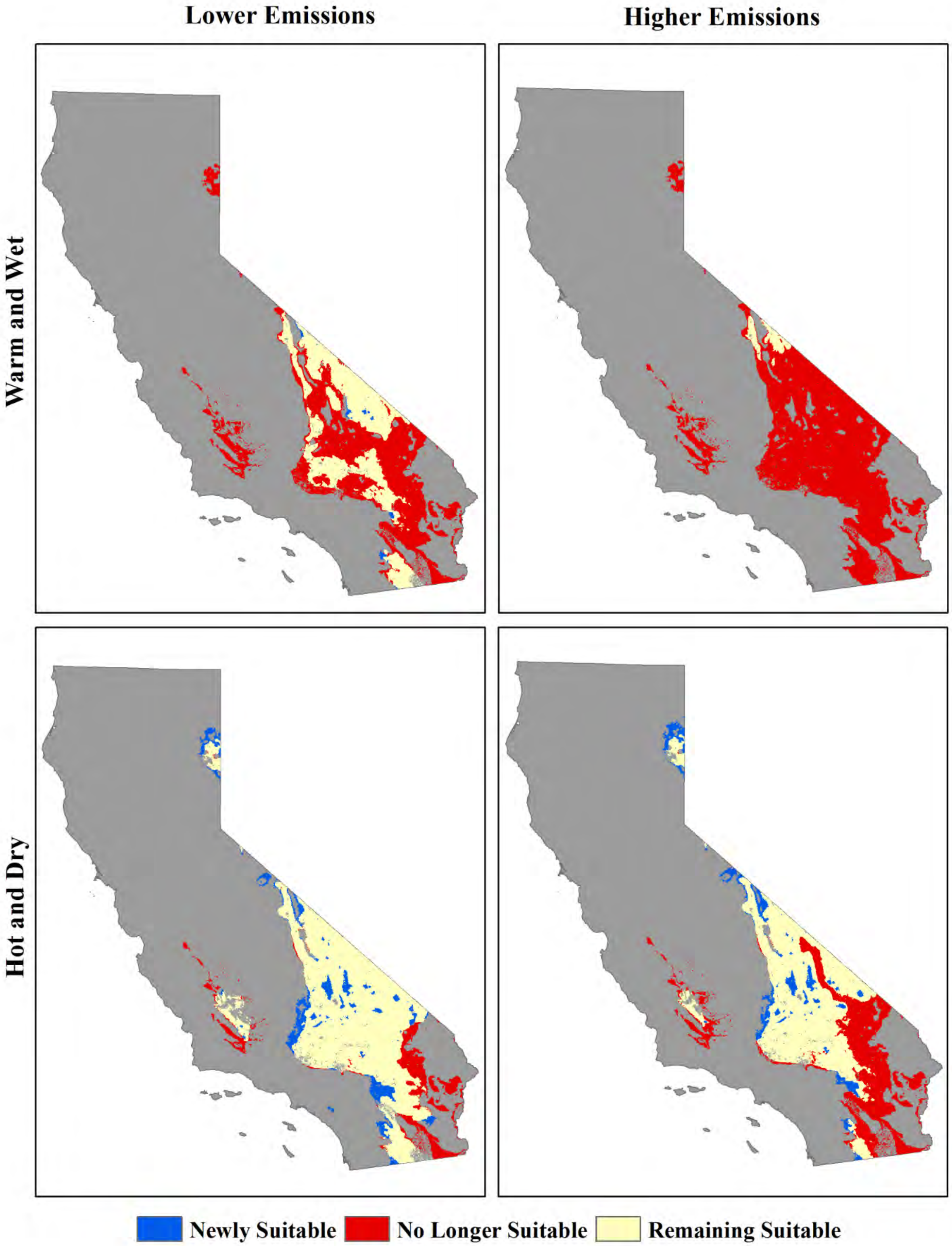


Figure 129. Maps of the Projected Climatically Suitable Range for Macrogroup 93. Maps showing the modeled climatically suitable range for macrogroup 93 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 75. Area of Projected Climatic Suitability for Macrogroup 93. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 93, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	49,834	31,773	707	61%	39%	1%
CNRM CM5 - RCP 8.5	78,847	2,760	2	97%	3%	0%
MIROC ESM - RCP 4.5	12,026	69,580	10,040	15%	85%	12%
MIROC ESM - RCP 8.5	30,598	51,009	8,210	37%	63%	10%

MG096: Macrogroup Western North America Tall Sage Shrubland and Steppe
Common Name: Big Sagebrush Scrub

This macrogroup is emblematic of the valleys and lower slopes of the Great Basin Desert and enters California in the Modoc Plateau, south and east of the Cascades and Sierra, into the higher mountains of the Mojave Desert. It also occurs in isolated patches in the Transverse and Peninsular ranges, the south and the inner north Coast Ranges sporadically northward to the eastern Klamath Mountains.

Several closely related species and subspecies of Artemisia (*A. tridentata* var. *tridentata*, var. *vaseyana*, *A. rothrockii*, and *A. cana*) are included in this macrogroup. These taxa all form separate stands in separate alliances based on adaptation to temperature, snow load, depth and porosity of soil, and moisture availability. All of them tend to be fire sensitive and typically do not resprout following fire. Depending upon fire interval and intensity, stands may be mixed with native or nonnative grasses, forbs, and different associated shrubs.

Macrogroup 96 is comprised of approximately one WHR type for which we scored three representative dominant species. The statewide extent for the current time period cover 16,020 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 130). Using the current climate conditions for the extent of Macrogroup 96, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

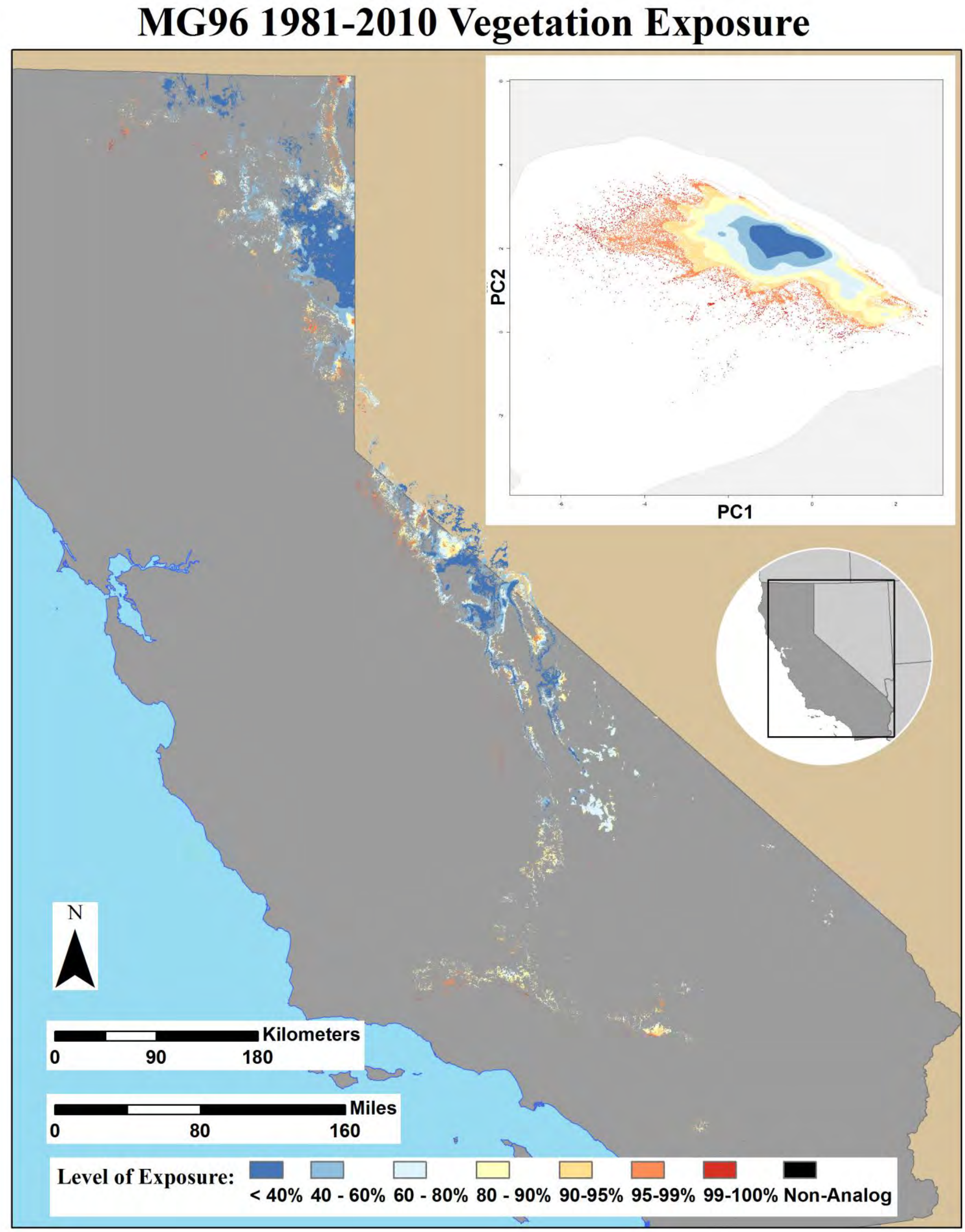


Figure 130. Map of Current Climate Suitability for Macrogroup 96. The 2015 mapped extent of macrogroup 96, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 96 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 76). The overall or grand mean for macrogroup 96 was found to be 2.67 for sensitivity and adaptive capacity.

Table 76. Sensitivity and Adaptive Capacity Rankings for Macrogroup 96. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 96.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Artemisia tridentata	3	3	2	3	3	3	2	5	2	**2.9**
Artemisia cana	3	3	2	3	2	2	3	4	1	**2.6**
Artemisia vaseyana	3	3	2	3	3	3	2	3	1	**2.6**
Mean	**3.00**	**3.00**	**2.00**	**3.00**	**2.67**	**2.67**	**2.33**	**4.00**	**1.33**	
Grand Mean	**2.67**				**Mean**	**2.72**		**Mean**	**2.56**	

Projected Climate Exposure

The future climate exposure for macrogroup 96 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 131).

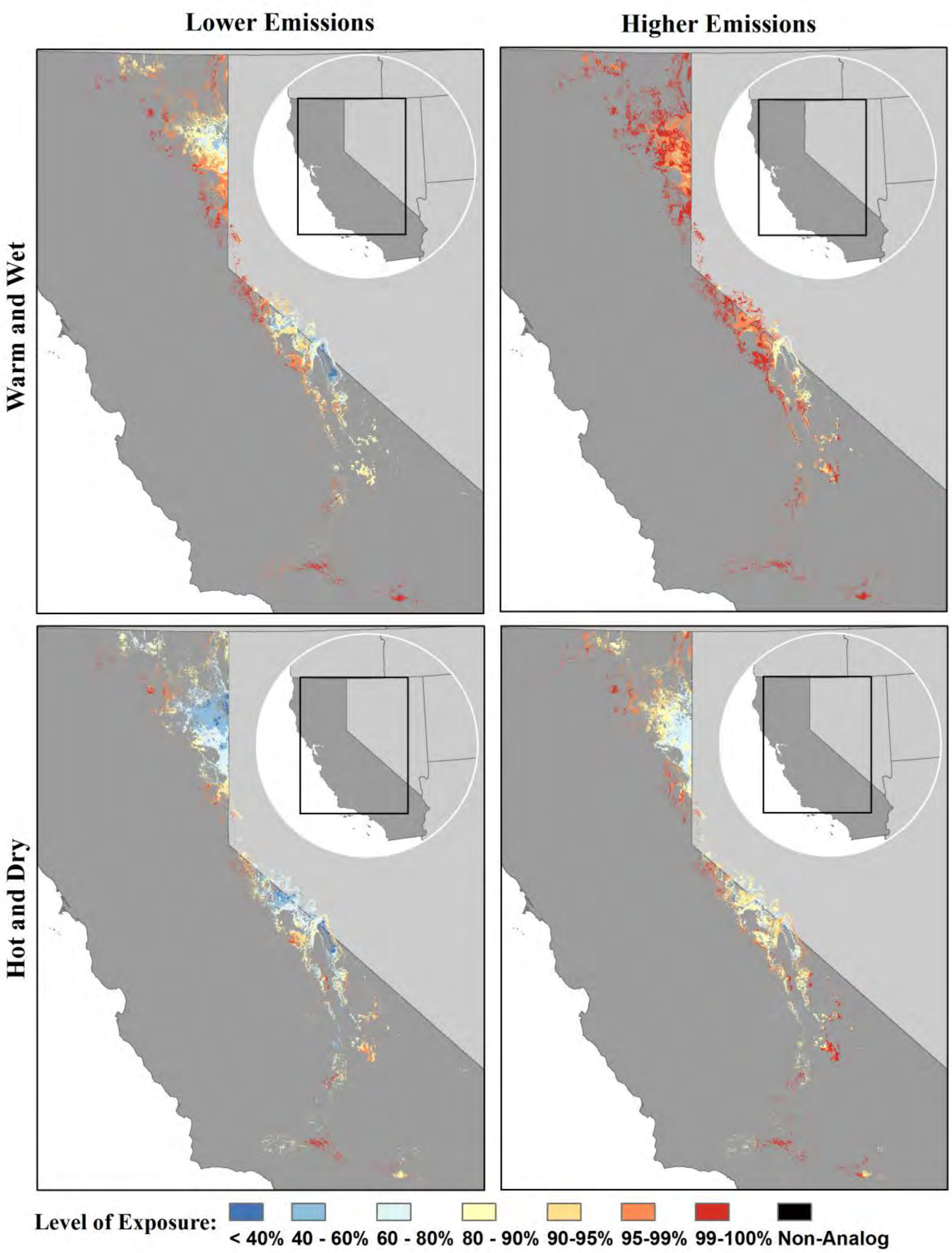


Figure 131. Maps of Projected Climate Exposure for Macrogroup 96. The climate exposure level for macrogroup 96 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 131 is derived from the PCA charts (Figure 132), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

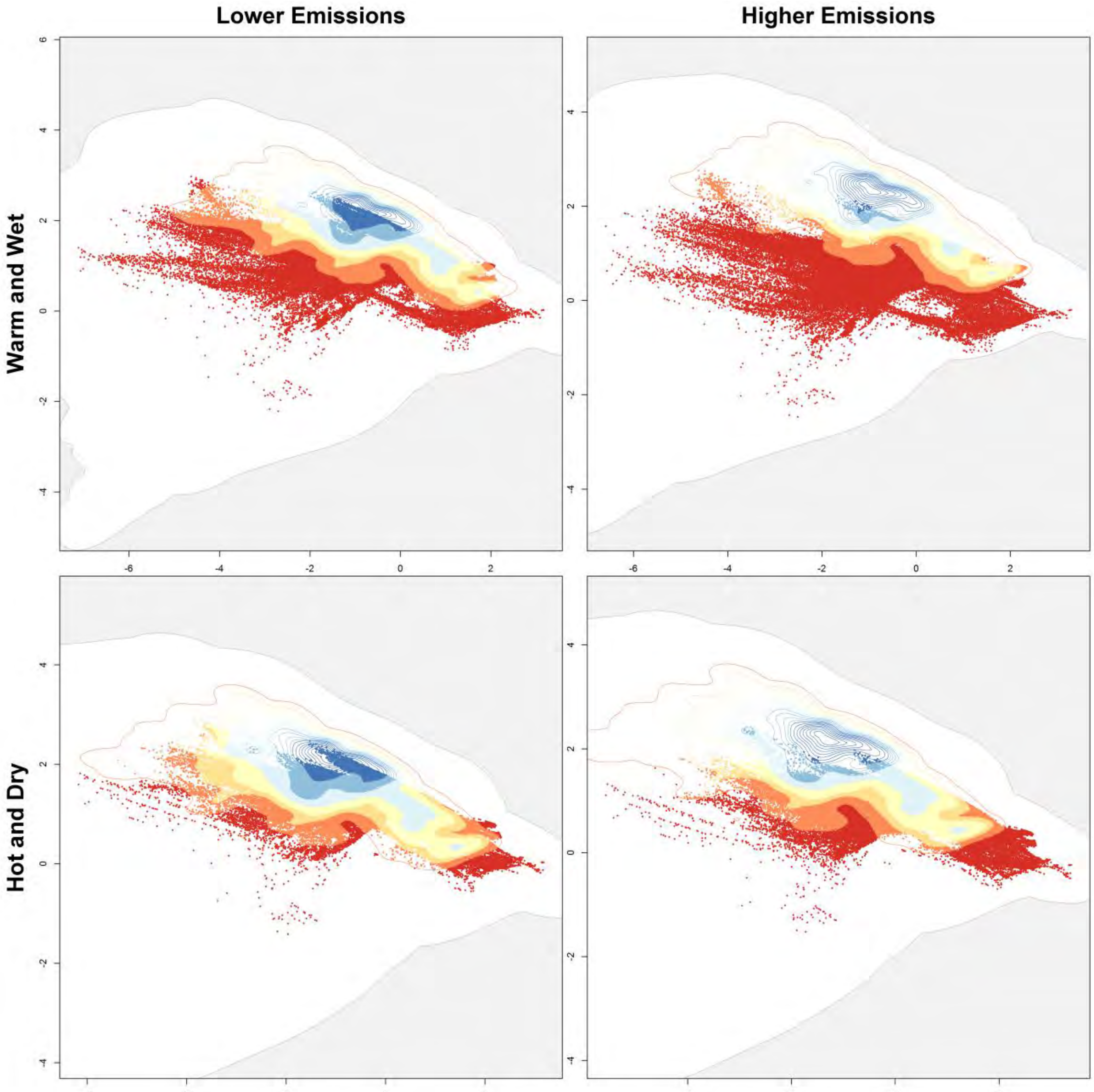


Figure 132. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 96. The PCA charts are two dimensional representations of climate exposure for macrogroup 96 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called “non-analog” conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 77). In the current time period, macrogroup 96 occupies 16,020 km^2. By the end of the century, there will be between 221 km^2 (1%) and 9,151 km^2 (57%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 1,957 km^2 (12%) and 13,829 km^2 (86%) of this type will be climatically exposed by the end of century.

Table 77. Percentage of the Current Extent of Macrogroup 96 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	3,203	3,204	3,204	3,206	1,602	799	642	161	0
1980-2010 (%)	19.99	20.00	20.00	20.01	10.00	4.99	4.01	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	1.32	10.22	25.50	25.61	14.64	6.52	7.62	8.57	0.00
2040-2069 (%)	1.11	1.30	13.13	27.33	19.52	13.56	13.44	10.60	0.00
2070-2099 (%)	0.46	0.89	3.30	13.80	21.03	20.06	25.19	15.27	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	1.04	5.03	22.83	24.96	18.05	9.48	9.18	9.43	0.00
2040-2069 (%)	0.81	0.90	5.14	19.42	22.59	17.91	20.52	12.71	0.00
2070-2099 (%)	0.00	0.02	0.22	1.15	5.39	6.91	31.37	54.95	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	5.64	12.14	34.36	22.83	10.95	5.66	6.39	2.02	NA
2040-2069 (%)	0.99	7.81	29.82	29.68	16.08	7.29	5.36	2.96	NA
2070-2099 (%)	0.26	2.94	20.21	33.72	19.59	11.07	7.81	4.40	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	10.35	18.33	30.92	18.02	9.96	5.75	5.06	1.61	NA
2040-2069 (%)	0.17	2.68	21.63	35.33	18.23	11.11	7.16	3.68	0.00
2070-2099 (%)	0.00	0.03	0.69	24.76	28.07	18.73	15.12	12.61	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 96 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 133), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 57,112 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

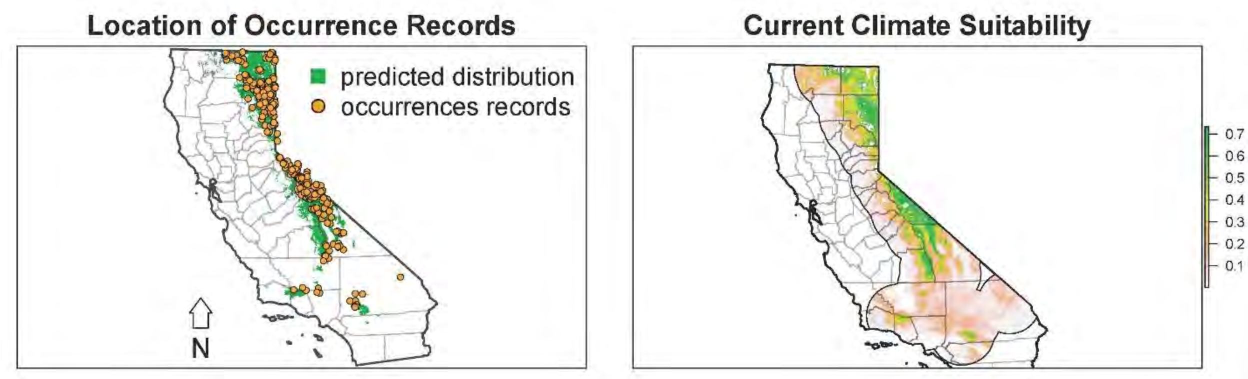


Figure 133. Map of Points Selected from the Extent of Macrogroup 96 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 96. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 96 (Figure 134). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 96, between 8,411 km^2 (15%) and 48,067 km^2 (84%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 9,044 km^2 (16%) and 48,701 km^2 (85%) will remain climatically suitable, and between 478 km^2 (1%) and 10,797 km^2 (19%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 78.

