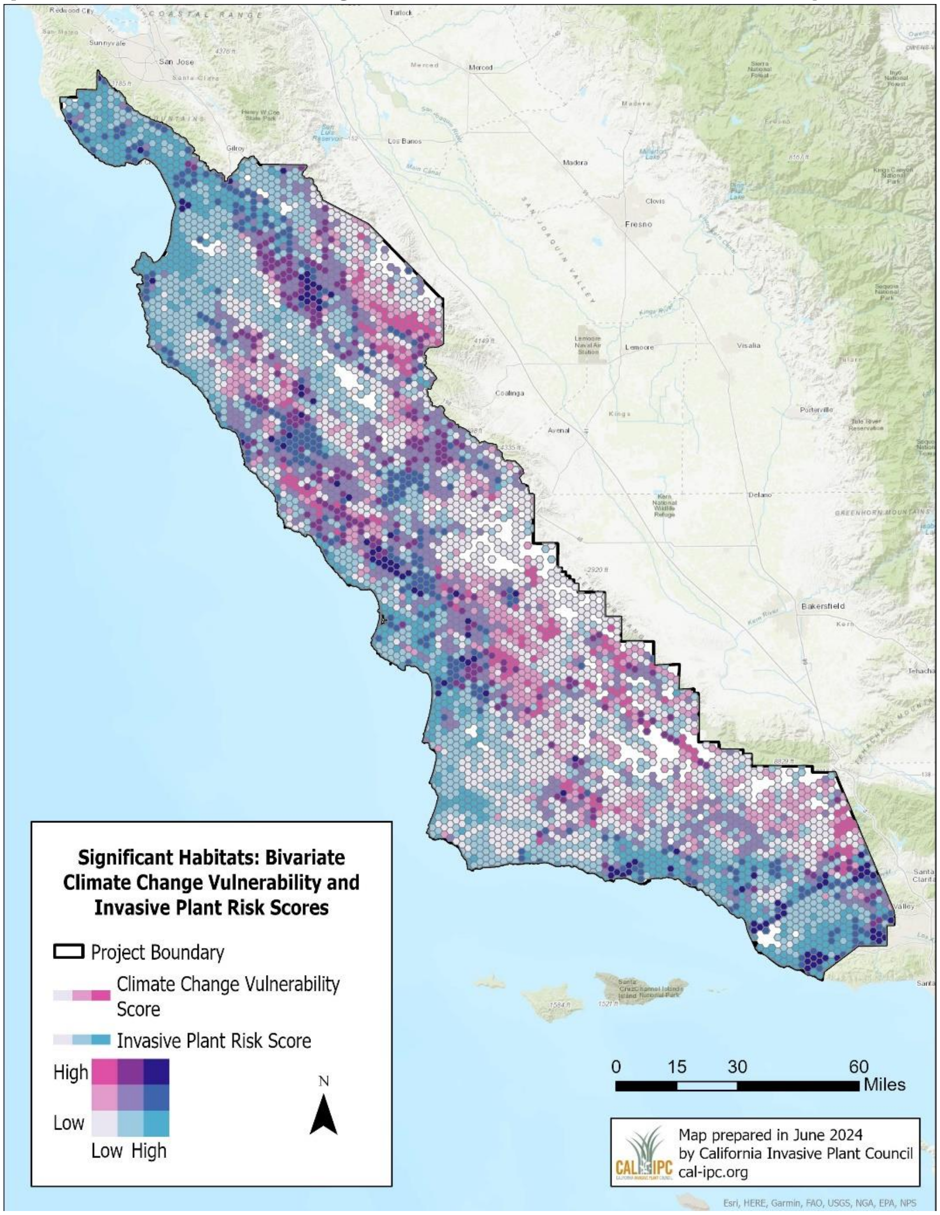
PROTECTING CENTRAL COAST HABITAT for LISTED PLANT SPECIES
SANTA CRUZ, SAN BENITO, MONTEREY, SAN LUIS OBISPO, SANTA BARBARA, and VENTURA COUNTIES, CALIFORNIA

Final Report for WCB Grant Agreement No. WC–2075KM; Project ID: 2020172



California Invasive Plant Council
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Executive Summary

This project plans for climate-smart invasive plant management to improve climate resilience of federally listed species and sensitive habitats within the California Central Coast region encompassing Santa Cruz, Monterey, San Benito, San Luis Obispo, Santa Barbara, and Ventura counties. Specific attention is paid to how climate change vulnerability might compound the risks that invasive plants pose to species and habitats.

Competition from invasive plants and climate change are considered major threats to the long-term survival and recovery of federally listed rare plants and is highlighted in many recovery plans (Lawler et al. 2002; e.g., United States Fish and Wildlife Service [USFWS] 2008, 2023). To date there have been few collective spatial or cross-species analyses of the threats from invasive species and their interplay with climate change, yet this information is critical when prioritizing management actions to protect rare plant species. Furthermore, land managers managing lands where listed species occur rarely have clear guidance as to where and how to consider taking management actions (as permitted) to address threats.

This project addressed this information shortfall by: (1) developing a regional invasive plant risk scoring system for 50 federally listed plant species in the California Central Coast; (2) compiling existing spatial data on listed plants, invasive plant species, and sensitive habitats; (3) calculating Invasive Plant Risk Scores (IPRS) for listed plant species and their populations, (4) creating a sensitive habitat (here, “Significant Habitat”) GIS layer, (4) calculating IPRS for sensitive habitats that occur within the central coast region; (5) calculating climate vulnerability scores for both listed plants and sensitive habitats; and (6) combining IPRS and climate vulnerability ranking to identify areas of high versus low presumed combined risk.

We compiled information on 50 federally listed plant species in the Central Coast. Our invasive plant risk analysis scored 17 of the 50 rare plant species studied as at high risk of facing impacts from invasive plant species and 23 rare plant species as moderate-high risk. Invasive plant impacts appeared to be higher for coastal populations of rare plants than those for populations that occurred inland. The invasive species most frequently listed as co-occurring with rare plants and potentially impacting them were invasive annual grasses (including *Bromu*s spp., *Avena* spp., *Festuca* spp., and others), ice plants (*Carpobrotus* spp. and *Mesembryanthemum* spp.), and perennial veldt grass (*Ehrharta calycina*). Rare species were also scored for vulnerability to the effects of climate changes, specifically considering fire risk, heat and solar incidence, and aridification. Of these, three were identified as highly vulnerable to the effects of climate change and an additional 15 as moderately to highly vulnerable. When Climate Change Vulnerability Scores were added to IPRS, 21 ranking high and 21 ranking moderate-high.

We identified, compiled information, and evaluated invasive plant risk and climate change vulnerability for 171 Significant Habitat types (SH). Of these, three SH were categorized as being under high risk of impacts by invasive plants and 71 were categorized as moderate-high risk. The number of high scoring Significant Habitats increased when Invasive Plant Risk and Climate Change Vulnerability scores were combined: there were 19 highly vulnerable SH and 72 moderate to highly vulnerable SH.

Lastly, we identified two sites occurring in an existing reserve area that met our criteria of containing both species and habitat that is at high risk of impacts from invasive plants and scored relatively high in terms of climate change vulnerability. As a pilot project, funds were subcontracted out to the Land Conservancy of San Luis Obispo (LCSLO) to provide a pulse of weed control around populations of Nipomo Lupine and sensitive foredune habitat containing state-listed species. This infusion of funds was well-timed in that it allowed LCSLO to address the flush of invasive plants that emerged after heavy rains in 2024, thus further effectively depleting the weed seed bank and improving the growth, vigor, and seed production of sensitive plants.