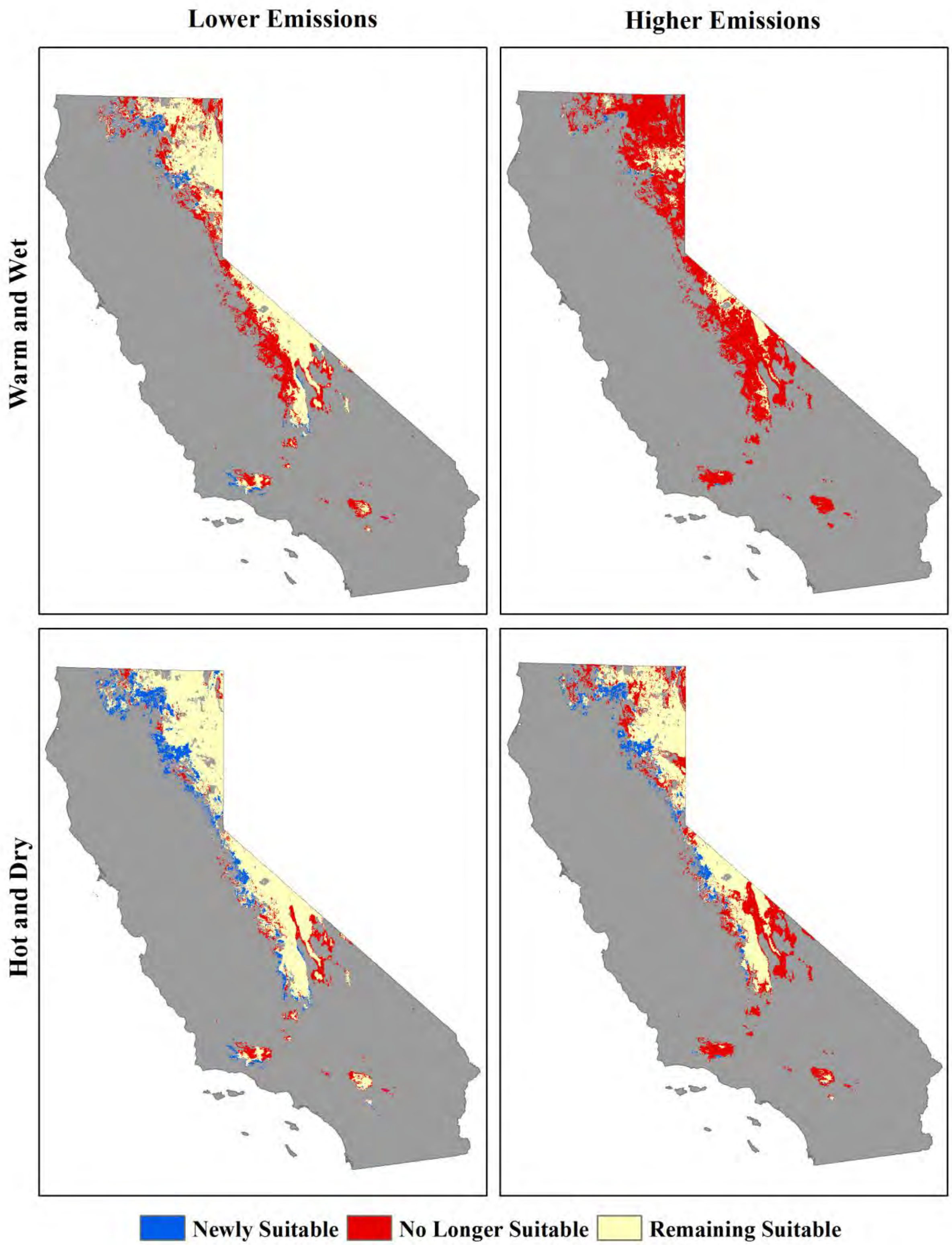


Figure 134. Maps of the Projected Climatically Suitable Range for Macrogroup 96. Maps showing the modeled climatically suitable range for macrogroup 96 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 78. Area of Projected Climatic Suitability for Macrogroup 96. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 96, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	22,273	34,839	2,854	39%	61%	5%
CNRM CM5 - RCP 8.5	48,067	9,044	478	84%	16%	1%
MIROC ESM - RCP 4.5	8,411	48,701	10,797	15%	85%	19%
MIROC ESM - RCP 8.5	21,515	35,597	6,152	38%	62%	11%

MG097: Macrogroup Western North America Dwarf Sage Shrubland and Steppe
Common Name: Great Basin Dwarf Sagebrush Scrub

This macrogroup occurs in cool desert or even high mountain settings from the Eastern Sierra, Cascades, Modoc Plateau, southward into the southern Great Basin Mountains, and the desert side of the Transverse Ranges. It is characterized by low subshrub species in the genus Artemisia (sagebrush). These species form stands on poor soils, or exposed slopes and ridges where larger sagebrush species are unable to grow.

The main species in this macrogroup include low sage (*Artemisia arbuscula* ssp *arbuscula*), Lahontan sagebrush (*A. arbuscula longicaulis*), and black sagebrush (*A. nova*). Each of these species has different ecological requirements from calcareous shallow soils, deep clay-rich soils, and shallow rocky upland soils.

The single best WHR type is low sage (LSG), a fairly close match at group level, that may allow for local stands of *Ephedra*, winter-fat, and *Ericameria* spp., which tend to overlap from the Great Basin upland scrub macrogroup.

Macrogroup 97 is comprised of approximately one WHR types for which we scored two representative dominant species. The statewide extent for the current time period cover 2,970 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 135). Using the current climate conditions for the extent of Macrogroup 97, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

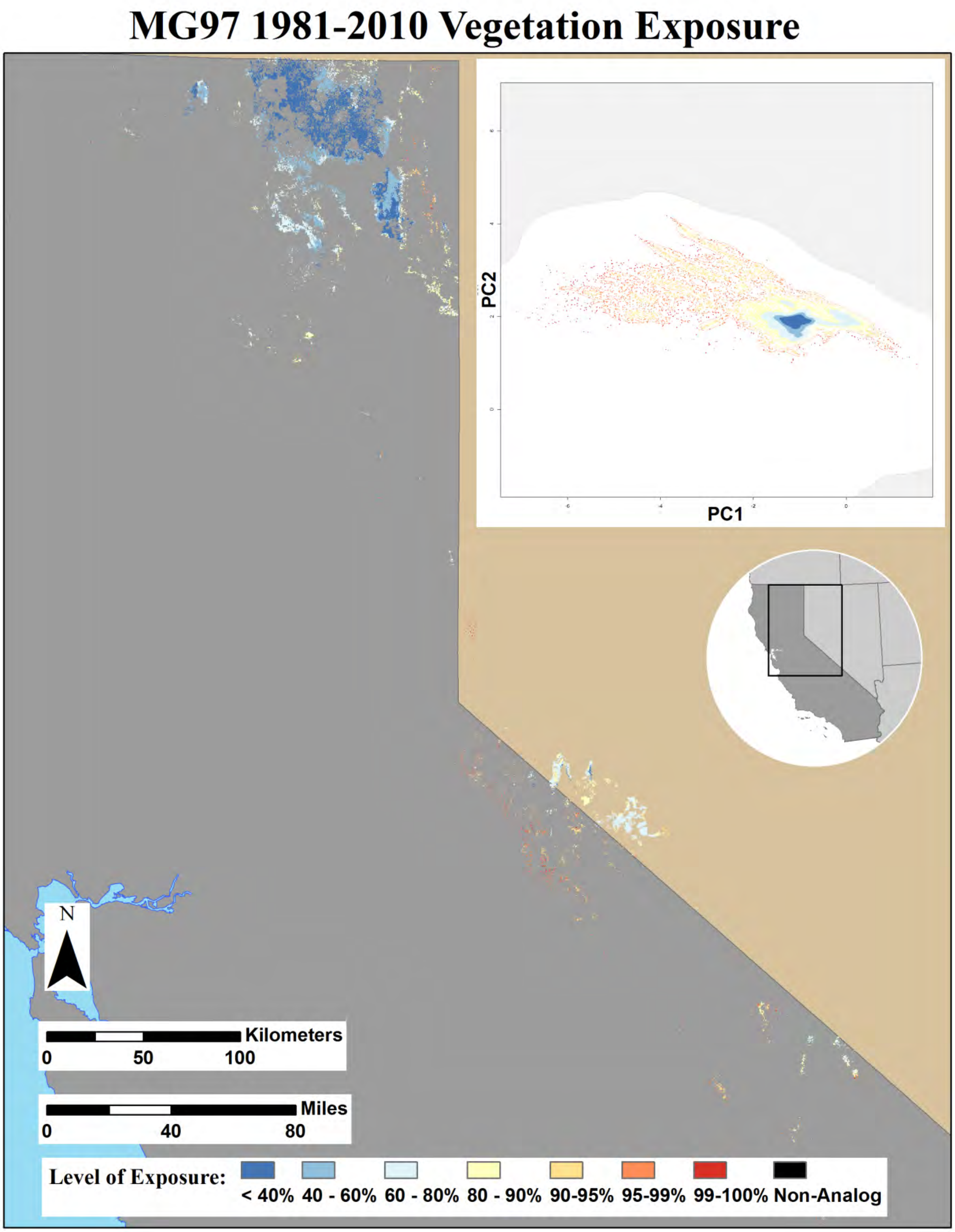


Figure 135. Map of Current Climate Suitability for Macrogroup 97. The 2015 mapped extent of macrogroup 97, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 97 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 79). The overall or grand mean for macrogroup 97 was found to be 2.33 for sensitivity and adaptive capacity.

Table 79. Sensitivity and Adaptive Capacity Rankings for Macrogroup 97. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 97.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Artemisia arbuscula	2	3	2	2	3	2	2	3	2	**2.3**
Artemisia nova	2	3	2	3	3	2	2	2	2	**2.3**
Mean	**2.00**	**3.00**	**2.00**	**2.50**	**3.00**	**2.00**	**2.00**	**2.50**	**2.00**	
Grand Mean	**2.33**				**Mean**	**2.42**		**Mean**	**2.17**	

Projected Climate Exposure

The future climate exposure for macrogroup 97 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 136).

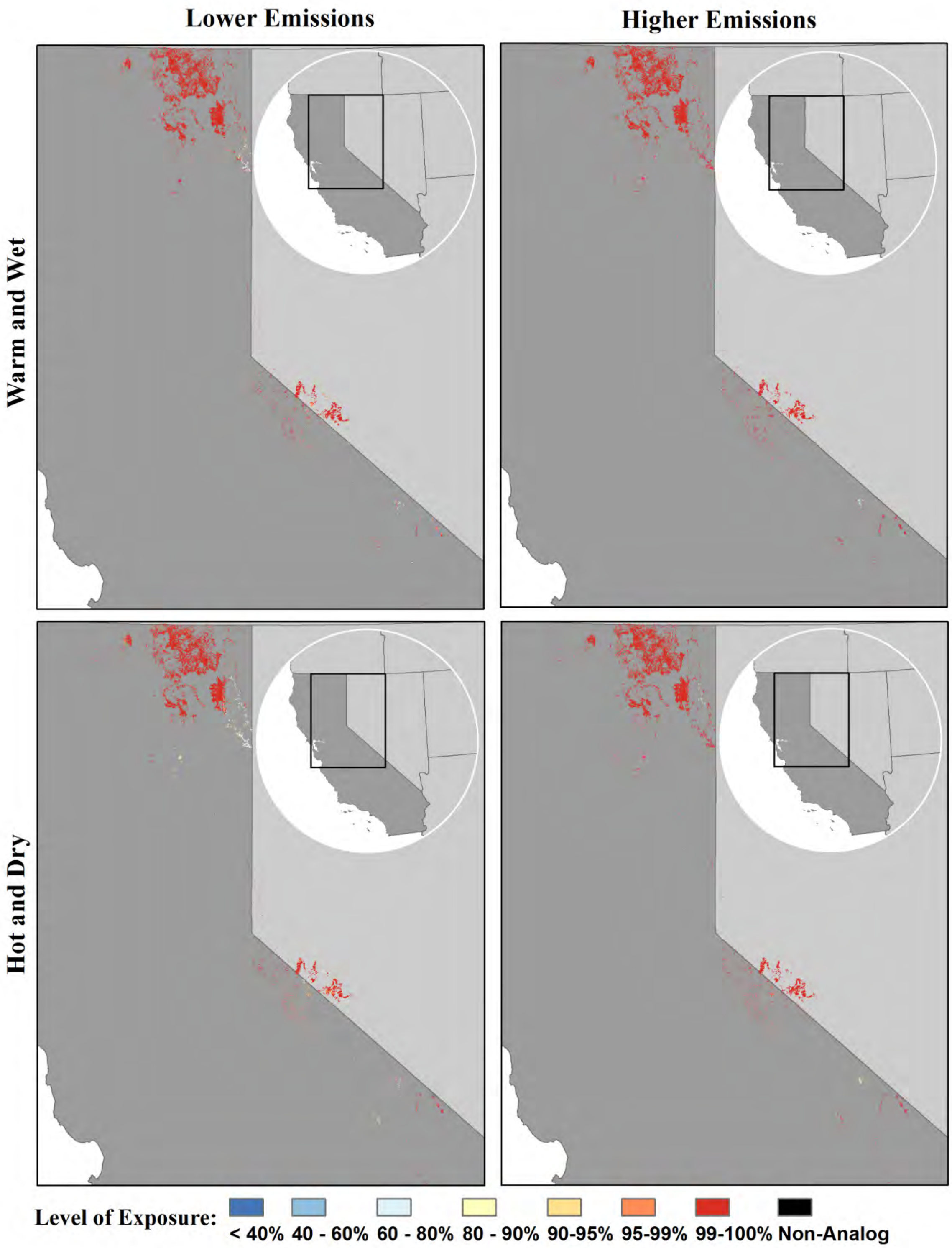


Figure 136. Maps of Projected Climate Exposure for Macrogroup 97. The climate exposure level for macrogroup 97 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 136 is derived from the PCA charts (Figure 137), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

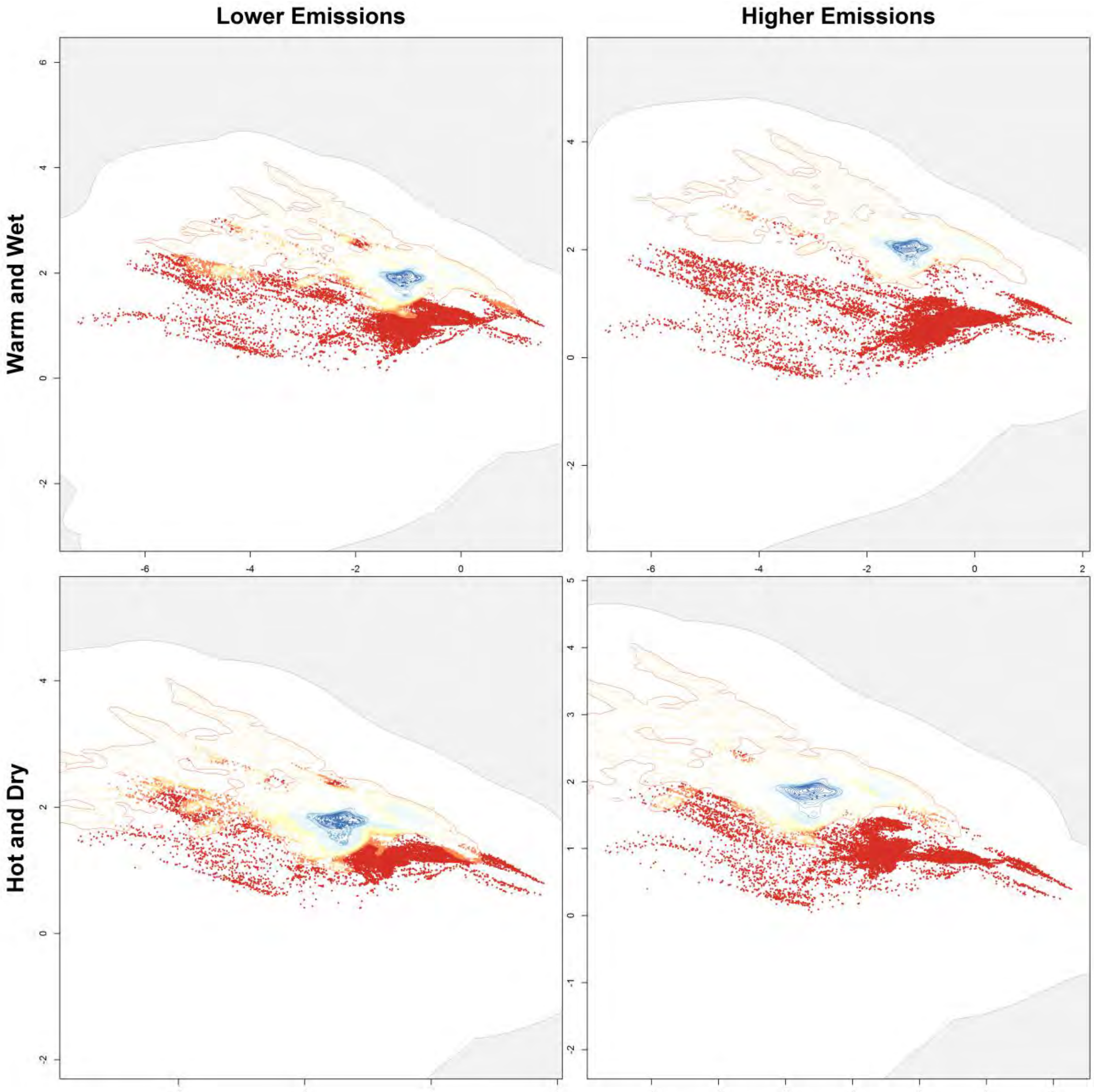


Figure 137. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 97. The PCA charts are two dimensional representations of climate exposure for macrogroup 97 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 80). In the current time period, macrogroup 97 occupies 2,970 km^2. By the end of the century, there will be between 10 km^2 (0%) and 85 km^2 (3%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 2,748 km^2 (93%) and 2,954 km^2 (99%) of this type will be climatically exposed by the end of century.

Table 80. Percentage of the Current Extent of Macrogroup 97 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	594	594	594	594	297	148	119	30	0
1980-2010 (%)	20.00	20.00	20.00	19.99	10.01	5.00	4.01	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	0.65	1.70	12.30	29.47	30.36	6.95	8.04	10.54	0.00
2040-2069 (%)	0.00	0.29	1.25	1.61	3.62	13.49	23.68	56.07	0.00
2070-2099 (%)	0.02	0.04	0.10	0.79	1.31	1.19	3.81	92.74	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.48	1.19	3.40	14.55	32.57	17.46	12.48	17.85	0.00
2040-2069 (%)	0.00	0.03	0.48	1.27	1.64	1.23	6.81	88.53	0.00
2070-2099 (%)	0.01	0.03	0.05	0.23	0.06	0.13	0.23	99.25	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	0.18	2.75	43.94	24.73	11.64	4.97	6.06	5.74	NA
2040-2069 (%)	0.48	0.94	2.06	3.65	4.55	5.07	20.46	62.80	NA
2070-2099 (%)	0.13	0.18	0.29	2.27	2.53	2.08	5.32	87.21	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	8.39	32.08	25.63	13.55	7.90	2.91	4.80	4.74	NA
2040-2069 (%)	0.12	0.20	0.67	2.62	2.95	1.81	12.77	78.85	0.00
2070-2099 (%)	0.02	0.01	0.03	0.37	0.64	0.42	0.96	97.55	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 97 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 138), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 18,346 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

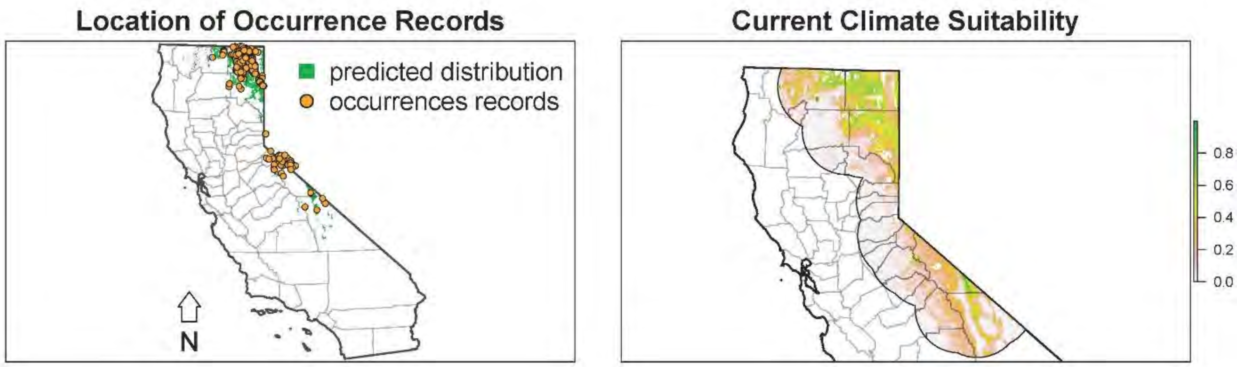


Figure 138. Map of Points Selected from the Extent of Macrogroup 97 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 97. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 97 (Figure 139). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 97, between 18,320 km^2 (99.9%) and 18,346 km^2 (100%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 0 km^2 (0%) and 26 km^2 (0.1%) will remain climatically suitable, and between 0 km^2 (0%) and 1 km^2 (0%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 81.

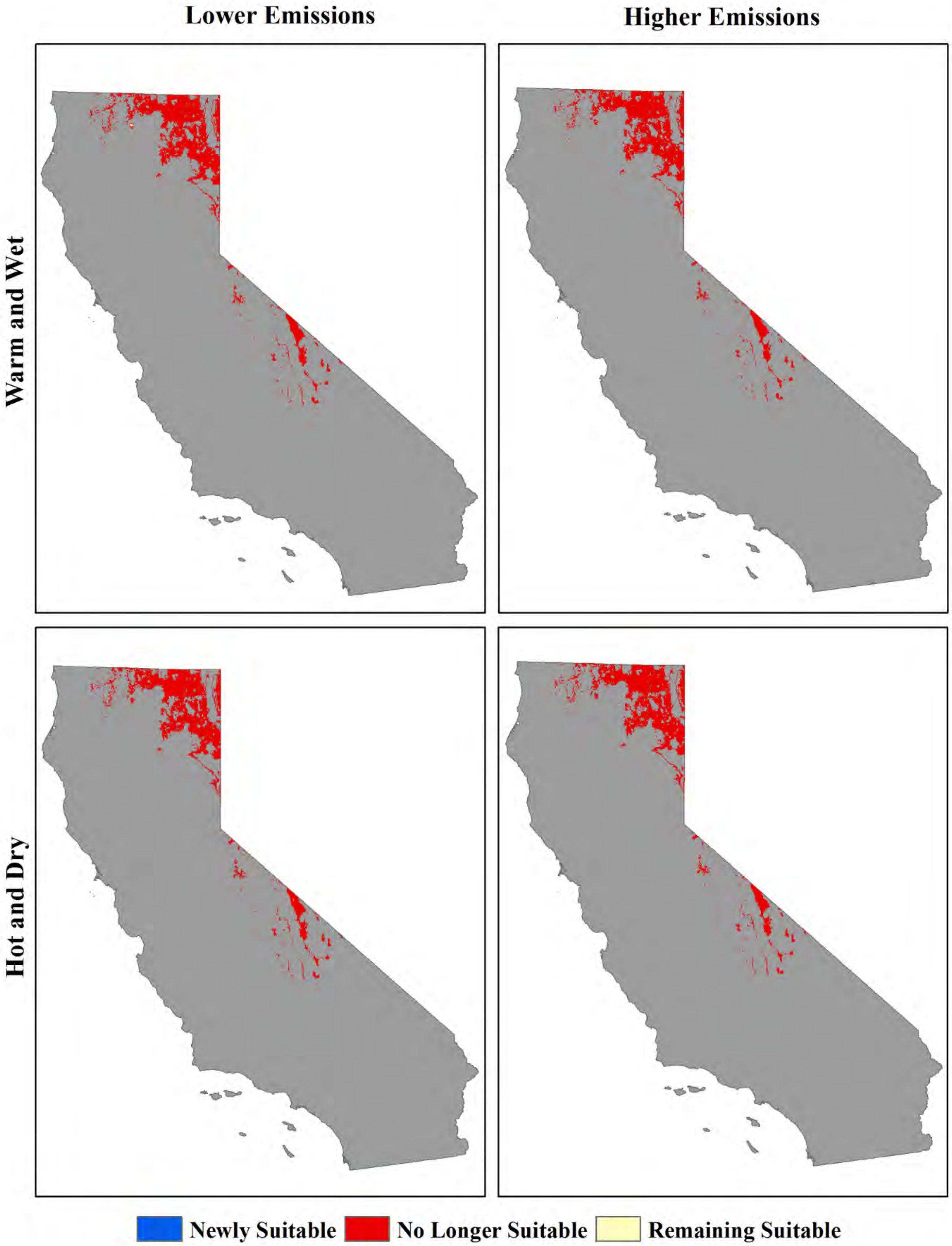


Figure 139. Maps of the Projected Climatically Suitable Range for Macrogroup 97. Maps showing the modeled climatically suitable range for macrogroup 97 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 81. Area of Projected Climatic Suitability for Macrogroup 97. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 97, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	18,320	26	1	100%	0%	0%
CNRM CM5 - RCP 8.5	18,341	5	0	100%	0%	0%
MIROC ESM - RCP 4.5	18,339	7	0	100%	0%	0%
MIROC ESM - RCP 8.5	18,346	0	0	100%	0%	0%

MG098: Macrogroup Inter-Mountain Dry Shrubland and Grassland
Common Name: Great Basin Upland Scrub

This macrogroup occurs in the cooler Mojave Desert Mountains, the uplands of the Great Basin and Modoc Plateau, and in isolated pockets of the inner South Coast Ranges such as Temblor Range and Carrizo Plains. It is composed of shrublands with cool desert affinities but has been segregated from the short and tall species of sagebrush (*Artemisia* spp.). Most of the vegetation in this macrogroup occurs well beyond the eastern borders of California into the Great Basin Province. Successional relationships exist between the several groups of alliances in this macrogroup, some are disturbance followers and may also occur in episodic washes. Some are persistent resprouting shrubs, which recover well after fire, and some are fire and browsing-sensitive with longer recovery times. Some perennial desert grasslands are also part of this macrogroup and increase with short fire intervals.