The information compiled and analyzed by this study provides a foundation for setting strategic priorities for land managers, helping land managers and agencies better identify which rare plant populations are most at risk from invasive plants, which rare plant species are most at risk regionally, and which habitats are most at risk today and into the future.

Fiscal Report

The budget was fully expended, and all tasks were completed. Minor adjustments were made to Task budgets before grant end to account for approved overages in Tasks 1 and 3. In kind funding provided was well over the $191,764 committed and came primarily from a concurrent CDFW Section 6 grant that supported much of the work associated with Task 1 (data collection and invasive plant risk assessment for rare species, not including climate vulnerability analysis). A total of $5505 additional Cal-IPC staff time was invested in kind for analysis and prioritization in Q2 of 2024.

Table 1. Expenditures by task and year.

Project Task	*Total Cost*	*Total Non-WCB (in-kind match)*	*WCB Allocation (amended)*	*Jan - June 2021*	*July '21 - June '22*	*July '22 - June '23*	*July '23 - June '24*	*Total Expended*
Task 1 Data collection and risk assessment	$ 211,764.00	$ 249,280.56	$ 20,008.36	$ 451.44	$ 13,121.40	$ 6,435.52	$ -	$ 20,008.36
Task 2 Compile invasive plant data	$ 20,000.00	$ -	$ 19,996.09	$ 451.44	$ 5,861.42	$ 9,476.54	$ 4,206.69	$ 19,996.09
Task 3 Prioritize invasive plant management	$ 60,000.00	$ 5,505.00	$ 60,003.91		$ 2,081.49	$ 17,670.09	$ 40,252.33	$ 60,003.91
Task 4 Plan implementation/CEQA	$ 20,000.00	$ -	$ 19,991.64	$ -	$ -	$ 217.69	$ 19,773.95	$ 19,991.64
				$ -				
TOTAL:	$ 311,764.00	$ 254,785.56	$ 120,000.00	$ 902.88	$ 21,064.31	$ 33,799.84	$ 64,232.97	$ 120,000.00

Grant Amendments

A no-cost extension to the grant was finalized on Feb. 28, 2023 extending the grant end date from March 31, 2023 to June 30, 2024.

Task 1: Data Collection and Risk Assessment

Data on location, status, biology, ecology, and invasive plant impacts were collected for fifty federally listed plant species from CNDDB, CAPR (California Rare Plant Recovery), USFWS reports, other available literature, and botanist interviews. Using this information, along with geographic parameters collected in GIS, we develop risk assessments for the region's 50 federally listed plant species.

Data Collection for Three Listed Plant Species in the Region

Demographic and invasive plant cover data were collected for three rare plant species that appeared to have limited information collected and showed indications of being at higher risk of impacts from invasive plants. These included: Pismo Clarkia (*Clarkia speciosa* ssp. *immaculata*), Gaviota tarplant (*Deinandra increscens* ssp. *villosa*), and Camatta Canyon amole (*Hooveria purpureum* var. *reductum*). Sites were surveyed using a modified California Native Plant Society (CNPS) relevé protocol (described in Cal-IPC 2020 annual report to CDFW) and data on target plant abundance, number of flowers per plant, co-occurring native and non-native cover, percent cover of all plant species, percent bare ground, approximate soil type, and level of disturbance were collected. Population assessments and collection data were submitted as status updates to CNDDB in January of each year: 2020, 2021, 2022, and 2023 by the Santa Barbara Botanic Garden and invasive plant co-occurrence data were included in this project.

See more details regarding the surveys and results in Cal-IPC's report to CDFW (Cal-IPC 2023).[1]

Design a Data Collection Form for Invasive Plant Observations at Rare Plant Populations

Cal-IPC contacted 24 botanical experts to collect information about invasive plant occurrences at rare plant populations. These experts were also questioned about management actions and any experiments performed for managing the populations. Observations for 249 populations informed by interviews were then entered into table format and incorporated into the Invasive Plant Risk Scores (Table 2).

Table 2. Data collection form for invasive plant observations.

ObjectIDs of Populations Referenced	Are invasive plants a threat to the referenced population?	General observations	Treatment performed?	Experimentation performed?	Type of experiment?	Non-native co-occurring species	Other notes

Invasive Plant Risk Score (IPRS) for Rare Plant Populations

Rare plant Invasive Plant Risk Scores were constructed from site-specific, species-specific, and geospatial association information collected for the 50 rare plant species under study. Each group of factors is described below.

[1] https://www.cal-ipc.org/resources/library/publications/protecting-rare-plants/

Site-Specific Data

Perceived rare plant population-level threat and data on co-occurring invasive species were collected and compiled for the central coast region. California Natural Diversity Database (CNDDB) spatial data for all federally listed species were initially downloaded in 2020, prior to WCB grant begin, and again in April 2023 (see CDFW 2023 report). These data served as the foundation of our invasive plant co-occurrence dataset. When available, information on the presence of invasive species and their level of threat from the CNDDB dataset.

Additional unique occurrence records and invasive plant co-occurrence information were added from the California Plant Rescue (CaPR) program database (CaPR 2023), interviews with regional botanical experts, unique information provided by California Botanic Garden (CBG) and SBBG collection records, and the California Consortium of Herbaria (CCH2; CCH2 Portal 2023). Overlapping occurrences were combined and any overlapping EOndx (element occurrence) codes or other ID fields were referenced for each base record. For the purpose of our study, “population” here is used to represent CNDDB, CaPR, and CCH2 occurrences with unique EOndx or, if lacking, other identifying codes.

CaPR data were accessed and downloaded in August 2021 and again in April 2023 (CaPR 2023). Data were added to the CNDDB dataset by first importing them into GIS as points and then transforming them into polygons with buffers dependent on their error radius. Records with biological status of “cultivated” or “data deficient” were excluded from the dataset. Whenever records were consolidated, the record with more accurate location data was used while retaining all record identifiers.

CCH2 data were imported into GIS as points, transformed into polygons with 100-meter buffers, and incorporated using the same rule set (CCH2 Portal 2023). When checked against CNDDB records, we found that CCH2 records were largely already represented. Only *Thysanocarpus conchuliferus* records that were missing in CNDDB were added.

We compiled perceived impact from invasives by tallying records—from CNDDB, CaPR, and the most recent USFWS five-year report or recovery plan for each listed plant species—that specifically called out invasive species as a threat to a given population. We also included reports from the 24 local botanists surveyed that had expertise with the listed species being studied. If there were any discrepancies between experts’ information, reports of invasive threat outweighed those of no threat.

Population-level invasive plant co-occurrences were tallied from existing records and local expert feedback. There were instances where only a non-native genus was listed in the CNDDB data or otherwise. We classified presence of any species in the genera *Avena*, *Briza*, *Bromus*, *Gastridium*, *Hordeum*, and *Festuca* (*Vulpia*) as instances of co-occurring invasives. In numerous cases, the co-occurring species were only listed as “annual grasses” or “non-native annual grasses”. Because the most common annual grasses in California are invasive, all above listed species and references to “annual grasses” were lumped into a category of “non-native annual grasses”.

These data were used as part of our Invasive Plant Risk Score (IPRS) calculation for each population, described further in this section.