Fire-sensitive long-lived species include blackbrush (*Coleogyne ramosissima*) and mountain mahogany (*Cercocarpus ledifolius*, *C. intricatus*). Species which recover well from disturbance include spiny hop-sage (*Grayia spinosa*), winter-fat (*Kraschinnikovia lanata*), Mormon-tea (*Ephedra* spp.), and some species of bitterbrush (*Purshia* spp.). Shorter fire intervals are conducive to emphasizing perennial grass cover such as desert needlegrass (*Stipa speciosa*), or desert rice grass (*Stipa hymenoides*; in sandy areas).

The single best WHR type for this macrogroup is bitterbrush (BBR), which can also include Parry rabbitbrush, antelope bitterbrush (*Ericameria parryi*), rubber rabbitbrush (*Ericameria nauseosa*), blackstem rabbitbrush (*Ericameria paniculata*), bluebunch wheatgrass (*Elymus spicatus*), cliffrose (*Purshia stansburyana*), and scrub and curlleaf mountain mahogany (*Cercocarpus ledifolius*) alliances. Also partially included in this macrogroup is the sagebrush (SGB) and low sage (LSG) habitat types.

Macrogroup 98 is comprised of approximately three WHR types for which we scored six representative dominant species. The statewide extent for the current time period cover 1,650 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 140). Using the current climate conditions for the extent of Macrogroup 98, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

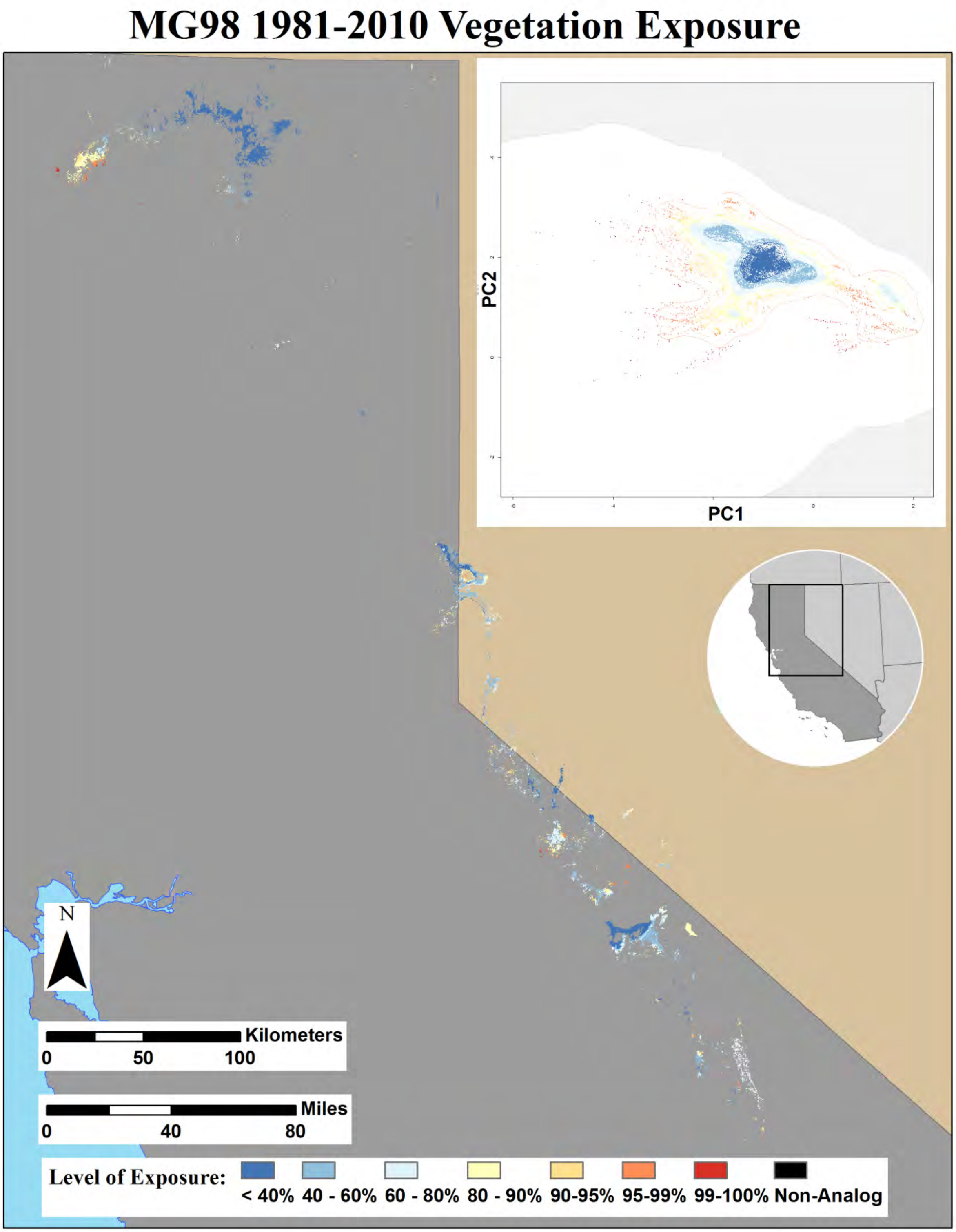


Figure 140. Map of Current Climate Suitability for Macrogroup 98. The 2015 mapped extent of macrogroup 98, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors **in the inset and the map refer to the same categories of climate exposure.**

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 98 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six

sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 82). The overall or grand mean for macrogroup 98 was found to be 2.52 for sensitivity and adaptive capacity.

Table 82. Sensitivity and Adaptive Capacity Rankings for Macrogroup 98. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 98.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Grayia spinosa	2	2	2	2	5	2	1	3	3	**2.4**
Kraschinnikovia lanata	2	3	2	2	3	2	1	1	3	**2.1**
Ephedra sp.	2	3	4	3	3	3	5	2	2	**3.0**
Coleogyne ramosissima	4	4	1	2	2	2	1	1	3	**2.2**
Cercocarpus ledifolius	2	3	2	2	3	5	1	1	3	**2.4**
Ericameria nauseosa	4	3	3	3	3	1	3	5	1	**2.9**
Mean	**2.67**	**3.00**	**2.33**	**2.33**	**3.17**	**2.50**	**2.00**	**2.17**	**2.50**	
Grand Mean	**2.52**				**Mean**	**2.7**		**Mean**	**2.2**	

Projected Climate Exposure

The future climate exposure for macrogroup 98 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 141).

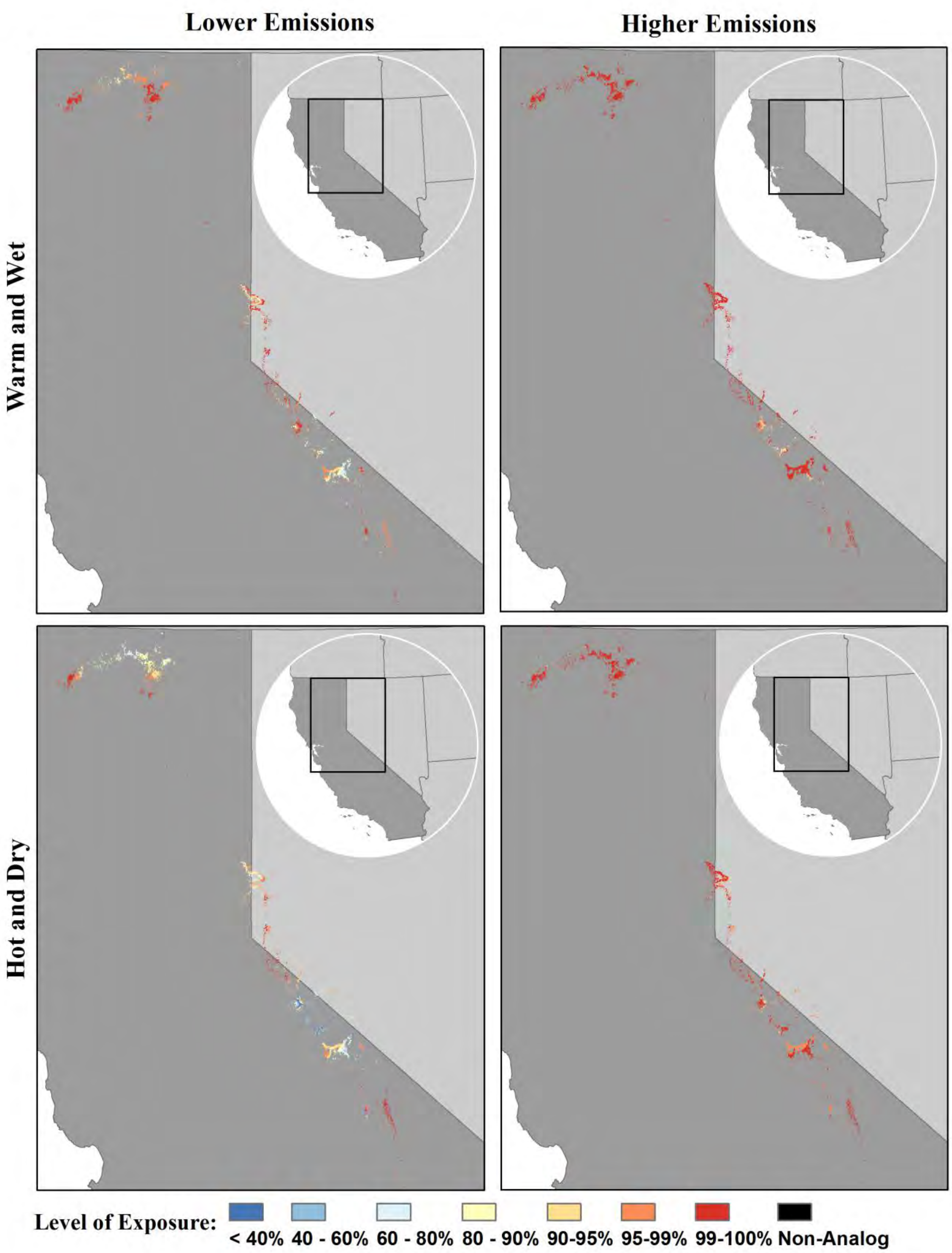


Figure 141. Maps of Projected Climate Exposure for Macrogroup 98. The climate exposure level for macrogroup 98 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 141 is derived from the PCA charts (Figure 142), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

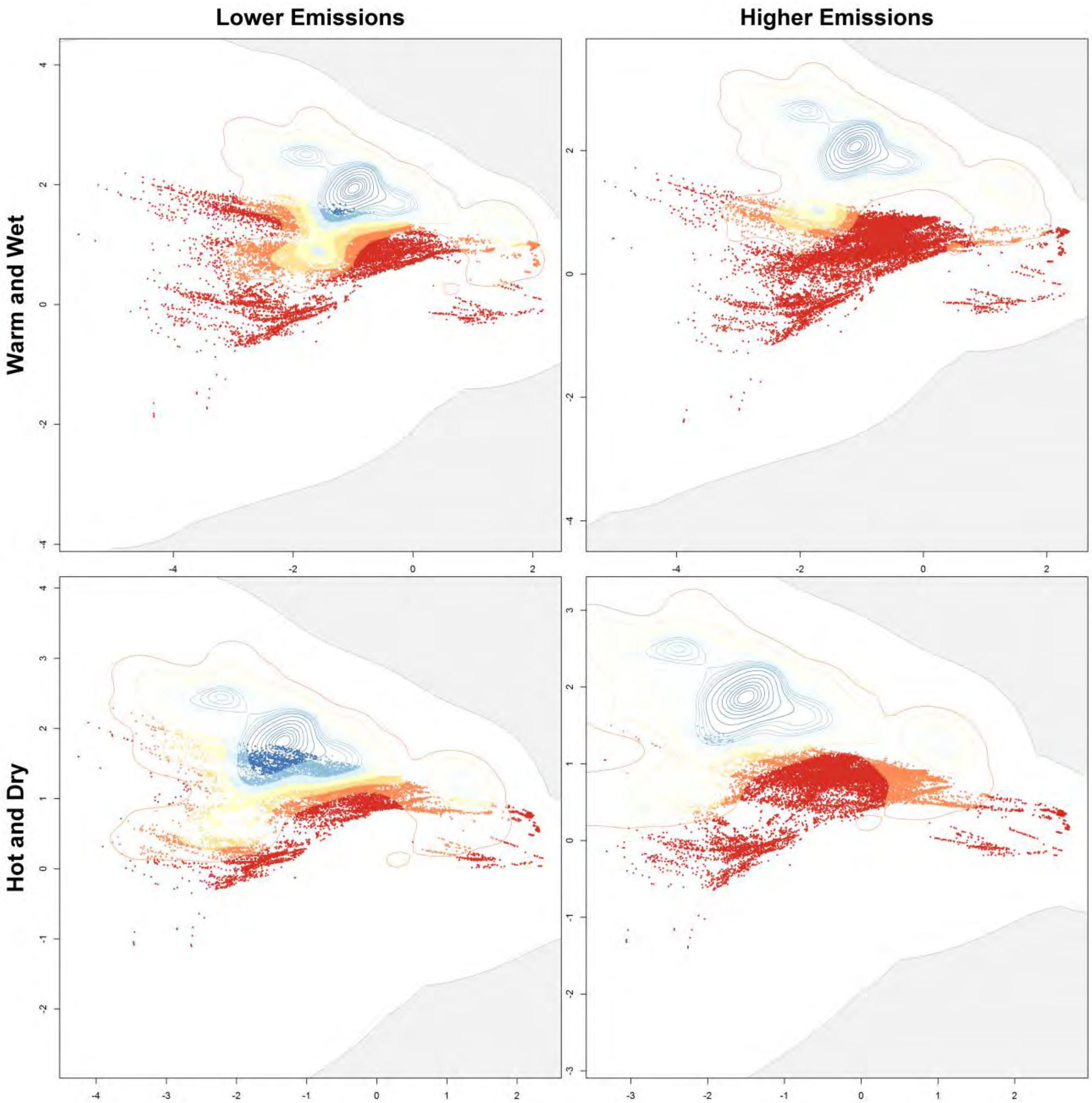


Figure 142. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 98. The PCA charts are two dimensional representations of climate exposure for macrogroup 98 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 83). In the current time period, macrogroup 98 occupies 1,650 km^2. By the end of the century, there will be between 5 km^2 (0%) and 409 km^2 (25%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 595 km^2 (36%) and 1,610 km^2 (98%) of this type will be climatically exposed by the end of century.

Table 83. Percentage of the Current Extent of Macrogroup 98 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	330	330	330	330	165	83	66	17	0
1980-2010 (%)	20.01	20.00	20.00	20.00	10.00	5.00	3.99	1.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.00	18.08	18.58	13.64	11.90	8.12	12.26	15.43	0.00
2040-2069 (%)	0.10	6.39	8.96	12.55	16.84	21.59	15.67	17.89	0.00
2070-2099 (%)	0.00	0.21	1.94	7.52	9.69	13.45	29.23	37.95	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	1.18	10.45	12.63	19.23	15.94	9.56	12.71	18.31	0.00
2040-2069 (%)	0.01	1.52	4.67	6.68	11.41	16.02	31.34	28.35	0.00
2070-2099 (%)	0.00	0.00	0.00	0.33	1.55	3.18	6.38	88.56	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	5.42	33.75	14.96	9.17	10.09	10.93	9.58	6.11	NA
2040-2069 (%)	1.60	9.95	31.96	18.27	9.24	8.89	11.24	8.83	NA
2070-2099 (%)	0.17	3.03	6.63	14.97	19.42	19.72	17.19	18.88	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	13.42	33.08	13.06	9.40	7.86	10.44	8.04	4.70	NA
2040-2069 (%)	0.11	2.80	10.03	22.22	16.57	16.43	15.67	16.17	0.00
2070-2099 (%)	0.00	0.00	0.16	0.30	0.64	1.31	20.78	76.81	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 98 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 143), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 43,953 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

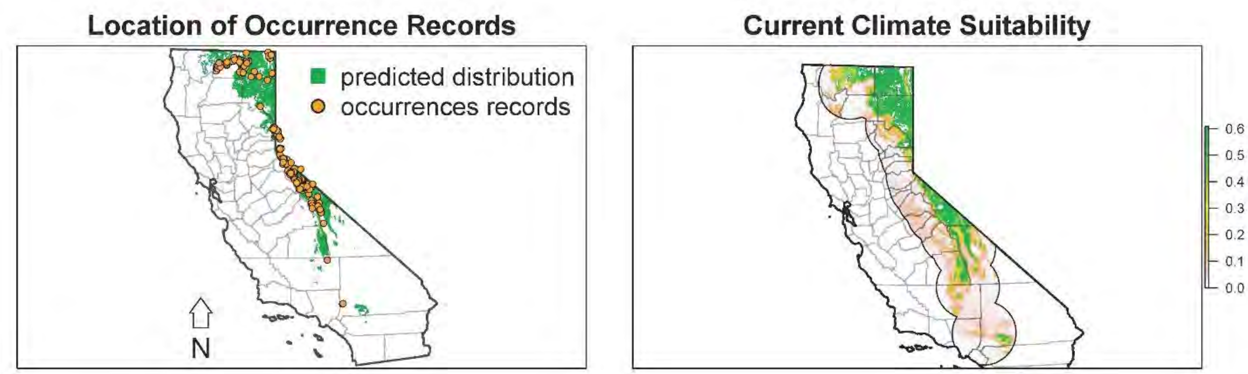


Figure 143. Map of Points Selected from the Extent of Macrogroup 98 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 98. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 98 (Figure 144). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 98, between 7,147 km^2 (16%) and 32,863 km^2 (75%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 11,090 km^2 (25%) and 36,806 km^2 (84%) will remain climatically suitable, and between 160 km^2 (0%) and 8,634 km^2 (20%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 84.

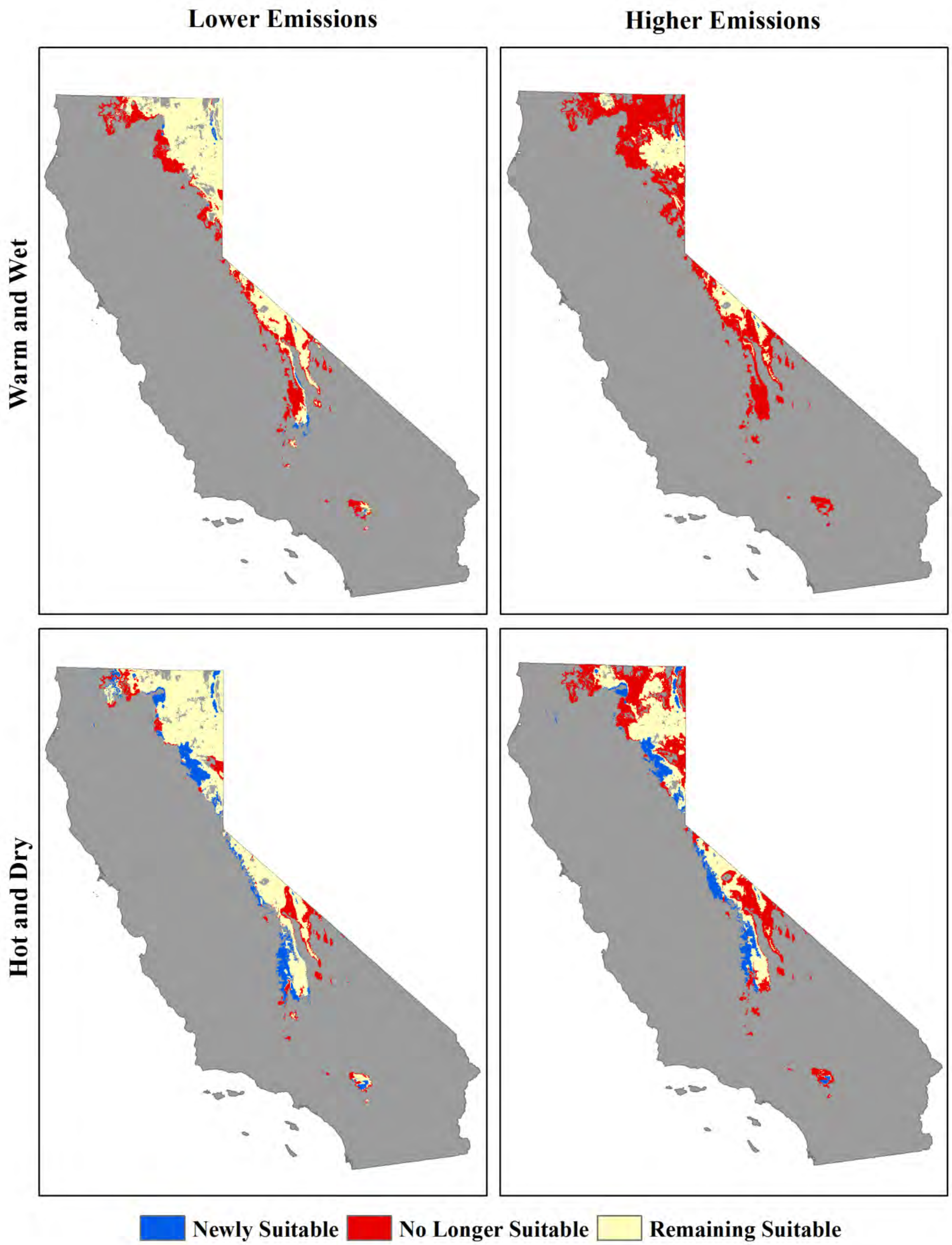


Figure 144. Maps of the Projected Climatically Suitable Range for Macrogroup 98. Maps showing the modeled climatically suitable range for macrogroup 98 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 84. Area of Projected Climatic Suitability for Macrogroup 98. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 98, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	14,844	29,109	923	34%	66%	2%
CNRM CM5 - RCP 8.5	32,863	11,090	160	75%	25%	0%
MIROC ESM - RCP 4.5	7,147	36,806	8,634	16%	84%	20%
MIROC ESM - RCP 8.5	22,510	21,443	8,197	51%	49%	19%

MG101: Macrogroup Vancouverian Alpine Scrub, Forb Meadow, and Grassland Common Name: Alpine Vegetation

This macrogroup is representative of the state's alpine zone in the Sierra, Cascades, White, Sweetwater, and Klamath Mountains. It either occurs above timberline or is found localized within subalpine areas in cold air drainages (e.g. North-facing slopes, often near long persisting snow banks). The characteristic species are either herbaceous (many are cushion plants, some tufted or rhizomatous graminoids) or low prostrate or dwarf shrubs. Different groups segregate based on substrate type (scree, talus, fellfield) and moisture regime (snowbank, fellfield, etc.).