Species-Specific Data

Species-level threat was assessed independently of population-level threat by compiling information from existing reports of invasive species being a species-level threat to each of the 50 listed species. Primary sources of information included the most recent USFWS five-year reports and recovery plans, the CNPS rare plant inventory, and the knowledge of local experts.

We also studied the unique physical characteristics and ecological affinities of the 50 species by creating a detailed matrix of plant characteristics and looking for associations between certain plant traits and their vulnerability to invasive plants (see Appendix A). A total of 17 plant characteristics and five ecological parameters (including level of endemism, fire vulnerability, and habitat specificity) were scored for each species. Collaborator Dr. Marina LaForgia assisted with a multivariate analysis of plant character traits, invasive plant risk, and components of climate vulnerability. Overall, we were not able to establish significant correlations between plant character traits and current (USFWS and expert knowledge-based) perceived invasive plant risk or climate vulnerability (data not shown), though the resulting matrix is a valuable comparison of rare plant characteristics and habitat associations. and elements were used for climate sensitivity scoring. Nevertheless, we did include two plant character traits, seed dormancy and perennial underground root storage, as modifiers to IPRS, as they represented the ability to escape competition over the short-term for established plants and included a few plant characteristics for climate vulnerability scoring.

Geospatial Associations

Additional geospatial data layers were used to inform invasive plant risk each rare plant population. These layers included: the ACE invasive plant stressor layer (CDFW 2017b), a USGS serpentine layer (Horton 2017), a composite shapefile of roads including active railroads (see below), and a nitrogen deposition layer (Schwede 2014). The ACE invasive plant stressor layer provides a USGS quadrangle-scale assessment on the level of invasive plant impact, as compiled by Cal-IPC and CDFW based on a statewide survey conducted by Cal-IPC of the status of Cal-IPC-listed invasive plants.

Road and railroad line data were sourced from the USGS National Transportation Dataset and the US Forest Service (USFS) and consolidated into a single transportation line shapefile (USGS 2014; USFS 2015). We used a 30-meter buffer from transportation line data to score whether a population was influenced by an active road or railroad. Additionally, ESRI and Google Maps satellite data were used to investigate and incorporate occurrences that appeared to be on industrial buildings and lots (ex. Object ID: 618) if populations were not already scored as road-adjacent (ESRI 2022, Google 2022).

All individual population records were initially scored regardless of their “presence” status (i.e., including records noted as “extirpated”, “likely extirpated”, or “presumed extant”) but were left out in later analyses. We did not attempt to match the total number of populations in our dataset with the total number of populations for each species accepted by agencies in species’ reviews.

Invasive Plant Risk Score (IPRS) Calculation

We developed a set of rules to score the level of risk posed by invasive plants to rare plant populations using the information compiled for site-specific data, species-specific data, and geospatial associations. The scoring system was used to score invasive plant risk for all rare plant populations. The scoring scale ranged from 0 to 10 and was comprised of eight components. Components included:

- One species-specific factor (the presumed species-level threat from invasive plants based on existing reports, max. 2 points);
- Three population-specific factors (co-occurrence with a Cal-IPC listed species, max. 1 point; co-occurrence with one or more of the three high threat invasive species/categories, max. 1 point; and documentation of threat at the local population-scale, max. 2 points);
- Four geographic factors (roadside adjacency, max. 1 point; high nitrogen deposition, max. 1 point; and occurrence within a USGS quad with high ACE invasive plant stressor score, max. 2 points; occurrence on serpentine soil, max -1 point adjustment).

Modifiers were added to reduce risk scores where specific factors were likely to reduce risk for either populations or species. Location records that overlapped serpentine or mafic soils were modified by subtracting 1 point from their score due to the documented lower invasibility of serpentine soils (Huenneke et al., 1990; included as one of the eight factors). Population records for rare species that exhibited strong dormancy or were perennial with underground storage organs were modified by subtracting 0.5 for each factor from their population score because of the additional resilience to invasive plant impacts that these traits likely provide.

Each population in our database was given an IPRS, calculated by adding up points across the eight components and two modifiers listed here. The layer was submitted to CDFW's Biogeographic Information and Observation System (BIOS) Viewer and includes population-level IPRS and their components.[2]

We used equal intervals of average IPRS to set the ranges for risk categories: "high" risk for scores above 7.5, "moderate-high" for scores above 5.5 and up to 7.5, "moderate-low" for scores above 3.5 and up to 5.5, and "low" for scores 3.5 and less (Figure 1). "Moderate-low" rankings also spanned the maximum score a rare plant could achieve when location-specific invasive plant threat data were missing (example: a population could receive a score of "4" if it occurred in high ACE stressor USGS quadrangle, overlapped with high nitrogen deposition, and was adjacent to a roadside, but otherwise had no evidence of impacts).

Population-level scores were averaged by 2.5-square mile hexagon to compare invasive plant risk spatially across the central coast region (Figure 2).

[2] https://services2.arcgis.com/Uq9r85Potqm3MfRV/arcgis/rest/services/biosds3181_fpu/FeatureServer

Table 3. Rare Plant Species with the highest modified average Invasive Plant Risk Score (see Appendix A for full list).

Species	Modified Average IPRS[1]	Invasive Plant Score Ranking[2]	# Populations[3]
Chorizanthe robusta var. hartwegii	8.92	High	4
Erysimum menziesii	8.89	High	9
Chorizanthe robusta var. robusta	8.87	High	15
Potentilla hickmanii	8.75	High	2
Diplacus vandenbergensis	8.74	High	17
Gilia tenuiflora ssp. arenaria	8.70	High	25
Chorizanthe pungens var. pungens	8.61	High	50
Hooveria purpureum var. purpureum	8.48	High	26
Layia carnosa	8.20	High	8
Clarkia speciosa ssp. immaculata	8.15	High	26
Holocarpha macradenia	8.09	High	17
Hooveria purpureum var. reductum	8.00	High	4
Chorizanthe parryi var. Fernandina	8.00	High	1
Lupinus nipomensis	8.00	High	2
Chorizanthe pungens var. hartwegiana	7.89	High	18
Polygonum hickmanii	7.67	High	3
Piperia yadonii	7.54	High	26

[1]The modified average Rare Plant Population Invasive Plant Risk Score for the species.
[2]The Invasive Plant Risk Score class ranking (High, Moderate-High, Moderate-Low, Low).
[3]The number of existing populations for the species.

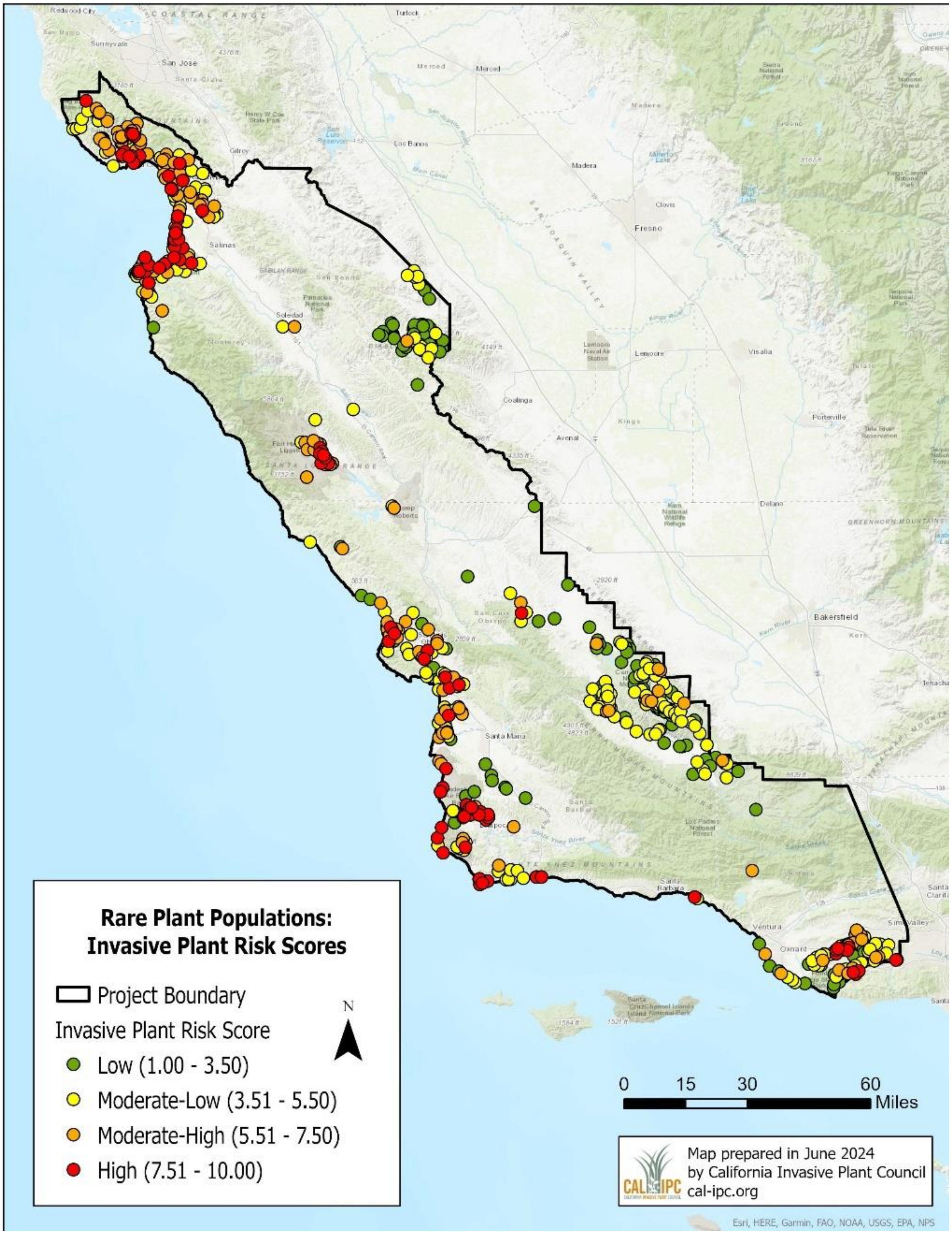

Figure 1. Invasive Plant Risk Scores for rare plant populations in the project area. Higher scoring populations are placed on top of lower scoring populations.

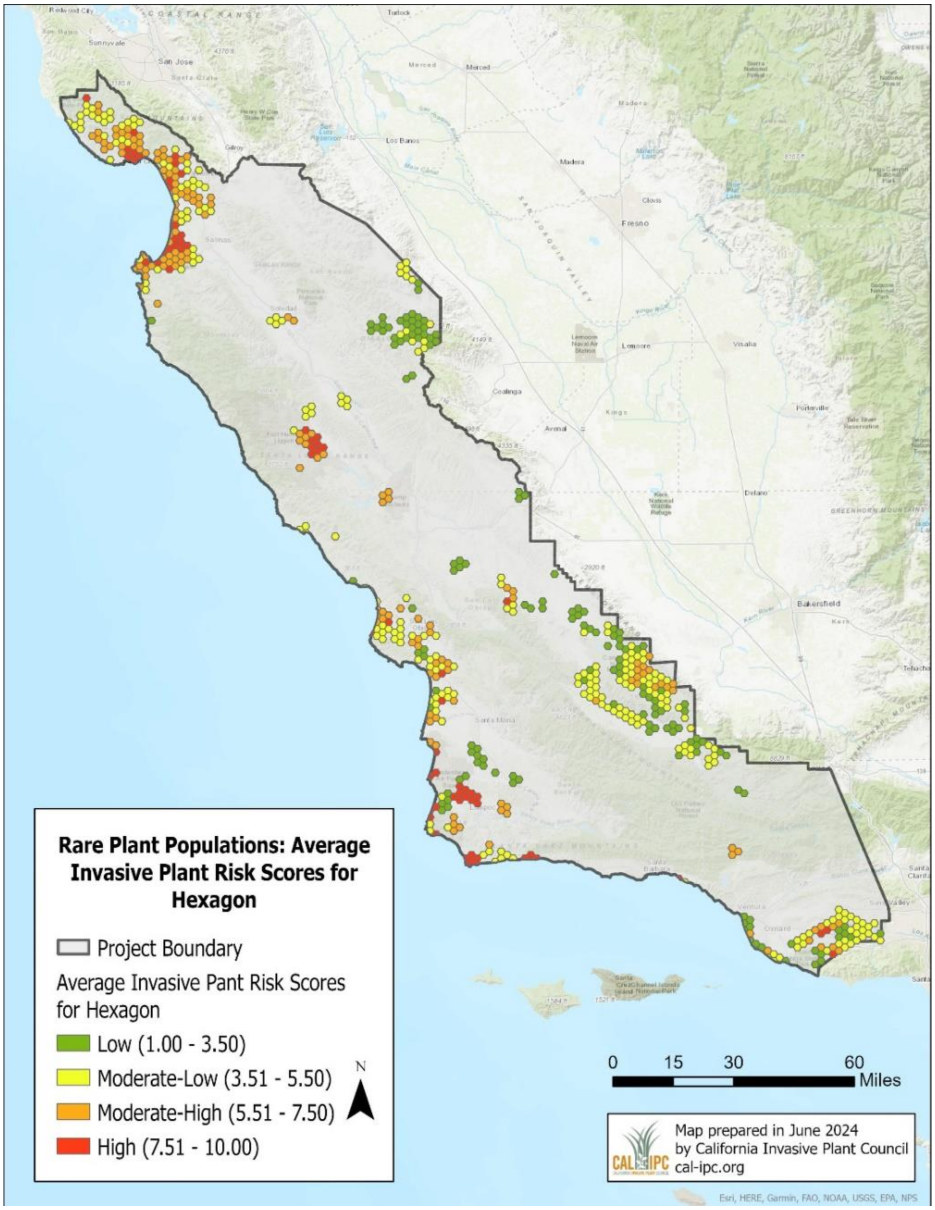

Figure 2. Rare Plant Population Invasive Plant Risk Scores averaged by hexagon in the project area.

Confidence Scores for Invasive Plant Risk to Rare Plant Populations

Several records were lacking information for one or more of the three population-specific components (co-occurrence of invasive species, co-occurrence of high threat invasive species, and documentation of the existence of a threat). We developed a confidence score to better identify where data were lacking by constructing a confidence score for each population record. Confidence was scored based on the level of population-level source information that was available (Table 3). A population score was "Low" confidence if it lacked both CNDDB and expert data, "Moderate" confidence if only one source was available (CNDDB or expert), and "High" if both were available. Expert data included feedback from either local botanists, CaPR, or USFWS reports. Confidence scores were given numeric values of 1, 2, and 3 so that confidence could be averaged for a species or USGS quarter quad (the spatial scale originally used for the CDFW grant).