Snowbank indicator species include white heather (*Cassiope mertensiana*), several species of saxifrage (*Saxifraga* sp.), and sedge (*Carex helleri*, *C. spectabilis*). Felfield indicators include alpine reedgrass (*Calamagrostis purpurescens*), Congdon sedge (*Carex congdoni*), alpine goldenbush (*Ericameria discoidea*), and Phlox species, among others. Alpine turf indicators include dwarf willows (*Salix petrophila*, *S. nivalis*), dwarf huckleberry (*Vaccinium cespitosum*), Muir's hairgrass (*Calamagrostis muriana*), and several sedges (*Carex* spp.)

Alpine dwarf-scrub (ADS) is the best single analog to this macrogroup and fits the general description.

Macrogroup 101 is comprised of approximately one WHR type for which we scored five representative dominant species. The statewide extent for the current time period cover 506 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 145). Using the current climate conditions for the extent of Macrogroup 101, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

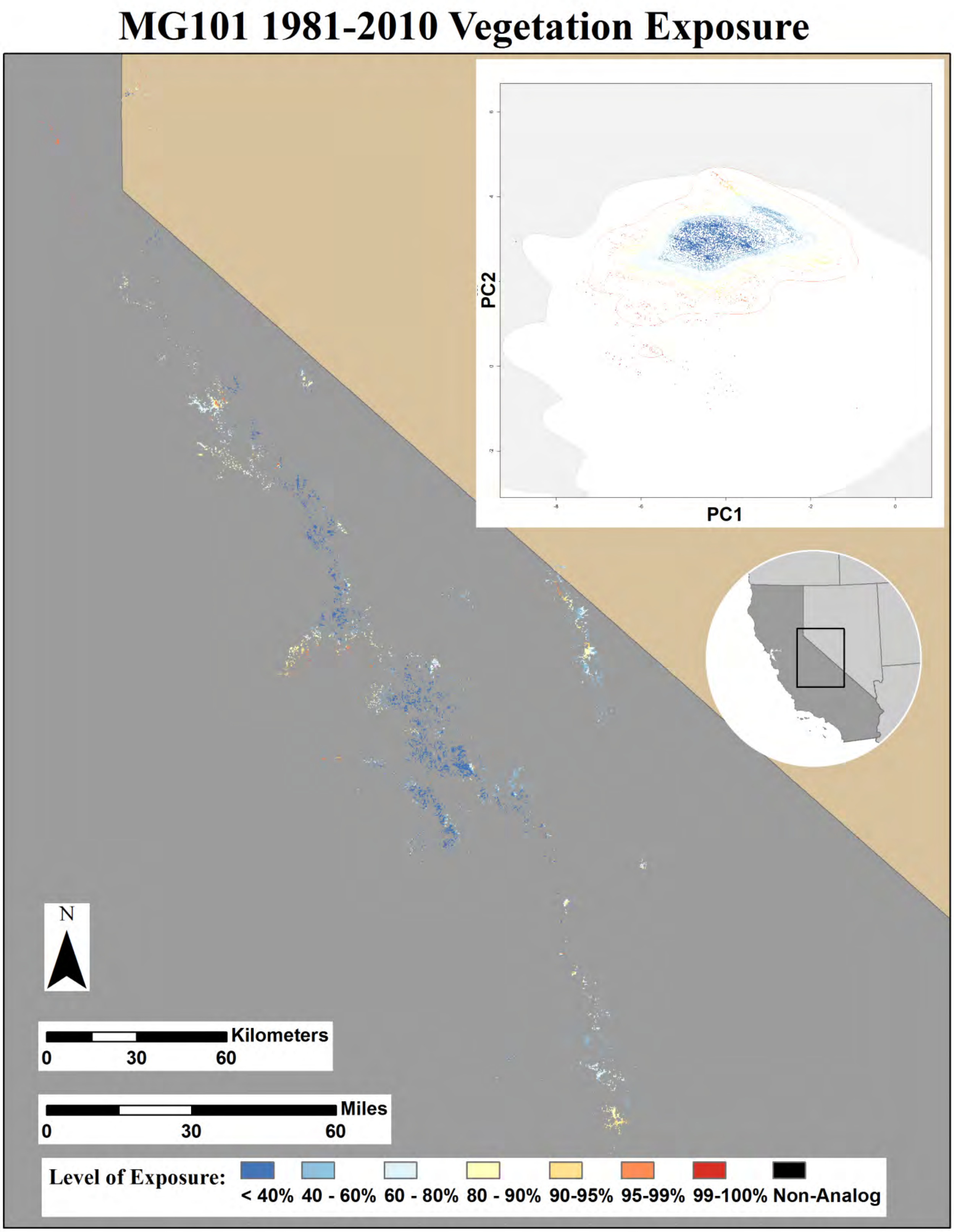


Figure 145. Map of Current Climate Suitability for Macrogroup 101. The 2015 mapped extent of macrogroup 101, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 101 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 85). The overall or grand mean for macrogroup 101 was found to be 2.76 for sensitivity and adaptive capacity.

Table 85. Sensitivity and Adaptive Capacity Rankings for Macrogroup 101. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 101. *Cassiope mertensiana* is named, but the life history data were not available. *Carex helleri* and *Carex spectabilis* are high-elevation *Carex* species.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Holodicus discolor	2	3	4	2	4	2	5	4	5	**3.4**
Carex helleri	2	2	4	2	3	3	5	3	1	**2.8**
Carex spectabilis	2	2	3	2	2	3	3	3	1	**2.3**
Calamagrostis purpurascens	3	3	3	2	2	3	3	3	1	**2.6**
Calamagrostis muiriana	2	3	4	3	3	2	3	3	1	**2.7**
Mean	**2.20**	**2.60**	**3.60**	**2.20**	**2.80**	**2.60**	**3.80**	**3.20**	**1.80**	
Grand Mean	**2.76**				**Mean**	**2.67**		**Mean**	**2.93**	

Projected Climate Exposure

The future climate exposure for macrogroup 101 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 146).

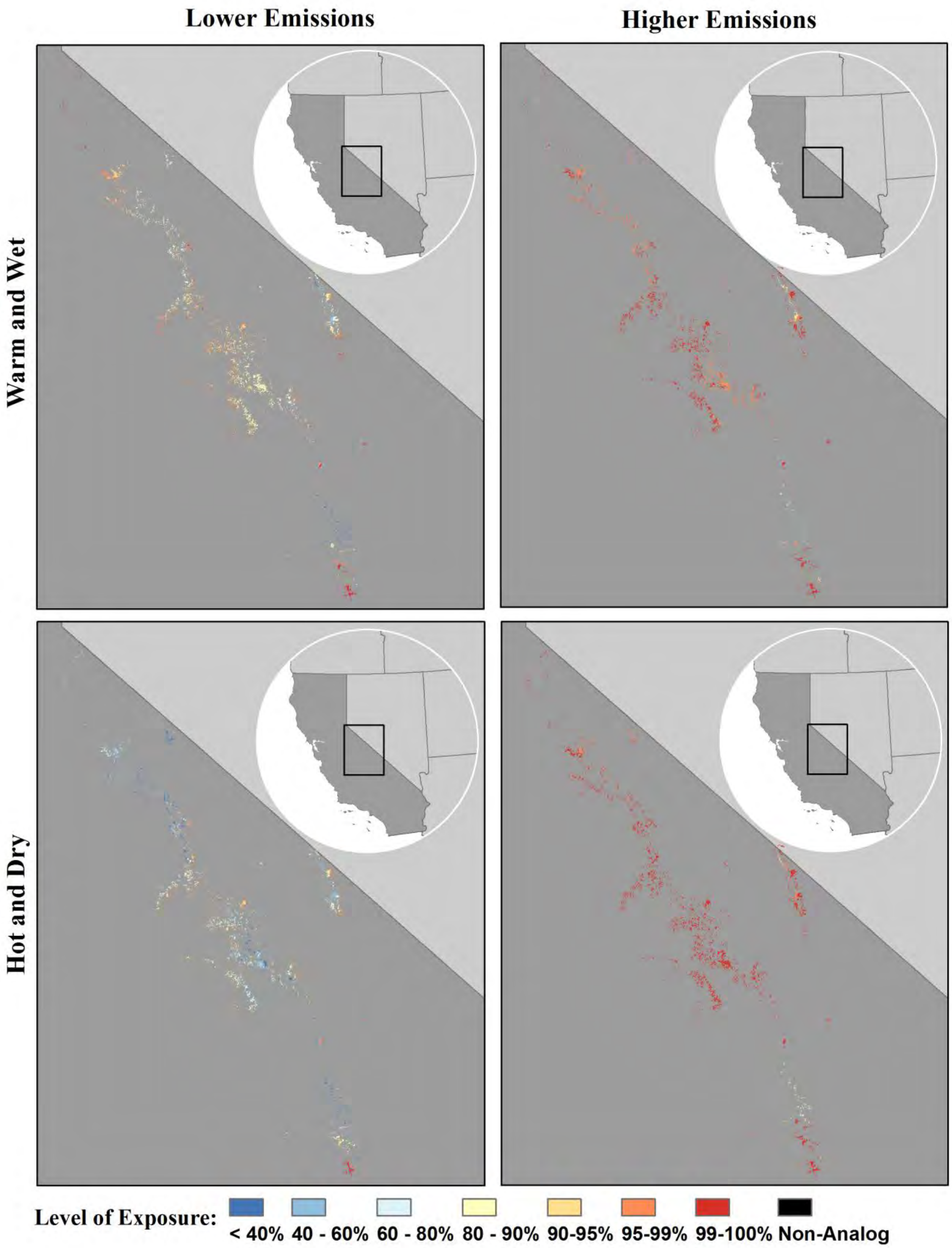


Figure 146. Maps of Projected Climate Exposure for Macrogroup 101. The climate exposure level for macrogroup 101 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 146 is derived from the PCA charts (Figure 147), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

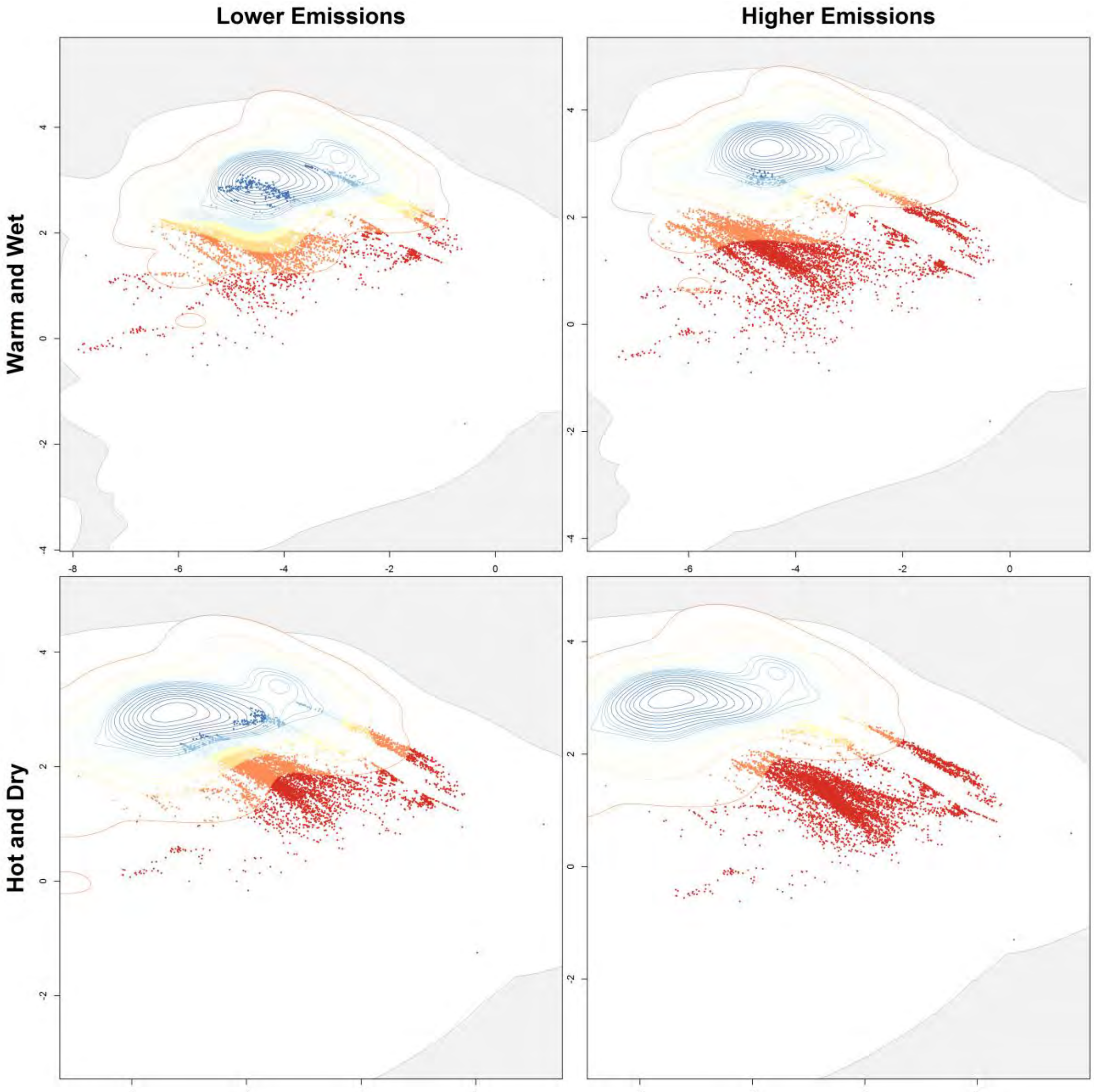


Figure 147. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 101. The PCA charts are two dimensional representations of climate exposure for macrogroup 101 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 86). In the current time period, macrogroup 101 occupies 506 km^2. By the end of the century, there will be between 0 km^2 (0%) and 86 km^2 (17%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 169 km^2 (33%) and 489 km^2 (97%) of this type will be climatically exposed by the end of century.

Table 86. Percentage of the Current Extent of Macrogroup 101 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	101	101	101	101	51	25	20	5	0
1980-2010 (%)	19.99	20.01	19.99	20.01	10.00	5.00	3.99	0.99	0.01
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.36	9.62	25.76	35.71	8.87	7.06	8.87	1.74	0.00
2040-2069 (%)	2.33	1.38	12.92	38.32	17.44	9.36	11.75	6.48	0.00
2070-2099 (%)	1.89	1.61	2.19	11.38	24.42	25.02	21.62	11.87	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	1.92	1.66	16.13	39.50	19.37	8.77	10.11	2.54	0.00
2040-2069 (%)	2.46	0.98	4.74	26.82	17.24	18.70	18.21	10.85	0.00
2070-2099 (%)	0.00	0.27	1.40	1.28	0.85	2.22	32.24	61.74	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	4.35	12.11	21.32	19.88	12.27	13.81	12.72	3.53	NA
2040-2069 (%)	0.85	5.85	5.63	9.69	9.31	18.42	37.58	12.66	NA
2070-2099 (%)	0.00	1.43	2.79	4.88	4.67	8.96	38.94	38.33	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	6.14	16.72	17.08	18.41	11.38	12.24	14.32	3.70	NA
2040-2069 (%)	0.00	0.86	2.33	3.98	4.32	6.84	35.54	46.13	0.00
2070-2099 (%)	0.00	0.00	0.00	0.04	1.63	1.73	6.74	89.86	0.00

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 101 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 148), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 11,499 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

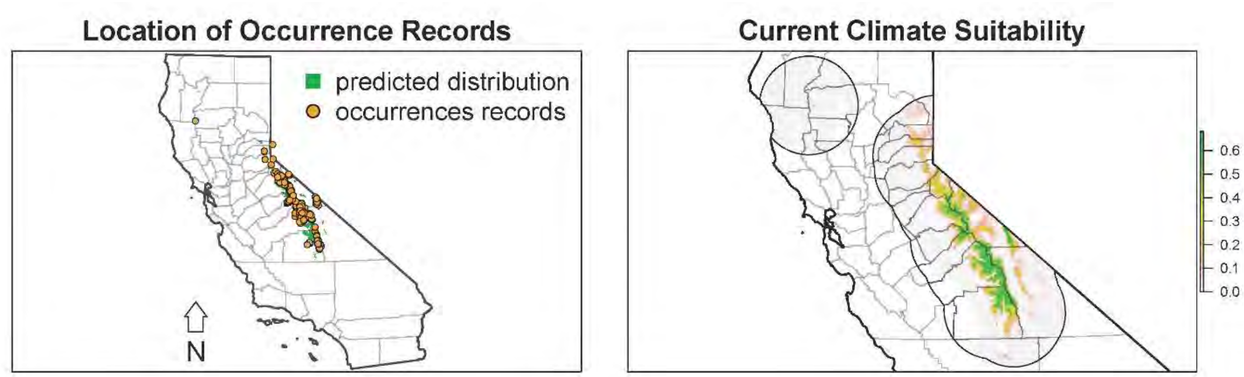


Figure 148. Map of Points Selected from the Extent of Macrogroup 101 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 101. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 101 (Figure 149). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 101, between 5,442 km^2 (47%) and 11,293 km^2 (98%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 206 km^2 (2%) and 6,057km^2 (53%) will remain climatically suitable, and between 0 km^2 (0%) and 56 km^2 (0.5%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 87.

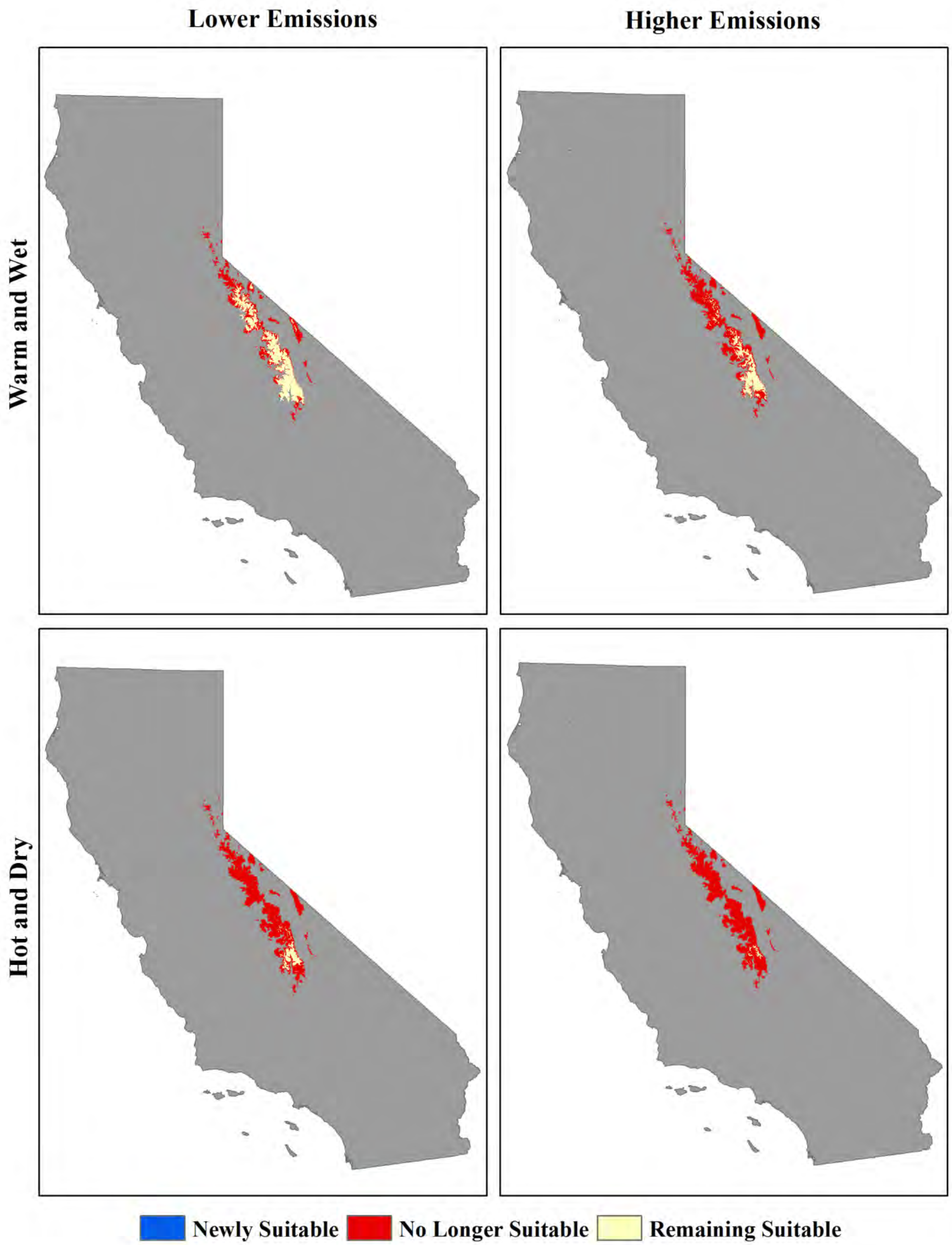


Figure 149. Maps of the Projected Climatically Suitable Range for Macrogroup 101. Maps showing the modeled climatically suitable range for macrogroup 101 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 87. Area of Projected Climatic Suitability for Macrogroup 101. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 101, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	5,442	6,057	56	47%	53%	0%
CNRM CM5 - RCP 8.5	8,740	2,759	0	76%	24%	0%
MIROC ESM - RCP 4.5	10,430	1,069	0	91%	9%	0%
MIROC ESM - RCP 8.5	11,293	206	0	98%	2%	0%

MG106: Macrogroup Temperate Pacific Intertidal Shore
Common Name: Brackish (Estuarine) Submerged Aquatic Vegetation

This macrogroup is poorly defined currently in CA, but should include both hard and soft bottom intertidal settings.

A likely indicator species would be eelgrass (*Zostera pacifica*), and a number of macro-algae species.

Estuarine (EST) is the best WHR type for this macrogroup.