Task 2: Compile Existing Invasive Plant Data for Other Important Habitats

We used a similar methodology to calculate risk for other important habitats as we did for rare species. However, we first needed to identify the habitats to use in this analysis. Initially, we planned to use the California Native Plant Society Important Plant Areas dataset that was due to be released in 2023, but this dataset was not available in time for analysis. We instead used component habitats belonging to each of the State Wildlife Action Plan's (SWAP) Significant Terrestrial Habitat (STH) classifications occurring in the central coast, which offered more fine-scale mapping than the hexagon-level resolution of the STH. The components habitats are referred to here as "Significant Habitats" (SH). Using the methods described below, we were able score SH IPRS for both habitat types, the specific locations in which they occur (data not shown), and the average these to the hexagon-scale used by CDFW's SWAP and ACE.

Significant Habitat Data Compilation

We first compiled the STH components as defined by CDFW. STH includes the following broad categories as components: Rare Vegetation Types, Oak Woodlands, Riparian, Freshwater Wetlands, and Saline Wetlands. CDFW lists the sources for each of the STH Component's geospatial data. Terrestrial data were sourced and identified as best as possible with some slight modifications.

There were slight differences (<5%) in the number of hexes for each STH component between the CDFW STH and our resulting Significant Habitats. As a result, the Cal-IPC SH IPRS may not map perfectly within the CDFW STH layer. We used the comprehensive USFS R5 Existing Vegetation dataset as an additional source to account for any gaps in the standalone VegCAMP datasets. We also excluded Ponds from our sensitive habitat dataset since we were concerned only with terrestrial sensitive habitats and invasive plant and climate change risks to them. The most recent update available to the CDFW Significant Terrestrial Habitat dataset was from August 2022 during our project. This may have accounted for some of the differences in number of hexes for each STH component between the CDFW STH and our resulting Significant Habitats.

Habitat Type Scoring

Each STH component consisted of several more specific Significant Habitat types, referred to here as Significant Habitats (SH), which in turn were each composed of multiple MCV plant alliances (e.g., Table 4). There are 171 different Significant Habitats across the project area. When SH types occurred multiple times within a hexagon, they were geospatially dissolved to prevent duplication. SH types with less than 1.0 acre within a hexagon were discounted from the scoring process. SH types were only scored once within a hexagon. This resulted in a total of 17,347 Significant Habitats within hexagons within the project area.

Table 4. Significant Habitat Type and MCV Classification crosswalk for the STH Component "Oak Woodland."

STH Component	Significant Habitat Type	MCV Alliance Classification
Oak Woodland	Blue Oak Woodland	Quercus douglasii Forest & Woodland Alliance Quercus wislizeni - Quercus parvula (tree) Forest & Woodland Alliance
	Blue Oak-Foothill Pine	Pinus sabiniana Woodland Alliance Quercus douglasii Forest & Woodland Alliance
	Valley Oak Woodland	Quercus lobata Riparian Forest & Woodland Alliance Quercus lobata Woodland Alliance
	Coastal Oak Woodland	Arbutus menziesii Forest Alliance Juglans californica Forest & Woodland Alliance Quercus (agrifolia, douglasii, garryana, kelloggii, lobata, wislizeni) Forest & Woodland Alliance Quercus agrifolia Forest & Woodland Alliance Quercus engelmannii Forest & Woodland Alliance Umbellularia californica Forest & Woodland Alliance

SH were converted to the Manual of California Vegetation (MCV) alliances based on their source. California Habitat Wildlife Relationship (CHWR) habitat types were converted using CHWR community alliance matches and CNDDB sourced habitat types were converted using the Holland community alliance matches. In cases where there was no direct match, the Significant Habitats were either generalized or matched to the most similar listed MCV alliance. For example, "Central foredunes" was matched to both "Northern foredunes" and "Southern foredunes." In some cases, the Significant Habitat was generalized up to the STH level, which then took the average score for SH.

Invasive Plant Risk Score for Significant Habitats

Invasive Plant Risk Scores for Significant Habitats (SH) were averaged by hexagon for area-based analysis and averaged across occurrences for SH-based scores. Significant Habitat IPRS were, similar to rare plant IPRS, scored 1-10, based on eight criteria: Habitat threat, Regional threat, Local threat, Ecological Co-occurrence, High Threat Co-occurrence, Roadside, High Nitrogen, and Serpentine.

SH IPRS components:

> *Habitat threat (0-2 points):* The inherent vulnerability of a MCV alliance to invasive plants. If the MCV noted invasive plants as a significant or major threat to the MCV alliance, habitat-level invasive plant threat scored "2". If invasive plants were mentioned as a lesser threat, potential threat, or one of several threats to the MCV alliance, it scored 1. If there was no mention of invasive plants as a threat, it scored 0. Alliance values were averaged by SH and the highest SH score was used per hexagon.

Regional threat (0-2 points): The weighted area average of CDFW ACE "Level of Terrestrial Plant Invasion" for the hexagon from USGS quadrangle-scale data. Areas with high levels of terrestrial plant invasion scored higher.

Local threat (0-2 points): If there are existing federally listed rare plant populations occurring in the hexagon, the local threat scores for these populations were averaged and scored. Originally populations listing "invasive plants" as a local threat scored 2. While populations that did not list invasive plants as a local threat scored a 0. Data was sourced either from CNDDB or expert knowledge about the specific locality record.

Ecological Co-occurrence (0-1 points): Whether the hexagon has an occurrence of ecosystem engineering invasive plants.[3] Hexagons with at least one occurrence scored a 1.

High Threat Co-occurrence (0-1 points): Whether the hexagon has an occurrence of a high threat invasive plant (Cal-IPC "HIGH" rated invasive plant species). Hexagons with at least one occurrence scored a 1. Data were downloaded from Calflora as points and include iNaturalist and CCH observations, CNPS releve (CDFW 2024), and USFS (2022) data back to 2010 with obscured data removed.

Roadside (0-1 points): If the percentage of the hexagon covered in 5-meter buffered roads is significant (greater than 3.47% based on natural breaks in data). Scores the likelihood of invasive plants colonizing and spreading at a site due to road-facilitated weed movement and road-associated disturbance.

High Nitrogen (0-1 points): If the weighted average for the hexagon is a "very high N deposition" area, (> 8.36 kg N/ha/yr from 2022 model). Scores the likelihood of a local environment that favors invasive plant dominance due to high N conditions.

Serpentine (-1-0 points): Whether the hexagon overlaps with serpentine soil. Overlap with serpentine soil scores a -1 since serpentine sites are often resistant to invasion. (from USGS layer)

MCV alliance scores were averaged for each SH. MCV alliances included native alliances, non-native alliances, and semi-natural alliances. MCV alliances that were clearly outside of the project area (ie. *Bistorta bistortoides - Mimulus primuloides; Carex lyngbyei*; Aspen) were excluded from MCV scores. If a vegetation community range wasn't defined as outside the project area, it was included.Several MCV alliances were "PENDING" status in the MCV. These MCV alliances do not have any information publicly available yet. MCV alliances that were

[3] Ecosystem engineering plants were those rated as having the capacity to "smother or overtop" other vegetation in Cal-IPC Plant Risk Evaluations or scored "high" for their biotic impact in Plant Assessment Forms used in the Cal-IPC inventory. Occurrence data these selected species were downloaded from Calflora and include iNaturalist and CCH observations, CNPS releve (CDFW 2024), and USFS (2022) dating back to 2010, with obscured data removed. https://www.calflora.org/entry/observ.html#srch=t&after=2010-01-01&cols=64,65,48,34,2,36,13,38,11,15,20,46,47&lpcli=t&cc=MNT!SBA!SBT!SCR!SLO!VEN&crnx=px3382&incobs=f&hfil=R&cch=t&inat=r.