Macrogroup 106 is comprised of approximately one WHR type for which we scored zero representative dominant species. The statewide extent for the current time period cover 53,263 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 150). Using the current climate conditions for the extent of Macrogroup 106, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

MG106 1981-2010 Vegetation Exposure

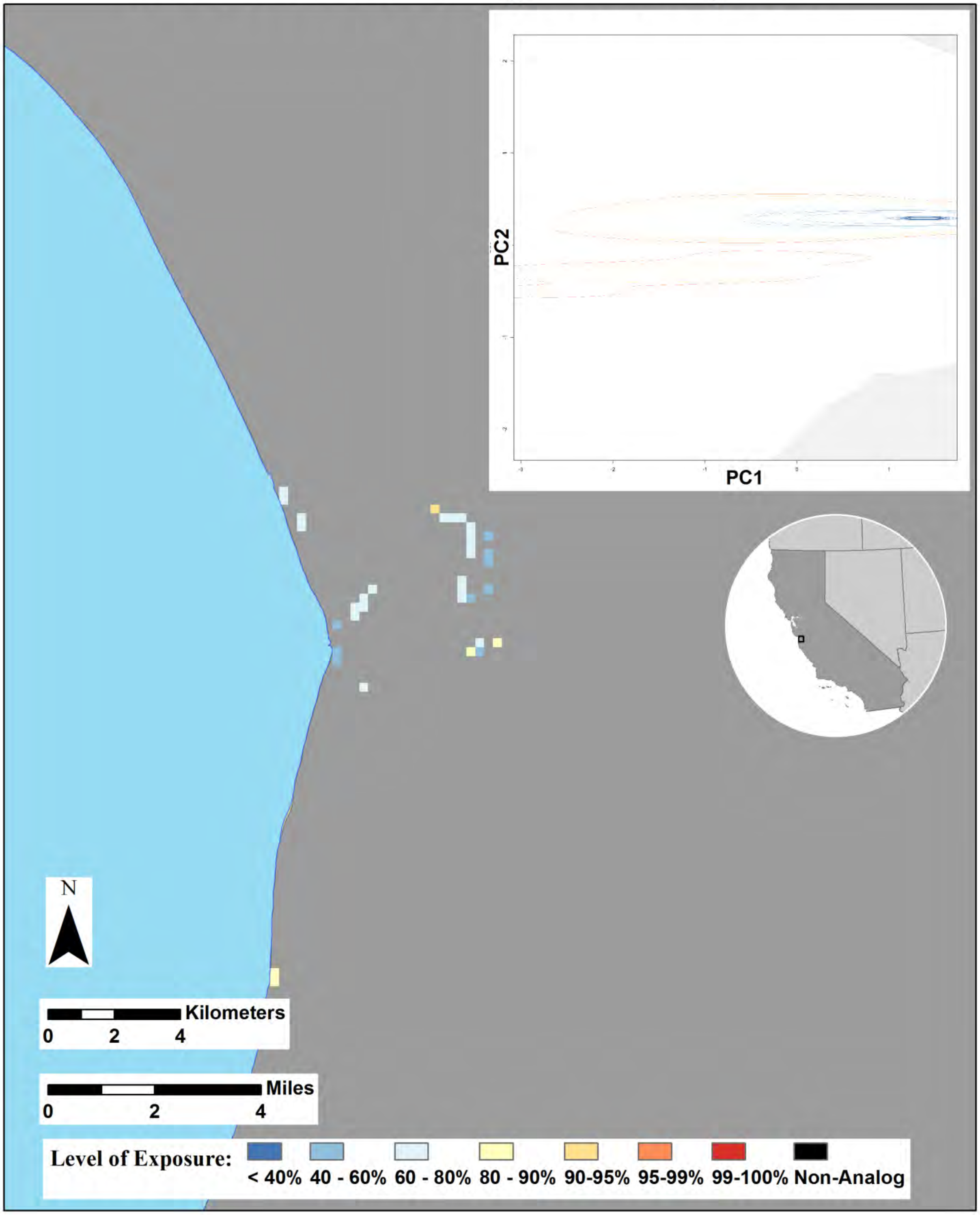


Figure 150. Map of the Current Climate Suitability for Macrogroup 106. The 2015 mapped extent of macrogroup 106, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

There were no species scored for the sensitivity and adaptive capacity component of this macrogroup.

Projected Climate Exposure

The future climate exposure for macrogroup 106 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. However, the Miroc ESM models did not resolve. The two climate scenarios that did resolve are show, and predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 151).

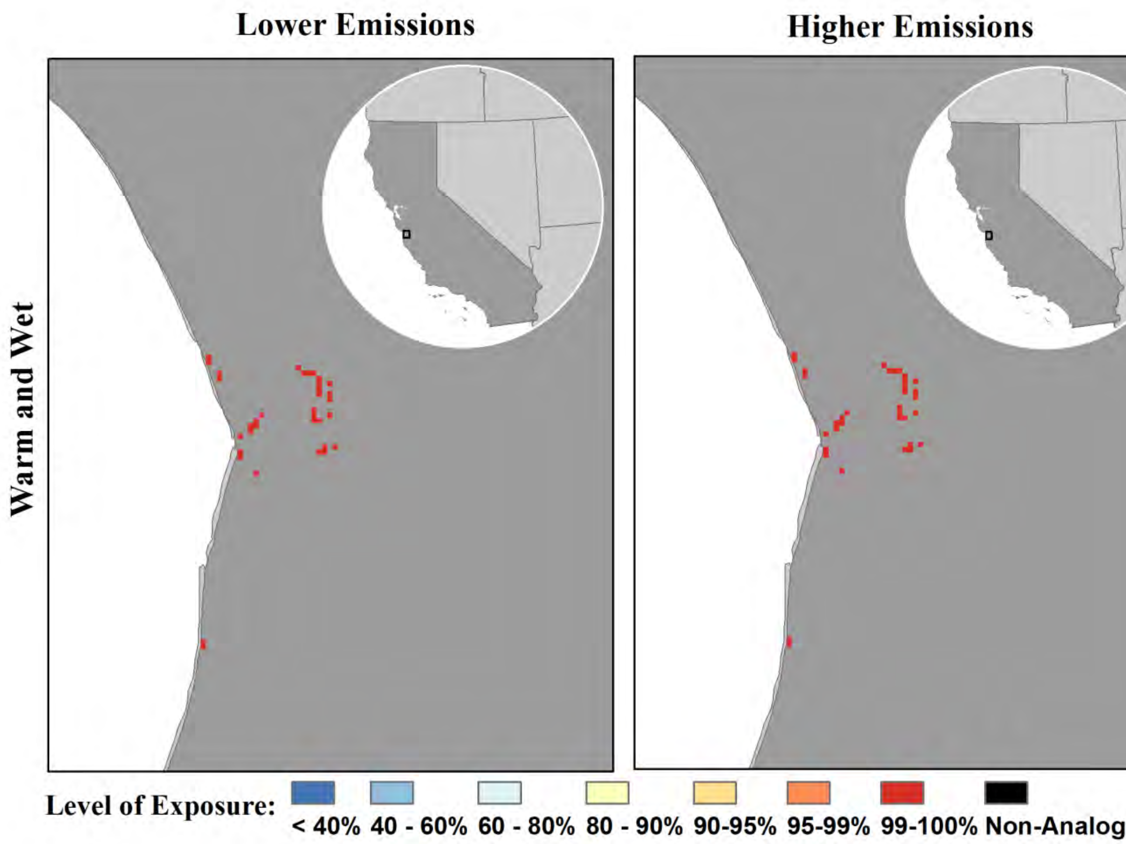


Figure 151. Maps of Projected Climate Exposure for Macrogroup 106. The climate exposure level for macrogroup 106 for two future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time. The data could not be modeled for the Hot and Dry climate scenario for macrogroup 106.

The future climate exposure in Figure 151 is derived from the PCA charts (Figure 152), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

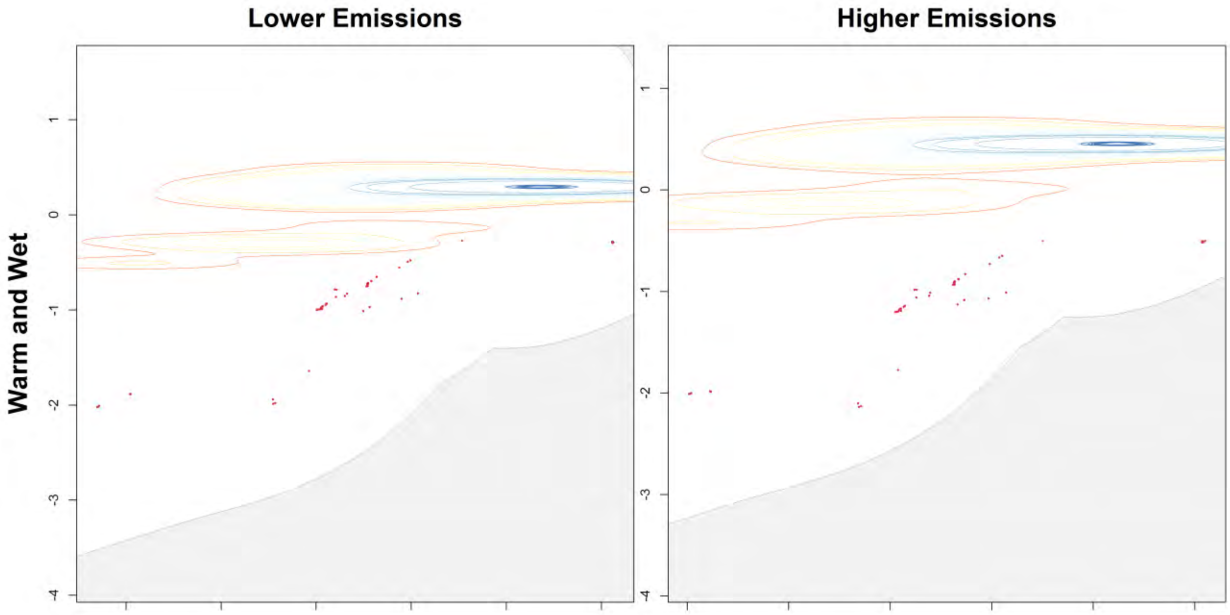


Figure 152. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 106. The PCA charts are two dimensional representations of climate exposure for macrogroup 106 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions. The model did not resolve for the Hot and Dry climate scenarios for macrogroup 106.

Table 88. Percentage of the Current Extent of Macrogroup 106 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1	1	1	1	1	0	0	0	0
1980-2010 (%)	19.57	20.65	18.48	20.65	9.78	6.52	4.35	0.00	0.00
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	0.00	0.00	0.00	0.00	0.00	2.17	2.17	95.65	0.00
2040-2069 (%)	0.00	0.00	0.00	0.00	0.00	2.17	2.17	95.65	0.00
2070-2099 (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	0.00	0.00	0.00	0.00	0.00	2.17	2.17	95.65	0.00
2040-2069 (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
2070-2099 (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA
2040-2069 (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA
2070-2099 (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA
2040-2069 (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA
2070-2099 (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 106 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 153), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 742 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

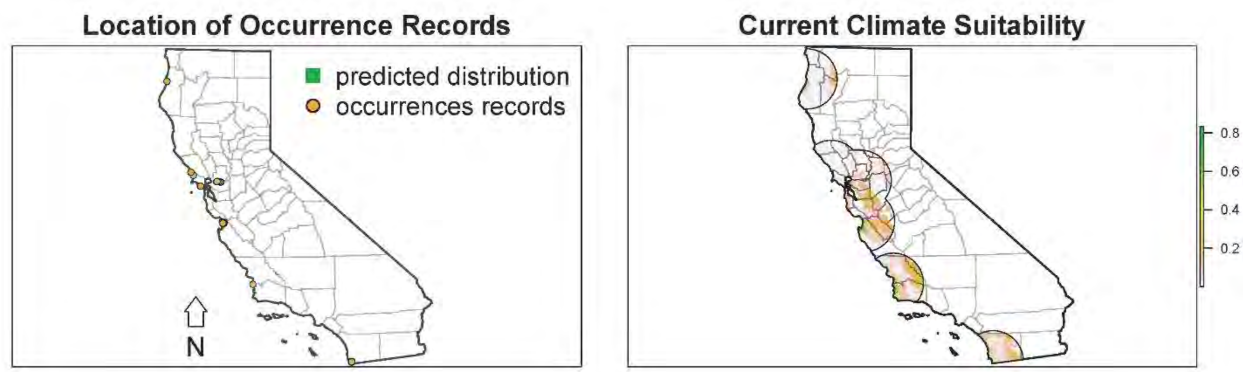


Figure 153. Map of Points Selected from the Extent of Macrogroup 106 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 106. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 106 (Figure 154). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption or the need for the vegetation type to shift its location will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 106, between 742 km^2 (100%) and 742 km^2 (100%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 0 km^2 (0%) and 0 km^2 (0%) will remain climatically suitable, and between 0 km^2 (0%) and 19 km^2 (0%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 89.

Figure 154. Maps of the Projected Climatically Suitable Range for Macrogroup 106. Maps showing the modeled climatically suitable range for macrogroup 106 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 89. Area of Projected Climatic Suitability for Macrogroup 106. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 106, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	742	0	0	100%	0%	0%
CNRM CM5 - RCP 8.5	742	0	0	100%	0%	0%
MIROC ESM - RCP 4.5	742	0	19	100%	0%	3%
MIROC ESM - RCP 8.5	742	0	0	100%	0%	0%

MG110: Macrogroup California Cliff, Scree, and Other Rock Vegetation
Common Name: California Foothill and Coastal Rock Outcrop Vegetation

Vegetative cover is generally < 2%. It is composed of cliffs and outcrops west of the deserts and inland from the immediate coast, south of central California. Rock surfaces or rapidly eroding unstable slopes are characteristic. Stands do not include alpine or subalpine sparse, rocky vegetation, and also do not include the sparsely vegetated portions of the warm and cold deserts.

This macrogroup is poorly understood floristically, but includes coastal succulents (*Dudleya* sp, *Coreopsis gigantea*, etc.).

The closest WHR type for this macrogroup is barren (BAR).

Macrogroup 110 is comprised of approximately one WHR type for which we scored one representative dominant species. The statewide extent for the current time period cover 6,179 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 155). Using the current climate conditions for the extent of Macrogroup 110, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

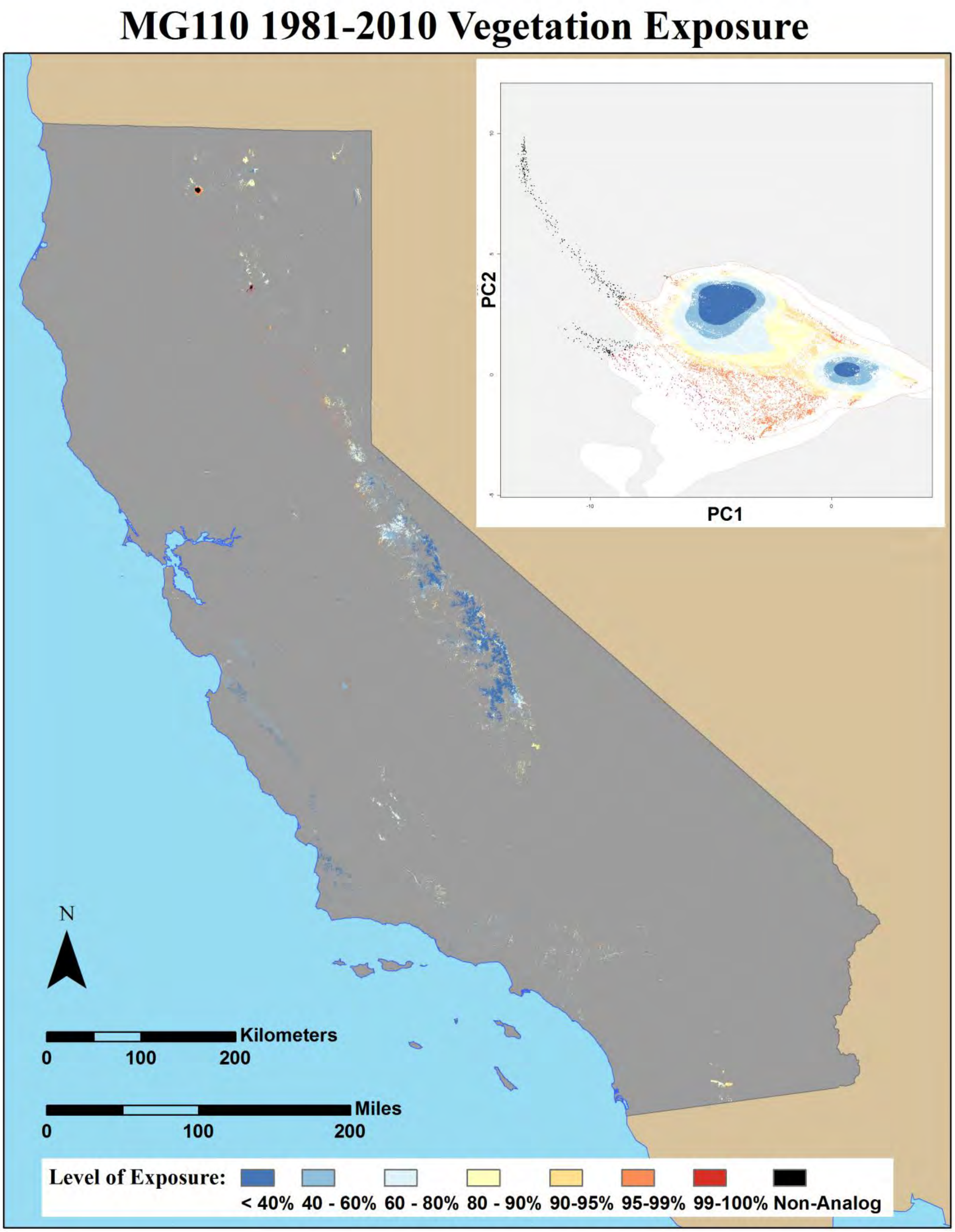


Figure 155. Map of Current Climate Suitability for Macrogroup 110. The 2015 mapped extent of macrogroup 110, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 110 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 90). The overall or grand mean for macrogroup 110 was found to be 2.78 for sensitivity and adaptive capacity.

Table 90. Sensitivity and Adaptive Capacity Rankings for Macrogroup 110. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 110. *Dudlea sp.* is not described.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Coreopsis gigantea	3	3	2	3	3	2	2	4	3	**2.8**
Mean	**3.00**	**3.00**	**2.00**	**3.00**	**3.00**	**2.00**	**2.00**	**4.00**	**3.00**	
Grand Mean	**2.78**				**Mean**	**2.67**		**Mean**	**3.00**	

Projected Climate Exposure

The future climate exposure for macrogroup 110 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 156).

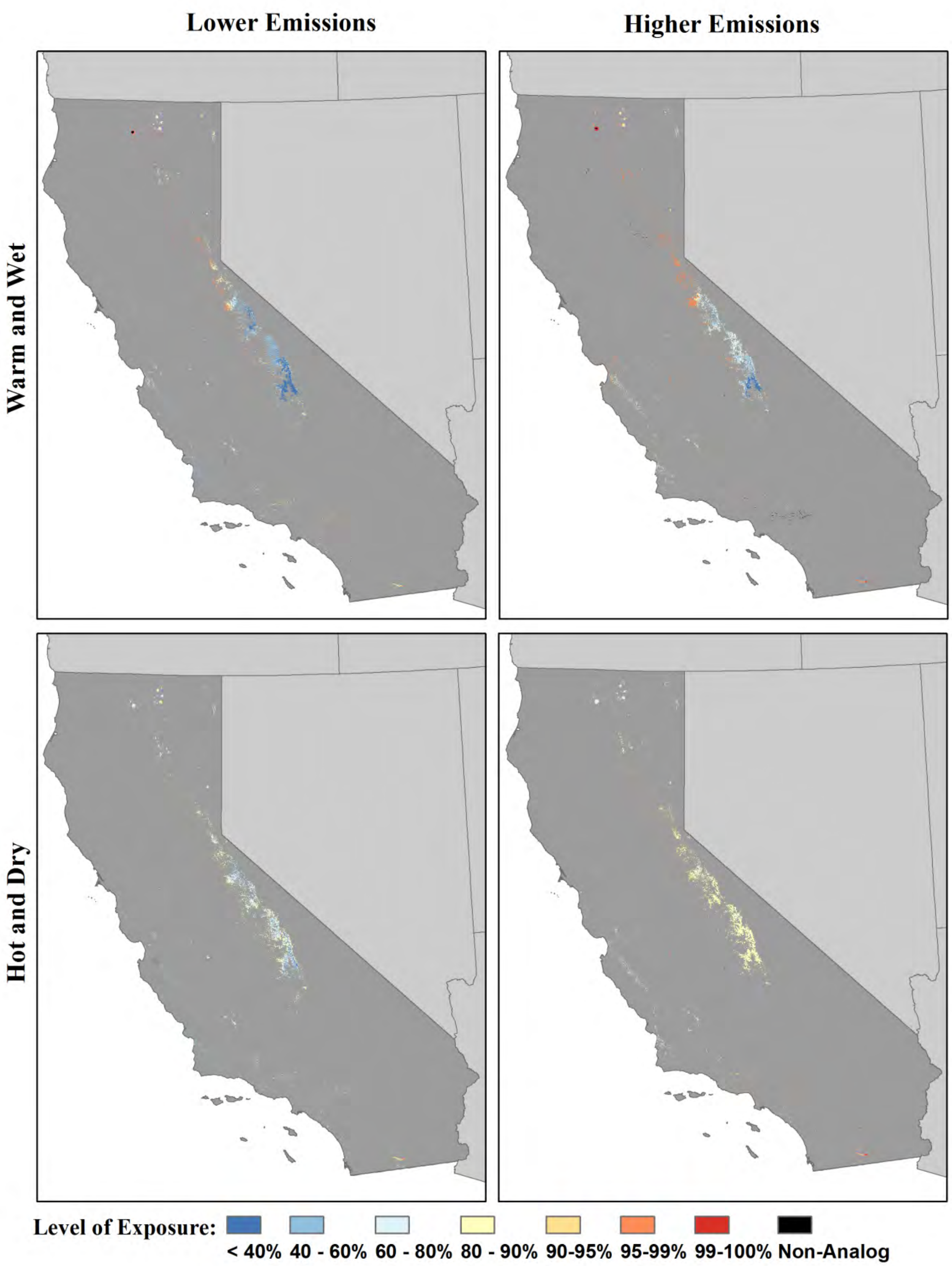


Figure 156. Maps of Projected Climate Exposure for Macrogroup 110. The climate exposure level for macrogroup 110 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 156 is derived from the PCA charts (Figure 157), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

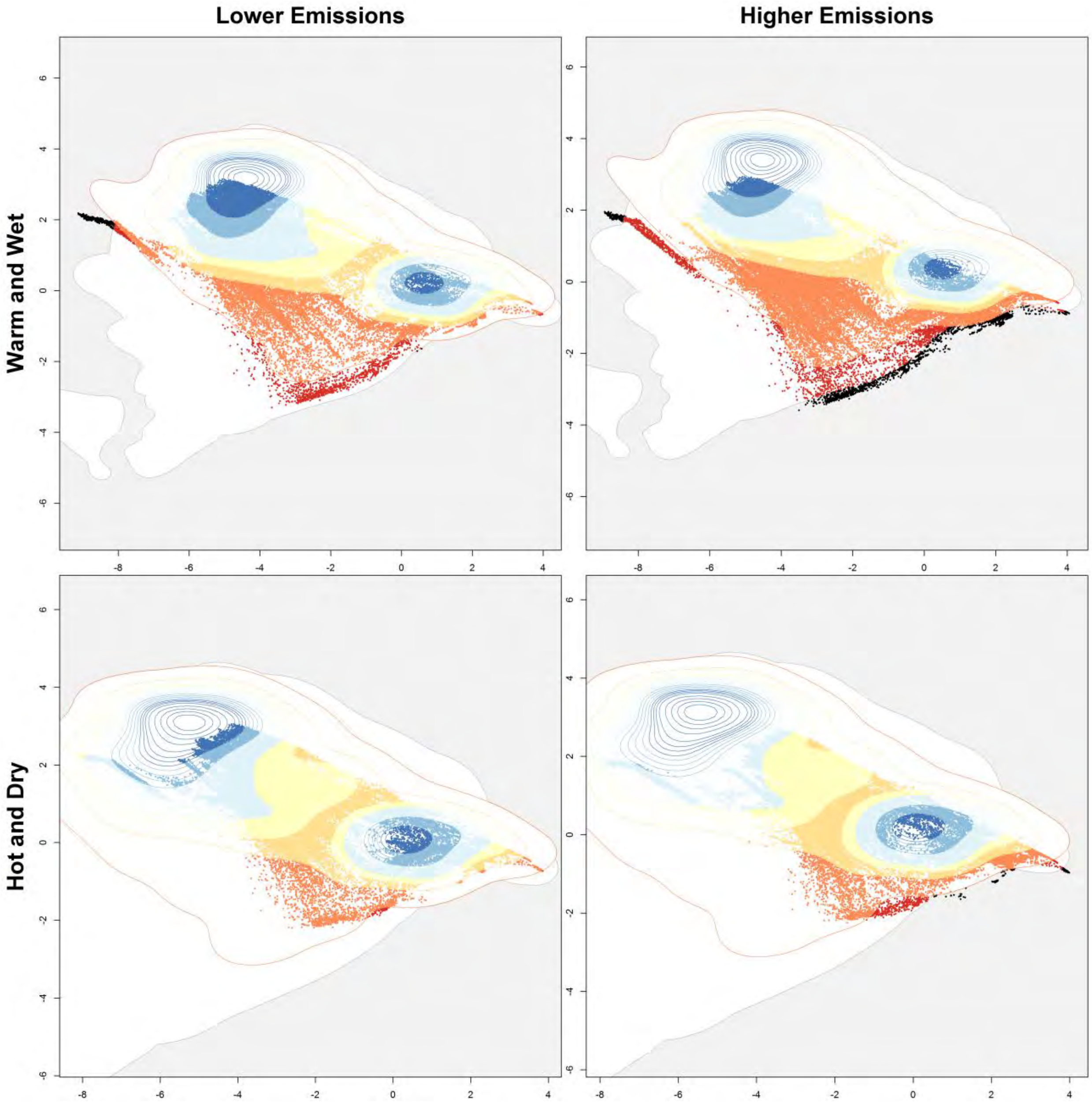


Figure 157. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogorup 110. The PCA charts are two dimensional representations of climate exposure for macrogroup 110 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 91). In the current time period, macrogroup 110 occupies 6,179 km^2. By the end of the century, there will be between 1,306 km^2 (21%) and 4,112 km^2 (67%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 183 km^2 (3%) and 1,866 km^2 (30%) of this type will be climatically exposed by the end of century.

Table 91. Percentage of the Current Extent of Macrogroup 110 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1,236	1,236	1,236	1,236	618	308	248	26	35
1980-2010 (%)	20.00	20.00	20.00	20.00	10.00	4.99	4.01	0.42	0.57
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	8.23	25.26	21.25	23.49	10.74	5.59	5.25	0.18	0.00
2040-2069 (%)	8.81	26.37	19.66	20.51	10.45	6.55	6.97	0.67	0.01
2070-2099 (%)	6.39	13.70	28.60	17.86	11.41	9.49	10.69	1.52	0.35
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	7.31	22.91	23.69	23.54	10.49	5.40	6.29	0.32	0.06
2040-2069 (%)	7.86	21.24	19.99	19.55	12.31	8.87	8.80	1.11	0.29
2070-2099 (%)	0.00	6.89	12.55	32.18	8.37	9.80	25.16	2.51	2.52
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	14.37	26.51	18.90	23.07	9.78	4.21	3.15	0.00	NA
2040-2069 (%)	2.21	16.79	19.92	35.24	17.73	5.99	2.12	0.00	NA
2070-2099 (%)	0.04	3.43	16.94	38.81	28.49	9.32	2.88	0.08	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	17.21	24.64	17.52	23.88	10.41	3.83	2.50	0.00	NA
2040-2069 (%)	0.02	4.40	14.22	35.15	35.32	8.60	2.29	0.00	0.00
2070-2099 (%)	0.00	0.78	4.29	16.07	53.15	17.42	7.36	0.70	0.23

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 110 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 158), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 18,332 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

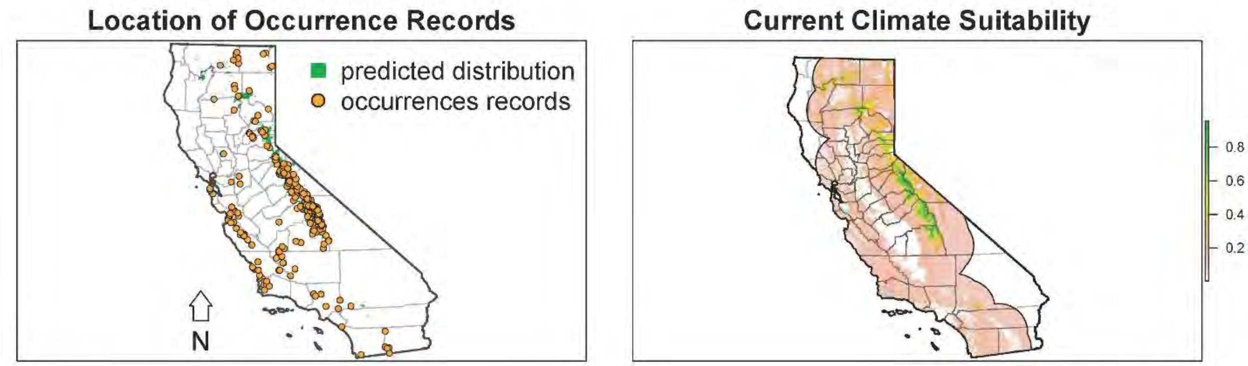


Figure 158. Map of Points Selected from the Extent of Macrogroup 110 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 110. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 110 (Figure 159). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 110, between 2,508 km^2 (14%) and 17,155 km^2 (94%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 1,177 km^2 (6%) and 15,824 km^2 (86%) will remain climatically suitable, and between 104 km^2 (1%) and 6,601 km^2 (36%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 92.

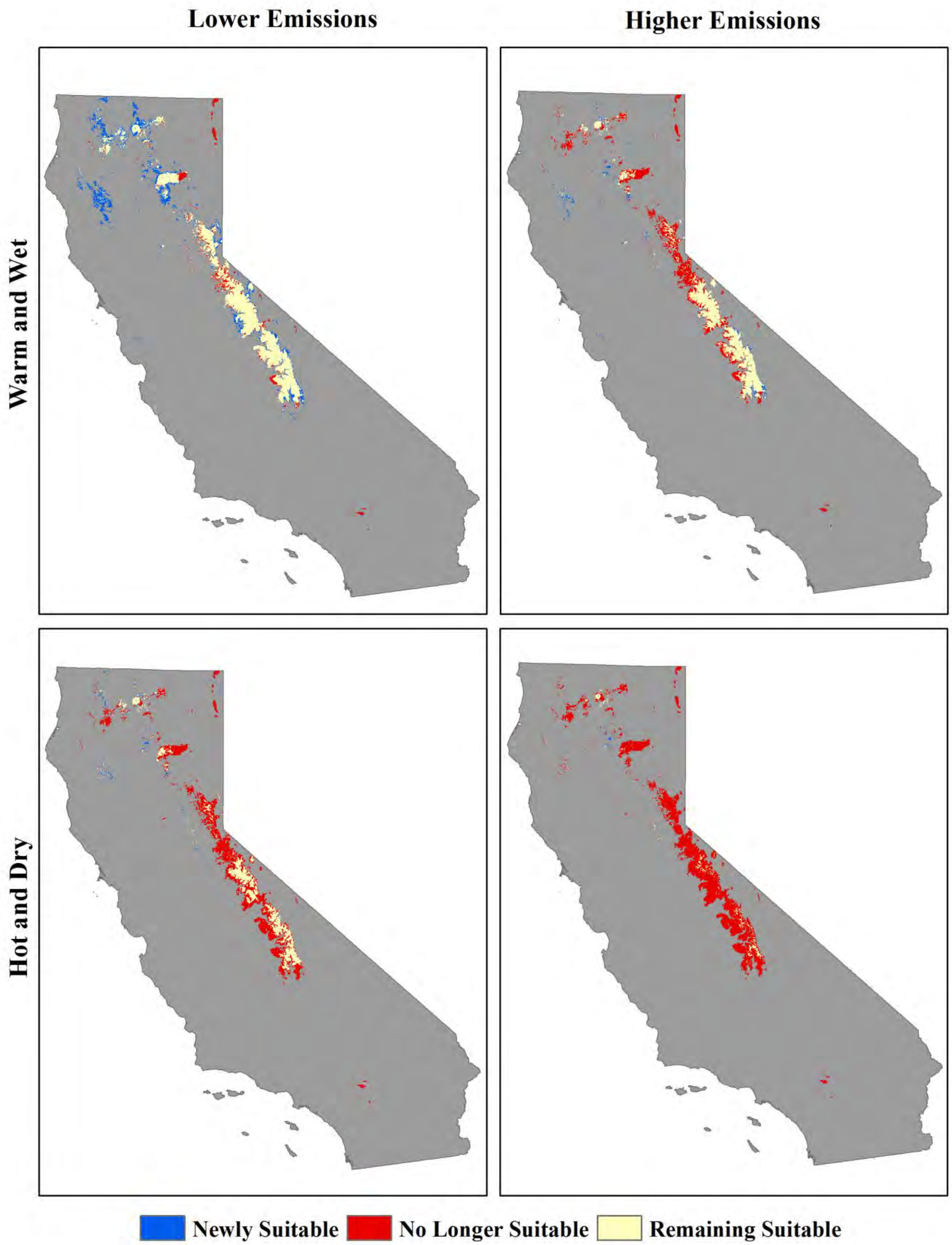


Figure 159. Maps of the Projected Climatically Suitable Range for Macrogroup 110. Maps showing the modeled climatically suitable range for macrogroup 110 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 92. Area of Projected Climatic Suitability for Macrogroup 110. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 110, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	2,508	15,824	6,601	14%	86%	36%
CNRM CM5 - RCP 8.5	8,381	9,951	1,202	46%	54%	7%
MIROC ESM - RCP 4.5	12,173	6,159	517	66%	34%	3%
MIROC ESM - RCP 8.5	17,155	1,177	104	94%	6%	1%

MG114: Macrogroup Vancouverian Cliff, Scree, and Other Rock Vegetation
Common Name: Northwest Coast Cliff and Outcrop

This macrogroup is poorly defined but is taken to describe coastal cliffs on headlands and islands of the north coast.

The most corresponding WHR type is barren (BAR). No species were identified for this type.

Macrogroup 114 is comprised of approximately zero WHR types for which we scored zero representative dominant species. The statewide extent for the current time period cover 564 km^2, here shown according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 160). Using the current climate conditions for the extent of Macrogroup 114, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

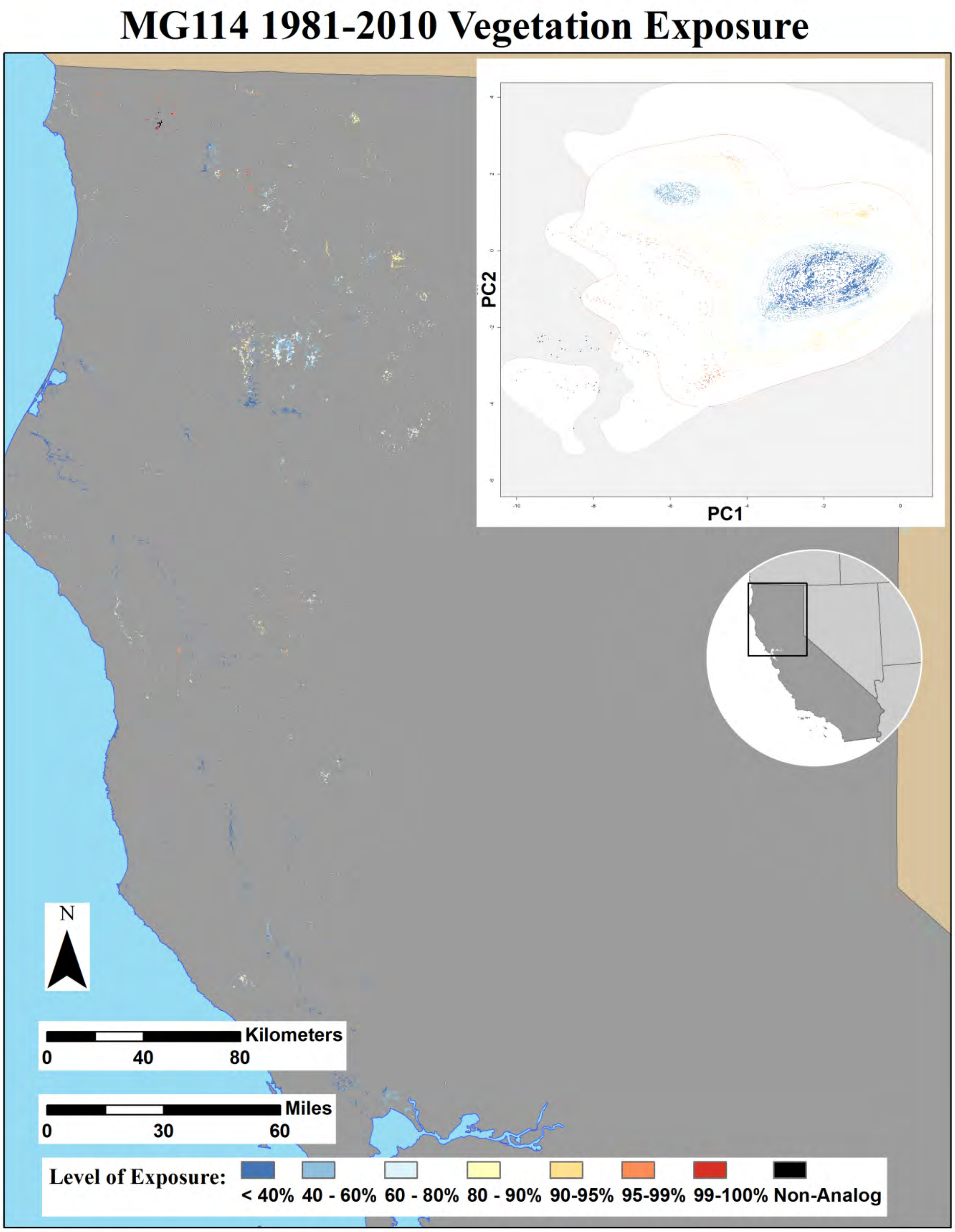


Figure 160. Map of Current Climate Suitability for Macrogroup 114. The 2015 mapped extent of macrogroup 114, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

There were no species scored for the sensitivity and adaptive capacity component of this macrogroup.

Projected Climate Exposure

The future climate exposure for macrogroup 114 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 161).

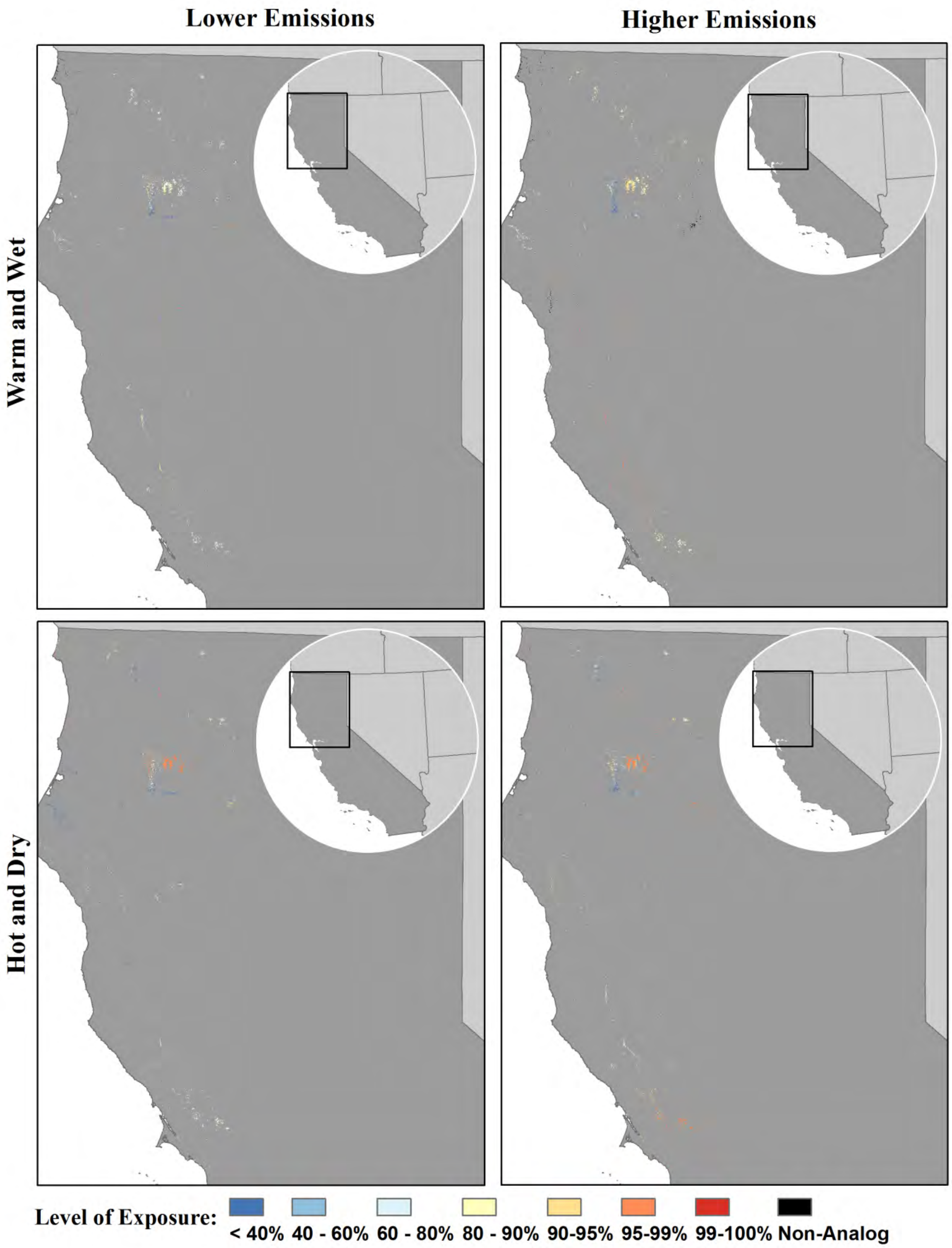


Figure 161. Maps of Projected Climate Exposure for Macrogroup 114. The climate exposure level for macrogroup 114 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 161 is derived from the PCA charts (Figure 162), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

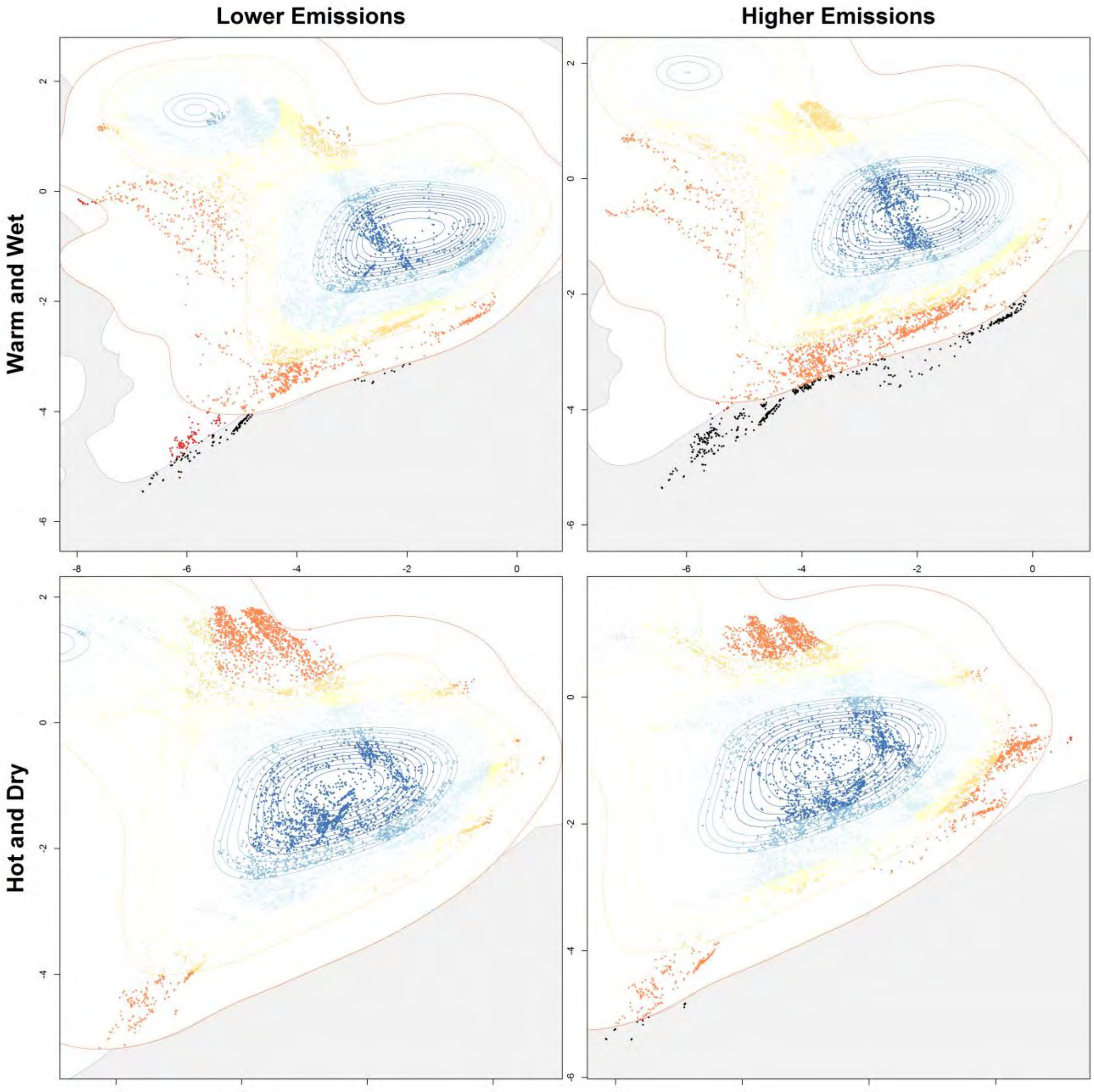


Figure 162. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 114. The PCA charts are two dimensional representations of climate exposure for macrogroup 114 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 93). In the current time period, macrogroup 114 occupies 564 km^2. By the end of the century, there will be between 192 km^2 (34%) and 336 km^2 (60%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 88 km^2 (16%) and 147 km^2 (26%) of this type will be climatically exposed by the end of century.