"PENDING" were scored as 0 for all categories and were not excluded from analysis because they represented some sensitive habitat types.

Once Invasive Plant Risk Score for all Significant Habitat occurrences were summed, we classified the resulting scores into four classes (Low, Moderate-Low, Moderate-High, High) based on the same natural breaks used for Invasive Plant Risk Score for rare plant populations. Hexagon scores were based on the highest SH IPRS score occurring within each hexagon. Hexagons without Significant Habitats were scored but not mapped. Of the 5,436 hexagons within the project area, 5,022 of these had Significant Habitats and were mapped (Figure 3).

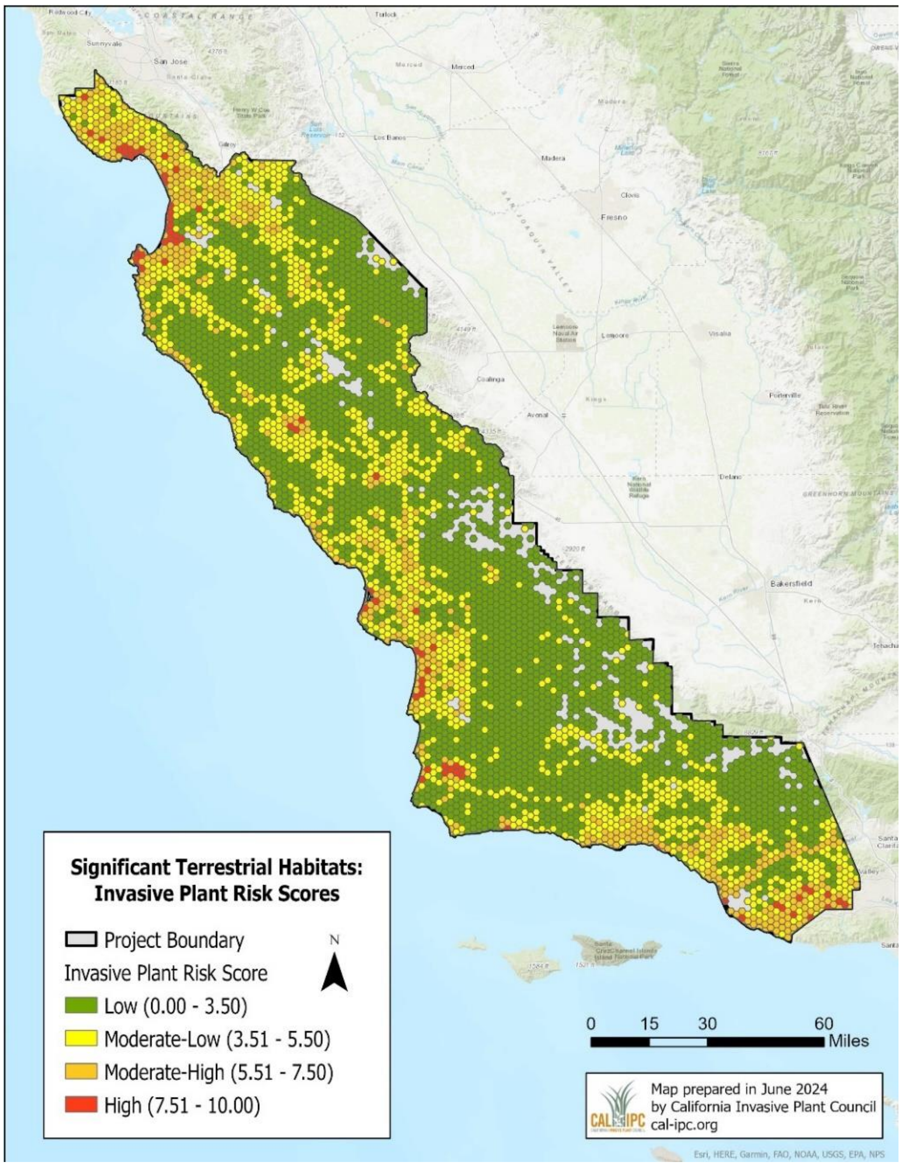

Figure 3. Significant Habitat Invasive Plant Risk Scores for the project area.

The hexagons with the highest SH IPRS tended to occur in more populated areas like Monterey, Santa Cruz, and Thousand Oaks (Figure 3). Additionally, several hexagons that had rare plant populations with high invasive plant risk scores also appropriately scored high, likely due to additional points contributed by the "Local Threat" score component in the SH IPRS. For example, Fort Hunter Liggett (Monterey Co.), which is a hotspot of high-scoring hexes, is also a hotspot of high-scoring *Chlorogalum purpureum* var. *purpureum*. Similarly, several rare plant populations occur near Capitola, Mission Hills, the Monterey Bay coastline, and Morro Bay, which also have high-scoring hexes.

Most of the populations of *Camissonia benitensis* had low Invasive Plant Risk Scores and occurred in hexagons with low Invasive Plant Risk Scores for sensitive habitat, however the highest scoring population of this species occurs in a high-scoring hexagon.

Table 5. Significant Habitats with highest IPRS scores across hexagons they occur in.

Significant Habitat Types	No. Hexagon Occurrences[1]	Ave. IPRS[2]	IPRS Ranking
Northern Bishop Pine Forest	3	7.98	HIGH
Monterey Pygmy Cypress Forest	4	7.68	HIGH
Southern Riparian Forest	4	7.55	HIGH
Arthrocnemum subterminale - Sarcocornia pacifica	4	7.50	MOD-HIGH
Distichlis spicata - Jaumea carnosa	5	7.50	MOD-HIGH
Encelia californica - Artemisia californica	1	7.50	MOD-HIGH
Eriogonum heermannii	1	7.50	MOD-HIGH
Sarcocornia pacifica - Brassica nigra	3	7.50	MOD-HIGH
Sarcocornia pacifica - Jaumea carnosa	1	7.50	MOD-HIGH
Sarcocornia pacifica - Jaumea carnosa - Batis maritima	2	7.50	MOD-HIGH
Sarcocornia pacifica - Jaumea carnosa - Distichlis spicata	2	7.50	MOD-HIGH
Spartina foliosa	1	7.50	MOD-HIGH
Ambrosia chamissonis - Abronia maritima - Cakile maritima	5	7.30	MOD-HIGH
Arthrocnemum subterminale	5	7.30	MOD-HIGH
Sarcocornia pacifica - Frankenia salina - Suaeda taxifolia	5	7.30	MOD-HIGH
Arthrocnemum subterminale - Monanthochloe littoralis	4	7.25	MOD-HIGH
Distichlis spicata - Ambrosia chamissonis	4	7.25	MOD-HIGH
Sarcocornia pacifica - Frankenia salina	8	7.25	MOD-HIGH
Sarcocornia pacifica	7	7.21	MOD-HIGH
Sarcocornia pacifica / algae	3	7.17	MOD-HIGH

[1] The number of hexagons the significant habitat type occurs in the project area.