Table 93. Percentage of the Current Extent of Macrogroup 114 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	113	113	113	113	57	28	23	3	2
1980-2010 (%)	19.98	19.99	19.99	19.99	10.03	5.00	4.00	0.62	0.39
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	5.26	13.96	12.13	30.72	21.11	8.60	7.72	0.50	0.00
2040-2069 (%)	5.14	7.55	17.12	33.10	17.17	10.21	8.76	0.94	0.00
2070-2099 (%)	3.72	3.60	8.82	39.53	17.60	11.09	12.18	1.42	2.04
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	4.22	11.35	14.46	31.71	19.58	9.31	8.16	1.20	0.00
2040-2069 (%)	4.89	4.47	14.82	35.41	18.44	10.09	10.11	1.27	0.50
2070-2099 (%)	6.03	4.22	5.86	17.94	25.40	14.85	19.05	0.13	6.52
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	11.08	17.24	14.50	21.41	11.42	10.99	13.21	0.15	NA
2040-2069 (%)	15.43	11.74	14.27	17.36	12.45	7.94	20.79	0.03	NA
2070-2099 (%)	14.13	9.93	11.38	24.16	11.54	7.64	21.20	0.01	0.00
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	13.15	15.99	12.71	21.10	8.82	10.74	17.47	0.03	NA
2040-2069 (%)	15.15	11.63	12.22	18.98	10.89	9.61	21.50	0.03	0.00
2070-2099 (%)	8.16	10.72	12.59	20.47	11.22	10.74	25.79	0.10	0.21

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 114 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 163), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 13,321 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

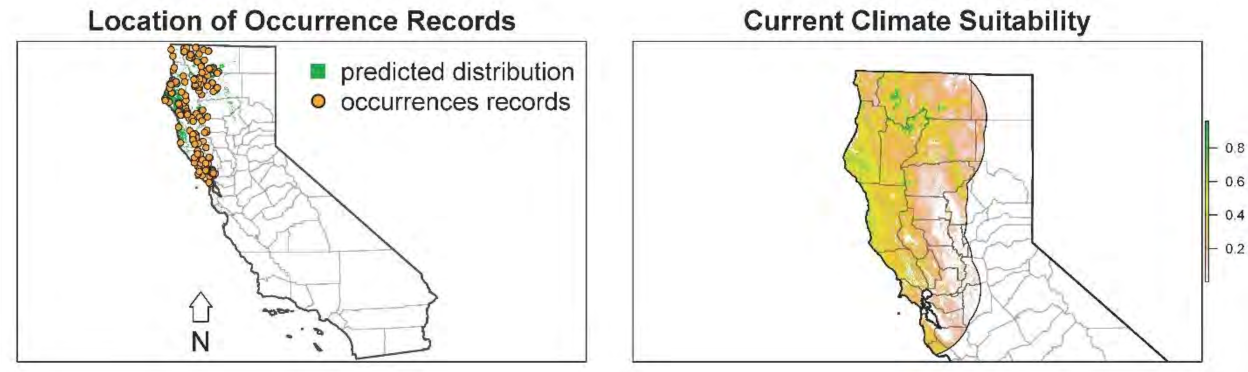


Figure 163. Map of Points Selected from the Extent of Macrogroup 114 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 114. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 114 (Figure 164). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 114, between 9,602 km^2 (72%) and 12,705 km^2 (95%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 617 km^2 (5%) and 3,719 km^2 (28%) will remain climatically suitable, and between 1,595 km^2 (12%) and 2,789 km^2 (21%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 94.

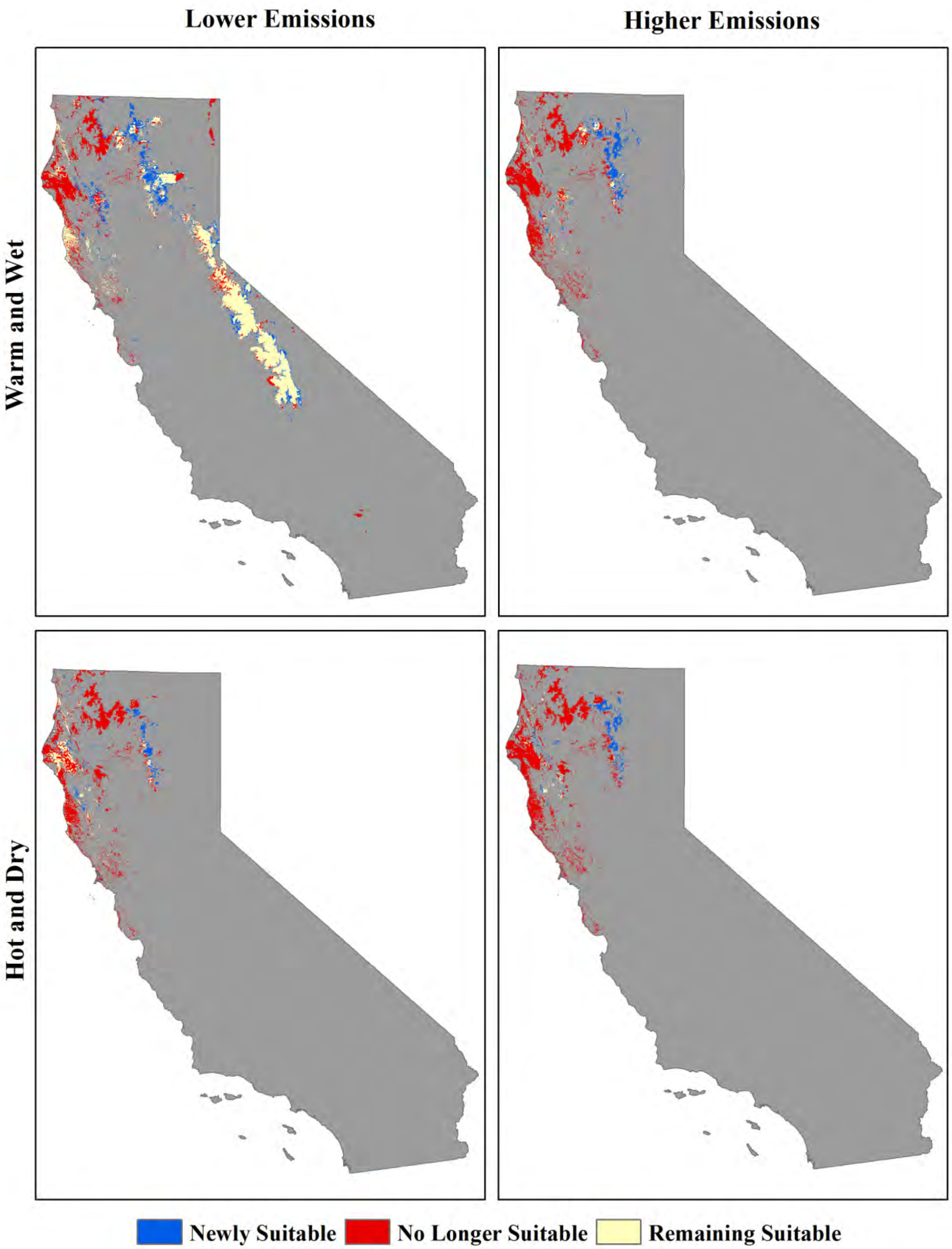


Figure 164. Maps of the Projected Climatically Suitable Range for Macrogroup 114. Maps showing the modeled climatically suitable range for macrogroup 114 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 94. Area of Projected Climatic Suitability for Macrogroup 114. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 114, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	9,602	3,719	1,750	72%	28%	13%
CNRM CM5 - RCP 8.5	11,879	1,443	2,789	89%	11%	21%
MIROC ESM - RCP 4.5	10,738	2,583	1,595	81%	19%	12%
MIROC ESM - RCP 8.5	12,705	617	1,895	95%	5%	14%

MG117: Macrogroup North American Warm Semi-Desert Cliff, Scree, and Other Rock Vegetation
Common Name: Sparsely Vegetated Desert Dune

This macrogroup is characteristic of the desert dunes and contains both annual and perennial species with special strategies to deal with the shifting sands and the dry and unpredictable climate. Vegetation cover is variable depending upon unpredictable rainfall patterns.

Diagnostic species include species in genera such as *Abronia*, *Palifoxia*, *Oenothera deltoides*, *Dicorea canescens*, among others, but also include perennial grasses such as *Panicum urvillianum*, and *Pleuraphis rigida*.

The best WHR type for this macrogroup is barren (BAR).

Macrogroup 117 is comprised of approximately one WHR types for which we scored three representative dominant species. The statewide extent for the current time period cover 5,581 km^2, here shown classed according to its frequency of occurrence in different parts of its current climate envelope, or distribution of climate conditions (Figure 165). Using the current climate conditions for the extent of Macrogroup 117, a vegetation climate exposure analysis was developed to indicate the portion of occupied climate conditions that occur infrequently, and represent the extreme of climate conditions where this macrogroup occurs. The macrogroup occurring in these areas (>95% and beyond) is defined as climatically stressed (or marginal), and is usually along the periphery of its current area. This climate envelope classification is used to measure the changes that will occur under the various future climate projections.

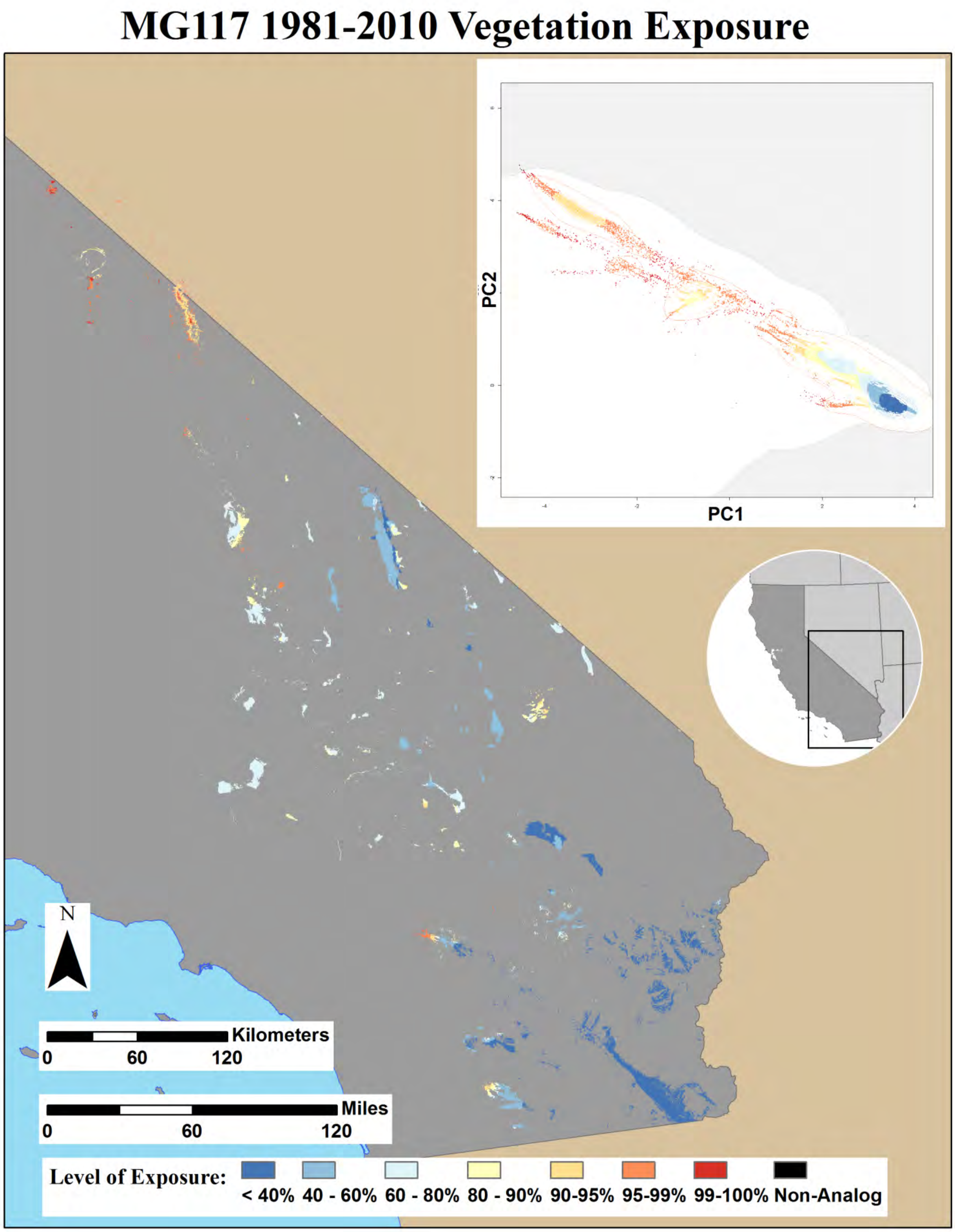


Figure 165. Map of Current Climate Suitability for Macrogroup 117. The 2015 mapped extent of macrogroup 117, classed into varying levels of current climate suitability. Locations in the <40 category are those where this vegetation type most commonly occurs, and therefore thought to be the least stressed locations. Vegetation at locations in the 95-99% and higher classes is occurring in areas that are already on the climatic margins of where the type occurs. The inset represents the distribution of the vegetation when the climate conditions are reduced to two dimensions using a principal components analysis. Colors in the inset and the map refer to the same categories of climate exposure.

Sensitivity and Adaptive Capacity

Traits for the dominant plant species of macrogroup 117 were scored according to their sensitivity to and ability to adapt to climate change. The set of scores are indicative of how each species will be impacted by climate change. The six sensitivity scores portray a species' sensitivity to temperature, precipitation, and fire, as well as requirements for seeds to germinate, the modes of seed dispersal and reproductive lifespan. The three adaptive capacity scores portray how adaptive each species is to fire, the modes and level of recruitment and seed longevity. Each criterion was scored on a relative 1-5 scale, with 1 being the most sensitive or lowest adaptive capacity, and 5 representing the least sensitive or highest level of adaptive capacity (Table 95). The overall or grand mean for macrogroup 117 was found to be 2.67 for sensitivity and adaptive capacity.

Table 95. Sensitivity and Adaptive Capacity Rankings for Macrogroup 117. Sensitivity and Adaptive Capacity rankings for the major species comprising macrogroup 117. *Abronia sp.* is represented by *A. villosa.* There was not enough information for *Oenothera deltoides* or *Palifoxia sp*.

	Sensitivity						**Adaptive Capacity**			**Species Score**
Species	**Climate Temp**	**Climate Precip**	**Fire Sensitivity**	**Germination Agents**	**Mode Dispersal**	**Reproductive Lifespan**	**Fire**	**Recruitment Mode /Fecundity**	**Seed Longevity**	
Abronia sp.	4	3	2	2	3	2	1	3	5	**2.8**
Dicorea canescens	4	3	1	2	3	2	1	3	5	**2.7**
Panicum urvilleanum	4	4	4	2	2	2	3	1	1	**2.6**
Mean	**4.00**	**3.33**	**2.33**	**2.00**	**2.67**	**2.00**	**1.67**	**2.33**	**3.67**	
Grand Mean	**2.67**				**Mean**	**2.72**		**Mean**	**2.56**	

Projected Climate Exposure

The future climate exposure for macrogroup 117 was assessed for four climate scenarios using the climate envelope of the mapped extent of this macrogroup under the current climate conditions. The four climate scenarios predict different proportions of area that will be climatically stressed, depending on the future climate conditions of each scenario, for the end-of-century time period, 2070-2099 (Figure 166).

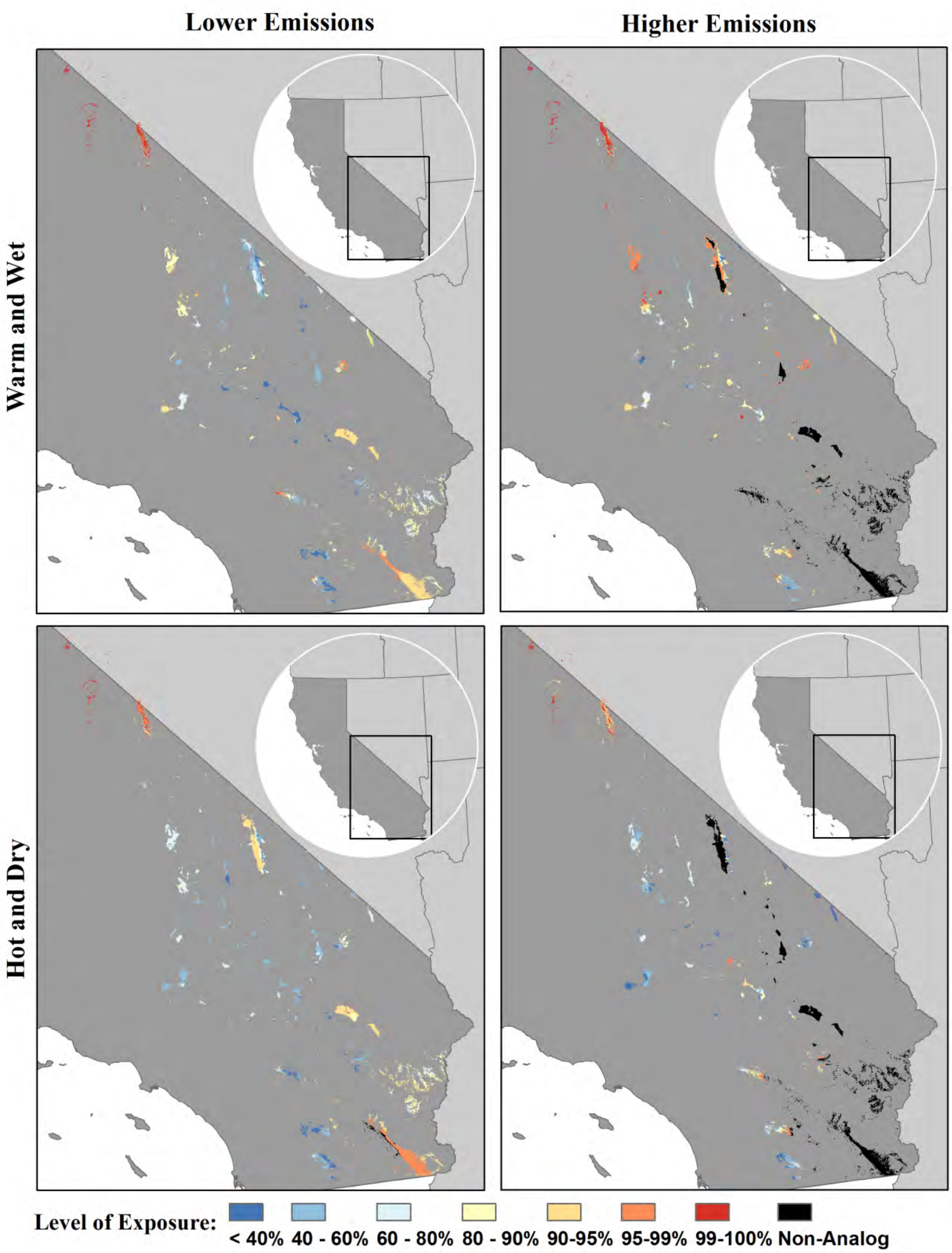


Figure 166. Maps of Projected Climate Exposure for Macrogroup 117. The climate exposure level for macrogroup 117 for four future climate scenarios, for the time period 2070-2099. The color coding is the same as for the current time.

The future climate exposure in Figure 166 is derived from the PCA charts (Figure 167), which portray the climate conditions for the range two-dimensionally, to show how much stress each macrogroup will encounter for each future climate scenario.

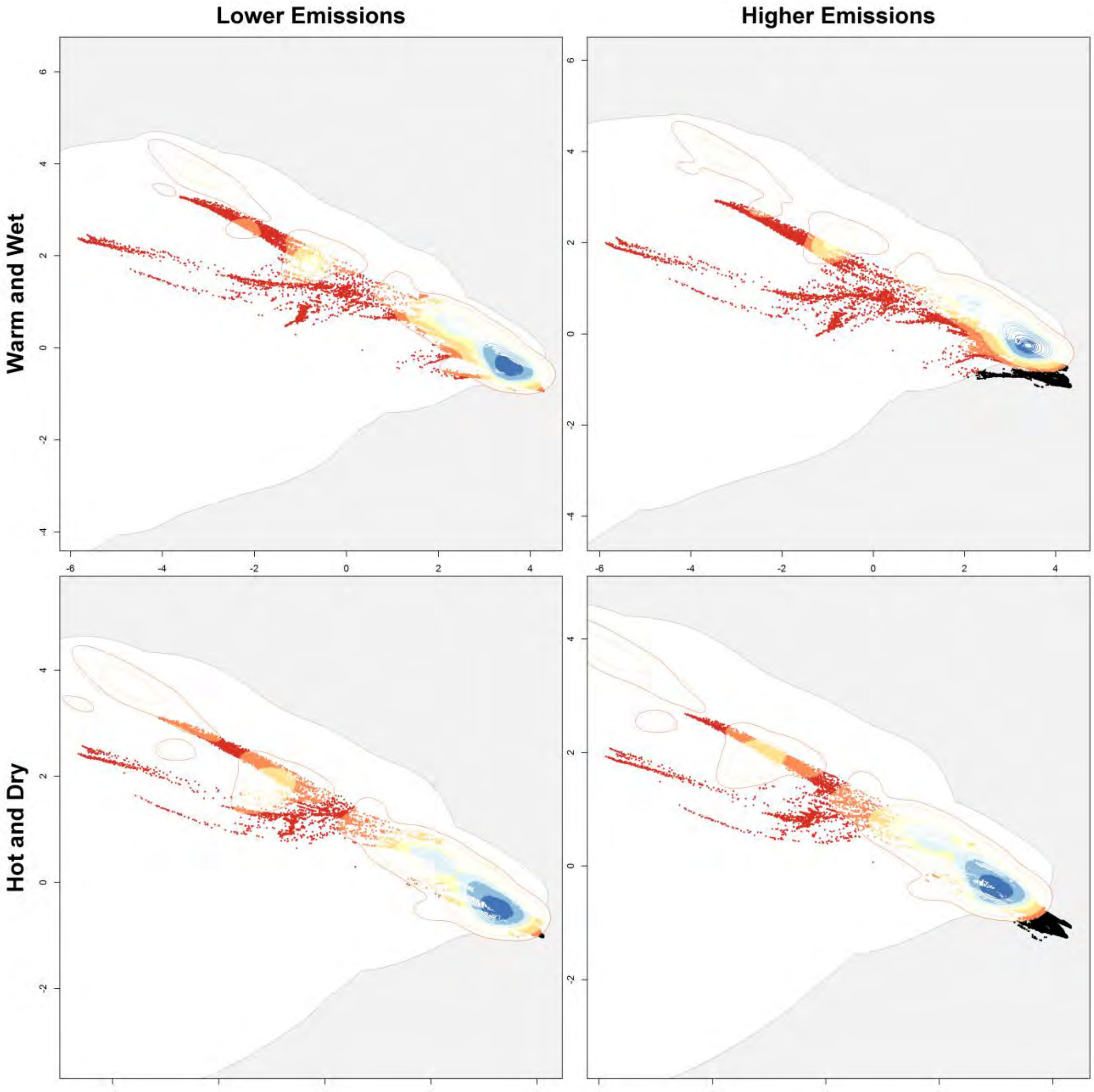


Figure 167. PCA Charts: Two-dimensional Representations of Climate Exposure for Macrogroup 117. The PCA charts are two dimensional representations of climate exposure for macrogroup 117 under four future climate projections, for the time period 2070-2099. Each dot corresponds to a location on the previous block of maps. The contour lines represent the distribution of dots from the current time period, while the location and coloring of the dots shows the future level of climate exposure. These images illustrate the shift to more stressful climate conditions (orange and red), and to conditions that this vegetation type does not currently experience (black), here called "non-analog" conditions.