[2] The significant habitat Invasive Plant Risk Score averaged for the hexagons the significant habitat type occurs in.

Invasive Plant Risk Score Confidence for Sensitive Habitats

Each MCV alliance was scored based on documentation on invasive plant vulnerability. If there was no evidence available from the MCV or the MCV was “PENDING,” then the MCV alliance received a 0. If there was any evidence used to score invasive plant risk vulnerability, the MCV received a 1 for confidence. The MCV alliance average scores were then averaged for each Significant Habitat Type. Confidence scores for the Significant Habitat Types were then averaged within hexagons, resulting in a confidence percentage based on natural breaks (Figure 4).

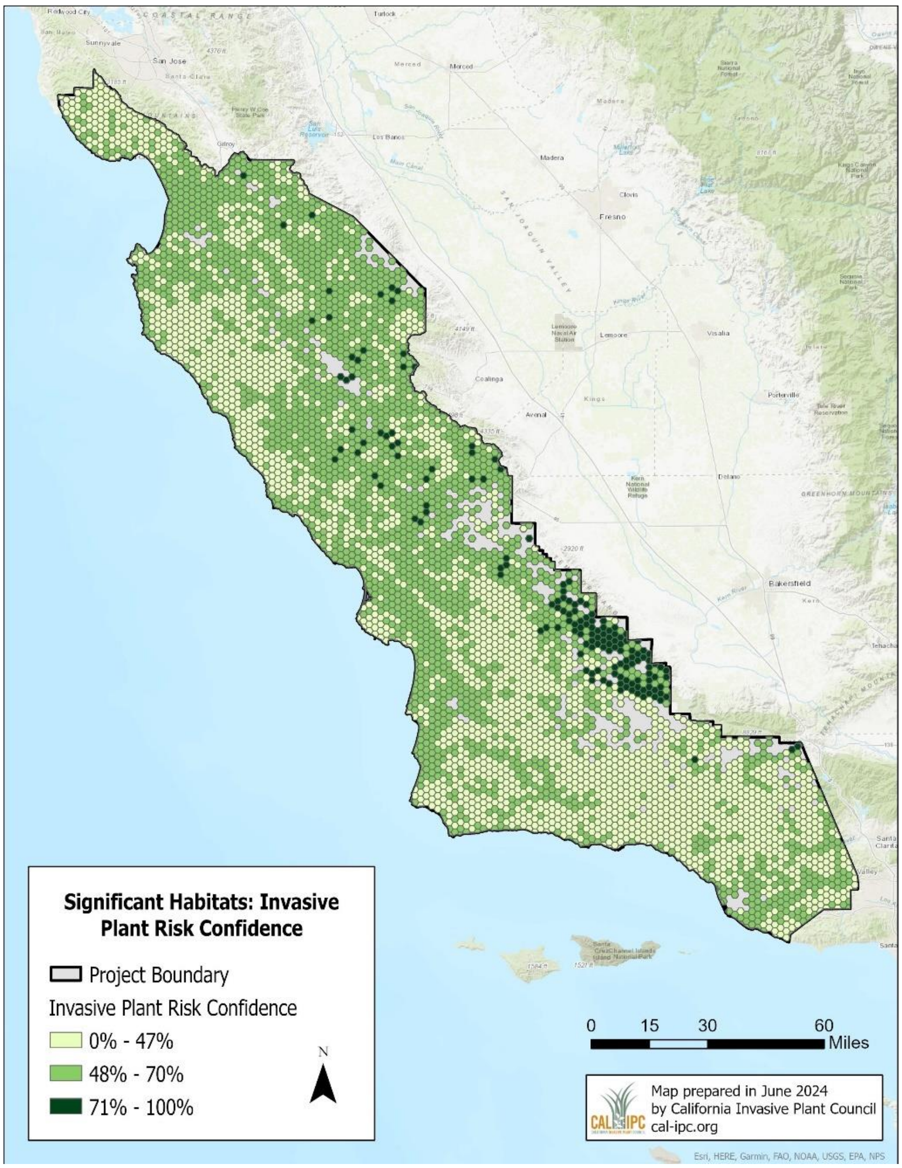

Figure 4. Significant Habitat Invasive Plant Risk Score confidence for the project area.

Confidence ranged with the number of habitat types within a hex. All 76 hexes with 100% Invasive Plant Risk Score Confidence had three or fewer habitat types. Since larger tracts of habitat types occur further inland and some of these included invasive plant information, hexes in these areas had high Confidence values. The 48 hexes with the lowest Invasive Plant Risk Score Confidence also had three or less habitat types. Hexes with ten or more habitat types typically had an Invasive Plant Risk Score Confidence between 40%-60%.

Task 3: Prioritize Invasive Plant Management

We analyzed invasive plant risk and climate change vulnerability for rare plants and Significant Habitats to identify species, habitat types, and geographic areas that were at highest risk and therefore highest priority to protect from the combined effects of both stressors. Management priorities were identified based on species-, habitat-, and area (hexagon)-based scores.

We chose not to model predicted future range expansions of individual invasive species as has been originally proposed, primarily because (1) risks from invasive plants come from many different species (rather than a few select species) that are both currently entrenched and being continually introduced; and (2) range shift models do not take biotic processes and feedback loops that are driven by climate change into account (i.e., self-perpetuating type conversions of native habitat to disturbance-tolerant non-native dominated habitat). Instead, we focused on estimating the additional risk that climate change could pose to species and habitats and how that could exacerbate the impacts of invasive plants. Climate change vulnerability was scored independent of invasive plant risk and subsequently added to risk scores as a modifier. Our assumption with this approach was that both stressors exacerbate, rather than ameliorate, one another.

Invasive Plant Risk Scores for Rare Species

Invasive plant risk scores for rare species were developed by Cal-IPC in collaboration with Heather Schneider and Sean Carson (Santa Barbara Botanic Garden) as part of a concurrent CDFW Section 6 grant (Cal-IPC 2023). Of the 50 species evaluated, 17 were rated high risk (IPRS score: >7.5) and 23 were moderate-high risk (IPRS score 5.5-7.5). *Chorizanthe* species, in particular, were scored as high risk. These species typically are low growing, have a high light requirement, are annuals, and typically occur on thin soils with (historically) little competition.

The high-ranking species and populations also occurred on coastal sites, where there are more disturbance factors (roads, high N deposition) and higher levels of regional invasive plant invasion. Invasive plants and associated thatch likely restrict sites for plant establishment and compete for limited seasonal rainfall and light.

Co-occurring invasive plants that were tallied from records, interviews, and a limited number of site visits are listed in Table 6. Invasive annual grasses (and their thatch), ice plant(s), and perennial veldtgrass were frequently cited as stressors for rare plant populations.

Table 6. The ten most frequently reported non-native plant taxa / categories listed when central coast rare plant populations are considered threatened by invasive species.