Within each future climate scenario, the proportion of area that has shifted from suitable (0%-80%) to climatically exposed (>95% and non-analog) can be calculated for each time period (Table 96). In the current time period, macrogroup 117 occupies 5,581 km^2. By the end of the century, there will be between 791 km^2 (14%) and 2,585 km^2 (46%) of its total area that will remain suitable as a result of future climate changes. These areas represent the vegetation refugia for this macrogroup. Between 886 km^2 (16%) and 3,882 km^2 (70%) of this type will be climatically exposed by the end of century.

Table 96. Percentage of the Current Extent of Macrogroup 117 Within Each Climate Exposure Class. This table shows the percentage of the current mapped extent within each climate exposure class, for the current time and for the four future climate and emissions scenarios. Maps in this report only portray the end century projections, but this table includes three future time periods, to permit assessment of the rate of transition of lands occupied by this macrogroup.

Time Period	0-20%	20-40%	40-60%	60-80%	80-90%	90-95%	95-99%	99-100%	non-analog
1980-2010 (km^2)	1,116	1,117	1,116	1,116	558	279	224	55	0
1980-2010 (%)	20.00	20.01	19.99	20.00	10.00	5.00	4.01	0.99	0.01
Warmer and Wetter, Lower Emissions (CNRM CM 5 RCP 4.5)									
2010-2039 (%)	2.66	19.77	35.60	9.12	10.42	10.33	5.65	6.46	0.00
2040-2069 (%)	2.77	9.89	29.00	12.55	24.73	8.60	2.91	9.54	0.00
2070-2099 (%)	3.29	8.56	16.99	13.12	17.30	24.86	6.44	9.43	0.01
Warmer and Wetter, Higher Emissions (CNRM CM 5 RCP 8.5)									
2010-2039 (%)	3.35	17.53	34.43	11.42	11.09	9.53	4.03	8.62	0.00
2040-2069 (%)	2.22	9.96	17.27	15.33	18.44	21.81	6.03	8.86	0.07
2070-2099 (%)	0.01	2.04	5.97	6.17	6.67	9.60	12.92	11.51	45.13
Hotter and Drier, Lower Emissions (MIROC ESM RCP 4.5)									
2010-2039 (%)	8.49	13.00	38.78	18.10	6.95	4.41	7.22	3.06	NA
2040-2069 (%)	1.83	6.96	22.35	27.20	14.97	16.01	3.48	7.21	NA
2070-2099 (%)	1.25	6.94	21.77	16.37	11.78	18.39	14.72	7.19	1.59
Hotter and Drier, Higher Emissions (MIROC ESM RCP 8.5)									
2010-2039 (%)	11.70	13.62	25.85	25.89	8.97	6.32	5.37	2.28	NA
2040-2069 (%)	1.31	6.34	17.54	20.96	11.21	25.43	9.43	6.94	0.85
2070-2099 (%)	1.43	7.67	11.52	9.86	3.84	5.29	4.95	6.06	49.37

Spatial Disruption

To determine the extent of relocation that may be required of species comprising macrogroup 117 under future climate scenarios, 300 locations were randomly selected from the currently mapped extent. These locations were used in the species distribution model Maxent (Figure 168), along with current climate conditions, to develop a current climate suitability model. The current climatically suitable area is modeled to be 34,449 km^2. Note that this predicted suitable extent is larger than the mapped extent used in the climate exposure analysis because not all suitable area is actually occupied.

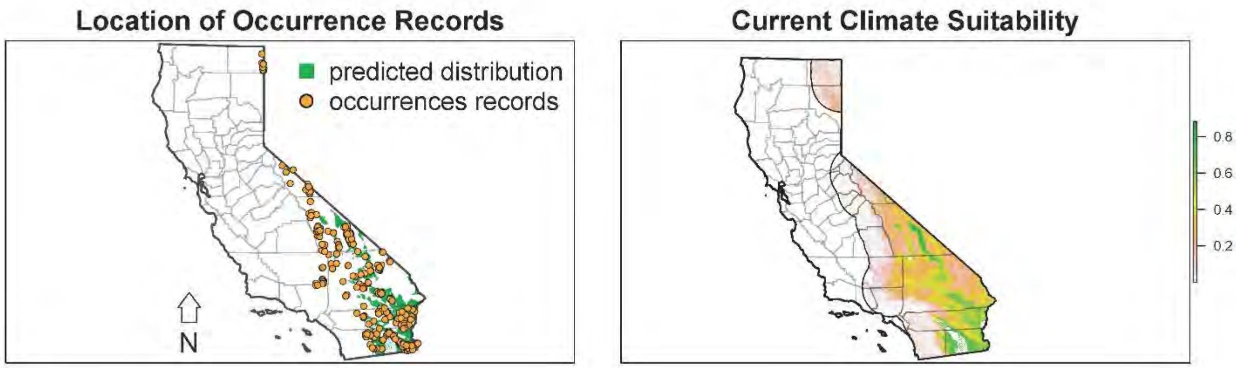


Figure 168. Map of Points Selected from the Extent of Macrogroup 117 for use in Maxent. Statewide maps showing 300 randomly selected points pulled from the mapped extent for macrogroup 117. The points were used in the species distribution model Maxent to develop a current climate suitability model (right panel), which can be portrayed as a range map (the green in the left panel).

Using the current climate suitability range model and the future climate scenarios, the future range extents can be mapped to show where the climate conditions remain suitable, are no longer suitable, and are newly suitable for macrogroup 117 (Figure 169). For the areas that remain suitable, no movement will be necessary for vegetation under future climate conditions. Spatial disruption, or the need for the vegetation type to shift its location, will be required to occupy areas that are newly suitable or to leave areas that are no longer suitable. By the end of the century for macrogroup 117, between 309 km^2 (1%) and 4,303 km^2 (12%) of the current extent will no longer be climatically suitable, depending on the climate scenario. Between 30,146 km^2 (88%) and 34,140 km^2 (99%) will remain climatically suitable, and between 2,334 km^2 (7%) and 51,426 km^2 (149%) will be newly suitable. The modeled suitability extents for each of the four climate scenarios can be compared for the time period 2070-2099 in Table 97.

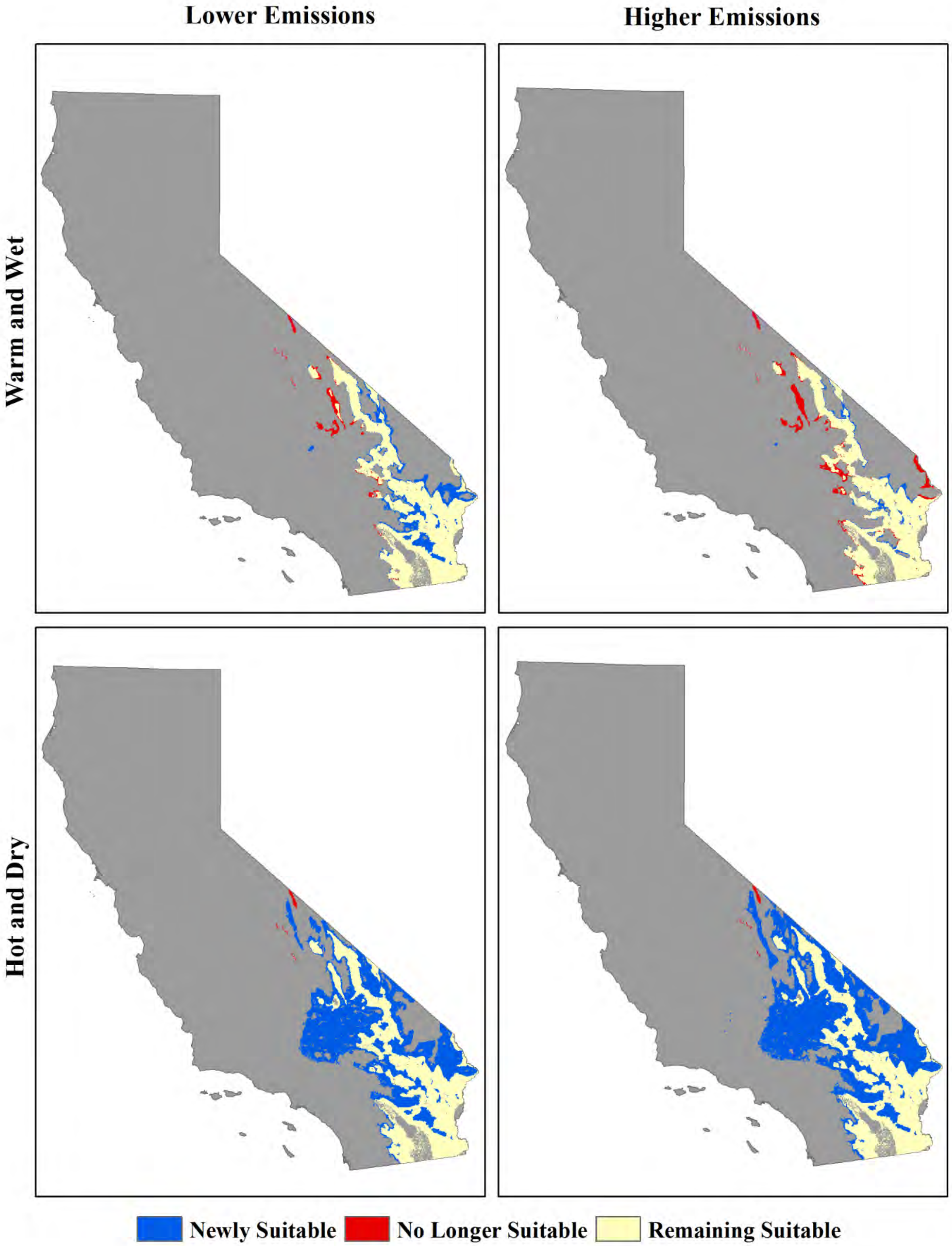


Figure 169. Maps of the Projected Climatically Suitable Range for Macrogroup 117. Maps showing the modeled climatically suitable range for macrogroup 117 under current time (yellow and red) and under four future scenarios (yellow and blue) for the time period 2070-2099.

Table 97. Area of Projected Climatic Suitability for Macrogroup 117. Table showing the amount of climatically suitable area and the percentage of climatically suitable area for species within macrogroup 117, for the four future climate scenarios for the time period 2070-2099.

Scenario	No Longer Suitable (km^2)	Remaining Suitable (km^2)	Newly Suitable (km^2)	No Longer Suitable (%)	Remaining Suitable (%)	Newly Suitable (%)
CNRM CM5 - RCP 4.5	2,118	32,332	8,299	6%	94%	24%
CNRM CM5 - RCP 8.5	4,303	30,146	2,334	12%	88%	7%
MIROC ESM - RCP 4.5	310	34,140	40,891	1%	99%	119%
MIROC ESM - RCP 8.5	309	34,140	51,426	1%	99%	149%

APPENDIX

Categories for scoring Sensitivity and Adaptive Capacity

SENSITIVITY

Climate Temperature - Sensitivity

The general sensitivity to temperature by dominant plant species is not covered in the Manual of California Vegetation. We used estimates based on vegetation location, with high elevation vegetation types presumed to be more sensitive to changes in temperature than lower elevation types; and desert types less sensitive than coastal types. This metric and precipitation are the least well documented, in terms of plant species responses. An argument could be made that the SDM analysis incorporates these criteria better than the estimates we provided for these scores. However, by scoring the species using this approach, we maintain transparency with regards to the assumptions in the vulnerability scoring process.

Temperature Sensitivity Scores
1 = highly sensitive to temperature
2 = moderately sensitive to temperature Most high elevation species were assigned here.
3 = neutral, or not known. Most species fell into this category
4 = moderately insensitive to temperature. Most desert species were assigned here.
5 = highly insensitive to temperature

Climate Precipitation - Sensitivity

The general sensitivity to precipitation by dominant plant species is not covered in the Manual of California Vegetation. We used estimates based on vegetation type, with types dependent on coastal fog and located in high precipitation areas as more sensitive, and types in more consistently arid regions as less sensitive.

Precipitation Sensitivity Scores
1 = highly sensitive to precipitation
2 = moderately sensitive to precipitation
3 = neutral, or not known. Most species fell into this category
4 = moderately insensitive to precipitation. Most desert species were assigned here.
5 = highly insensitive to precipitation

Fire (called Survivability after fire/disturbance in MCV) – Sensitivity

Sensitivity and Adaptive Capacity to fire received two scores in our system. Both scores were determined predominantly from the “Survivability after fire/disturbance” column life history table of the Manual of California Vegetation (2009), the list of whose categories are at the bottom of this section.

Fire Sensitivity
Species can be sensitive or hardy to fire, meaning that they are more or less able to withstand the direct effects of fire. This ranking is therefore a 1 for fire-sensitive and a 3 for fire-hardy, which includes a thick epidermis.
1 = Fire-sensitive; thin epidermis; high flammability; and/or canopy architecture susceptible
2 = Fire sensitive; thin epidermis or high flammability
3 = Not known
4 = Fire Hardy, and/or thick epidermis, and or canopy structure susceptible
5 = Fire-hardy; thick epidermis; canopy architecture resistant or low flammability

Categories from the MCV manual for Survivability after fire/disturbance

Null/unknown = 3
(Very) fire-sensitive; no/low sprouter = 1
Fire-sensitive = 2
Fire-sensitive, thin epidermis = 2
Fire sensitive/thin epidermis/high flammability = 1
Fire-sensitive; thin epidermis; high flammability; no/low sprouter = 1
Fire-sensitive; high flammability = 2
Fire-sensitive; high sprouter = 2
Fire-sensitive; low sprouter = 2
Fire-sensitive; no/low sprouter = 2
Fire-sensitive; no/low sprouter; architecture susceptible canopy = 1
Fire-sensitive; thin epidermis; high flammability; no/low sprouter; canopy architecture susceptible = 1
Fire-hardy = 4
Fire-hardy/thick epidermis/canopy structure susceptible = 4
Fire-hardy/thick epidermis/canopy structure resistant = 5
Fire hardy/high sprouter = 4
Fire-hardy; high flammability; high sprouter = 3
Fire-hardy; low flammability; high sprouter = 5
Fire-hardy (disturbance-hardy) = 4
Fire-hardy to fire-sensitive; high sprouter = 3
Fire-hardy; high flammability; high sprouter; canopy architecture susceptible = 4
Fire-hardy; thick epidermis; canopy architecture resistant = 5
Disturbance hardy; high sprouter = 4
Fire-hardy; low sprouter = 4
Fire-hardy; no/low sprouter to high sprouter = 4
Fire-hardy; thick epidermis = 4

Germination Agents – Sensitivity
Germination agents are forces that affect the germination of seeds. We classed this dynamic as sensitivity, because it is a direct response (or lack of response) by a plant to an environmental condition. These conditions are often temperature- or precipitation-related, but can also be related to fire, seed consumption by other species, or chemical drivers.

Categories in the MCV Life History Table
Inundation/high moisture = 1
Inundation and winter = 1
Scarification = 1 (assumes animals will eat the seeds and pass them, therefore dependent on animal(s) to be present
Winter/Cold = 2
Winter/Cold + Summer/Heat = 2
Sufficient moisture = 2
Scarification and seed dehulling by rodents; soil disturbance = 2
Null/Unknown = 3
Stratification Agents: None/Unknown = 3
Unknown/none = 3
Chemical/heat = 3
Heat = 4

Mode Dispersal – Sensitivity

Dispersal could be scored for either sensitivity or adaptive capacity. Modes of dispersal include gravity, seed capsule explosion, water, wind and animal. If thought of from a sensitivity perspective, the more modes of dispersal available to a species, the less sensitive to changes in climate it may be. Having more than one mode of dispersal could also be considered an adaptive capacity. We scored the metric as sensitivity as follows:

Gravity = 1;
Gravity + 1 = 2 ; with the exception of wind, which = 3
Gravity + 2 modes = 3
Gravity + 1 mode + wind = 4
Gravity + 3 or more modes = 5
Unknown = 3

Categories in the MCV Life History Table
Animal = 2
Animal (ants); expulsion from capsule; gravity = 3 (note *the limited distance of these dispersal agents*)
Animal; explosion from capsules = 3
Animal; gravity = 2
Animal; gravity; water/hydrological = 3
Animal; gravity; wind = 4
Animal; water/hydrological = 3
Animal; water/hydrological; wind = 5
Animal; wind = 3
Gravity = 1
Gravity; wind = 3
Water/hydrological = 1
Water/hydrological; wind = 3
Wind = 3

Reproductive Range/Longevity - Sensitivity
We scored life span, here represented by estimates of reproductive life span as a sensitivity metric for the mostly perennial species making up the macrogroup. The longer the lifespan, the lower the sensitivity, following the logic that the species has more opportunities for successful reproduction. We recognize that for some fire-adapted annuals and perennials, a shorter lifespan is potentially an adaptive advantage, if recruitment following a major disturbance is high. This will also interact with seed longevity.

1 year = 2
1-10 years = 1
10-100 years = 2
10-200 = 3
10-300 = 4
10- 350 = 5

Categories in the MCV Life History Table
(10) 20-200 + years = 2
(20) 50–100+ years = 2
(10) 20–300+ years = 4
(20) 50–100+ years = 2
(3) 6–40 (70) years = 2
(3)10–150+ years = 3
(5)10–100 years = 2

(Intermediately) long-lived = 3
(Moderately) long-lived = 3
1 year = 2
10–500 years = 5
2 years to life of plant =
20 years to life of plant =
20–100+ years = 2
20–200 years = 3
20–250 years = 3
20–2000+ years = 5
20–500+ years = 5
20–600+years = 5
20–700 years = 5
20–800 years = 5
20–900 years = 5
Long-lived =
Short-lived =

ADAPTIVE CAPACITY SCORES

Fire - Adaptive Capacity

If a species has a mechanism by which it reseeds itself, sprouts from basal roots, or otherwise has the ability to regenerate after a fire (or other stand clearing disturbance), we considered the species to have a higher adaptive capacity than if it does not. Given the limited number of mechanisms, adaptive scores were limited to:

1 = no adaptive capacity
3 = not known; low sprouter
4 = Fire ha
5 = one mechanism: high sprouter or seeds germinate with heat

Categories in the MCV Life History Table
Categories from the MCV manual for Survivability after fire/disturbance
Null/unknown = 3
(Very) fire-sensitive; no/low sprouter = 1
Fire-sensitive = 2
Fire-sensitive, thin epidermis = 2
Fire sensitive/thin epidermis/high flammability = 1
Fire-sensitive; thin epidermis; high flammability; no/low sprouter = 1
Fire-sensitive; high flammability = 2
Fire-sensitive; high sprouter = 2
Fire-sensitive; low sprouter = 2
Fire-sensitive; no/low sprouter = 2
Fire-sensitive; no/low sprouter; architecture susceptible canopy = 1
Fire-sensitive; thin epidermis; high flammability; no/low sprouter; canopy architecture susceptible = 1
Fire-hardy = 4
Fire-hardy/thick epidermis/canopy structure susceptible = 4
Fire-hardy/thick epidermis/canopy structure resistant = 5
Fire hardy/high sprouter = 4
Fire-hardy; high flammability; high sprouter = 3

Fire-hardy; low flammability; high sprouter = 5
Fire-hardy (disturbance-hardy) = 4
Fire-hardy to fire-sensitive; high sprouter = 3
Fire-hardy; high flammability; high sprouter; canopy architecture susceptible = 4
Fire-hardy; thick epidermis; canopy architecture resistant = 5
Disturbance hardy; high sprouter = 4
Fire-hardy; low sprouter = 4
Fire-hardy; no/low sprouter to high sprouter = 4
Fire-hardy; thick epidermis = 4

Fecundity/Recruitment mode - Adaptive Capacity
We scored recruitment mode to be an adaptive function. This mode includes high and low annual recruitment, and also various forms of episodic recruitment. Episodic recruitment is essentially an adaptive trait. Vegetative recruitment was treated as low.

Low = 1
Medium = 3
High = 5
Episodic = 4
Unknown = 3
Low- High = 3
Low- medium = 2
Medium – High = 4
Medium & Episodic = 4
Low & Episodic = 3

Categories in the MCV Life History Table
Episodic = 4
Episodic (disturbance dependent) = 4
Episodic (fire dependent) = 4
Episodic (rainfall dependent) = 4
Episodic (substrate dependent) = 4
Episodic (variable) = 4
Episodic; high = 4
Episodic; low = 4
High = 5
Medium = 3
Low = 1
Low (mostly vegetative) = 1
Low to high = 3
Low to high (secondary colonizer, fire intensity dependent) = 3
Low to high (sensitive to competition) = 3
Low to high (variable) = 3
Low to high (with rainfall); episodic = 3
Low to medium = 2
Low to medium (soil-dependent) = 2
Low to medium; episodic = 3
Low to moderate = 2
Low; episodic = 3
Low; episodic (disturbance dependent) = 3

Medium (obligate seeder) = 4
Medium to high = 4
Unknown = 3
Variable = 3

Seed Longevity – Adaptive Capacity
We scored seed longevity as an adaptive capacity, although it too could be considered a sensitivity trait. The logic is that the longer seeds can maintain in the seed bank, the more capacity a species has to await proper germination/growing conditions.

Categories in the MCV Life History Table
Short = 1
High = 5
Long = 5
Low = 1
Medium = 3
Medium to long = 4
Short to medium = 2
Short/Long = 3
Transient = 1
Transient to long = 3
Unknown = 3

Other categories in the MCV Life History Table
Mode of sprouting – not analyzed, relates to where buds for resprouting are located, being typically either underground or on trunks or branches.
Seed Storage – not analyzed, not enough variation in categories for targeted species in this analysis.
Disturbance stimulated flowering – not analyzed, refers to whether disturbance stimulates flowering (as opposed to seed drop). There is one species analyzed, *Populus tremuloides*, for which this is true. This was considered, but not scored.
Regional Variation – not analyzed, refers to variation in individuals from one location to another.