Non-native Genus / Category	# Co-occurrences
Bromus spp.	71
Iceplants (*Carpobrotus, Mesembryanthemum*)	66
Non-native annual grasses (unspecified)	61
Ehrharta calycina and sp.	44
Non-native species (unspecified)	44
Erodium spp.	29
Avena spp.	25
Centaurea spp.	22
Brassica spp.	17
Ammophila arenaria and sp.	14

Climate Change Vulnerability Scores for Rare Plant Populations

Climate Change Vulnerability Scores were developed by Tom Robinson Consulting, in collaboration with Cal-IPC, Heather Schneider (Santa Barbara Botanic Garden), and Marina LaForgia (UC Davis) and were composed of estimates of vulnerability to three environmental factors predicted to change with climate change: heat and solar incidence, aridification, and wildfire (Table 7). Rare plant populations were scored based on their level of exposure (where populations occurred relative to predicted future changes in heat and solar exposure, aridification, and fire regimes) and their sensitivity to each factor (each species' inherent characteristics presumed to be most related to climate sensitivity).

Predictive models used to determine future exposure are described in Appendix E. Species-specific plant characteristics used to estimate sensitivity are described in Task 2 (above) and in Cal-IPC (2023). Dispersal distance and seed dormancy were used for heat and solar effects; moisture requirement, root storage, and leaf size were used for aridification effects; and fire dependency was used for fire effects. Climate Change Vulnerability Scores did not incorporate sea level rise as a factor because only terrestrial plants and habitats were considered in this analysis.

Vulnerabilities for each population were summed to produce the Raw Climate Change Vulnerability Score, which ranged from 3 (less vulnerable) to 6 (highly vulnerable), using natural breaks (see Appendix F for raw scores and components). Population scores for each species were also averaged to produce an average climate vulnerability score for each species.

Raw Climate Change Vulnerability Scores were rescaled to a scale of 1 to 3 in order to be added later as a modifier to Invasive Plant Risk Score without overweighting climate change vulnerability. The two lowest ranks (3 and 4) were assigned a score of 0 (low climate change vulnerability); the next rank (5) was assigned a 1 (moderate vulnerability) and the highest rank (6) was assigned a 2 (high vulnerability).

Table 7. Tree of Rare Plant Population Climate Change Vulnerability Score inputs. Plant characteristics are highlighted in green.

Vulnerability	Input Category	Input Data
Vulnerability to Heat and Solar Exposure (Bivariate Combination)	Heat-Solar Exposure (Bivariate Combination)	Topographic Wetness Index (Quartiles)
		Heat Load Index (Quartiles)
	Heat-Solar Sensitivity (Bivariate Combination)	Dispersal Distance
		Seed Dormancy
Vulnerability to Aridification (Bivariate Combination)	Aridification Exposure (Bivariate Combination)	Climatic Water Deficit (Standard Deviation)
		Fog and Low Cloud Cover (Quartiles)
	Aridification Sensitivity (Weighted Sum)	Moisture Requirement
		Root Storage
		Leaf Size
Vulnerability to Wildfire (Bivariate Combination)	Wildfire Exposure	Wildfire Classification – Change in Mean Fire Return Interval (MFRI) (Quantile)
	Wildfire Sensitivity	Fire Dependency (of species)

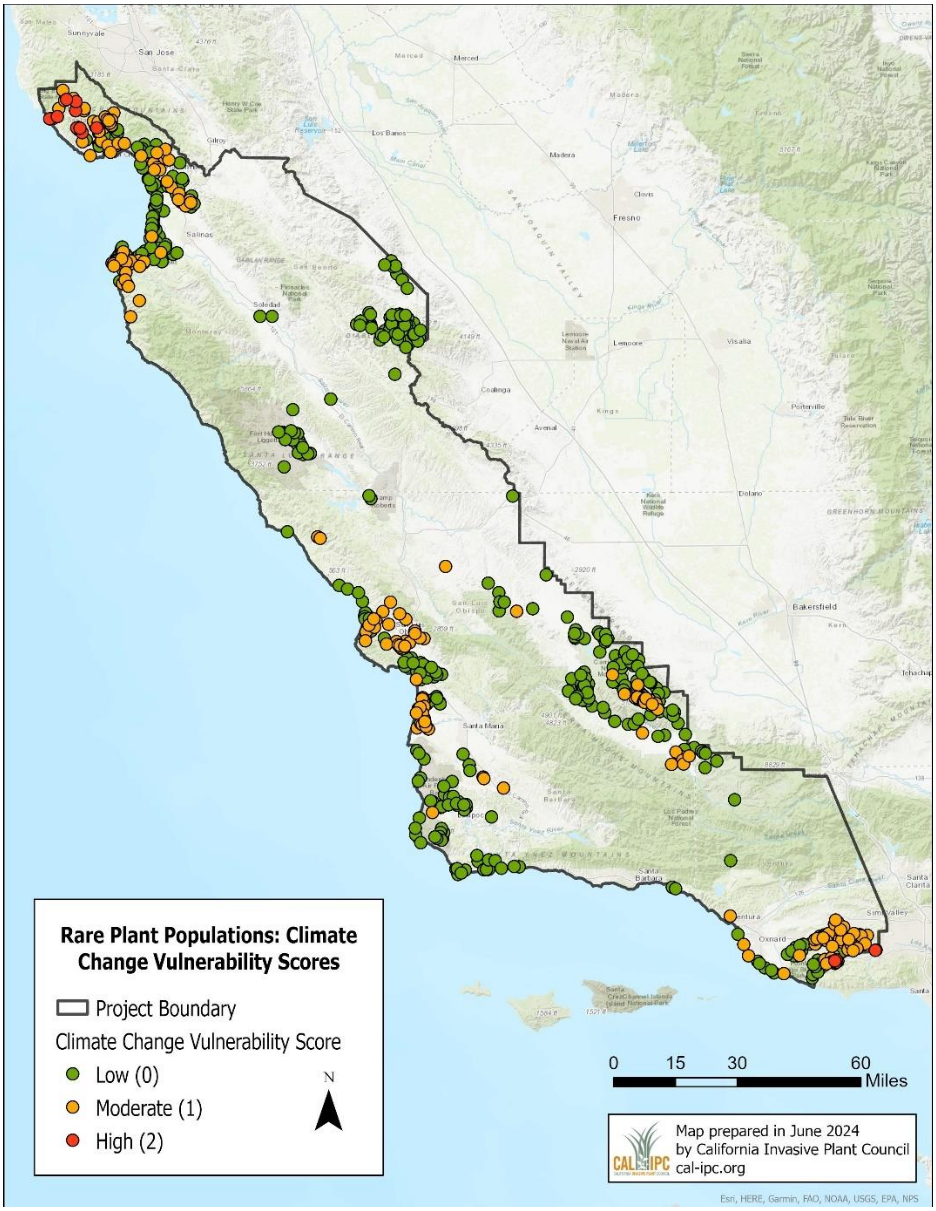

Figure 5. Rare Plant Population Climate Change Vulnerability Scores for the project area. Higher scoring populations are placed on top of lower scoring populations.

Three species ranked highest for climate change vulnerability: Agoura Hills Dudleya (*Dudleya cymosa* ssp. *agourensis*). Santa Cruz Cypress (*Hesperocyparis abramsiana* var. *abramsiana*), and San Fernando spineflower (*Chorizanthe parryi* var. *fernandina*). Agoura Hills Dudleya populations had high predicted future heat-solar exposure and moderate heat-solar vulnerability. Santa Cruz Cypress had moderate predicted future heat-solar exposure but high vulnerability. San Fernando spineflower had both high predicted future exposure and high vulnerability. Other CCV components scored variably for these species (see Appendix C). Fifteen species scored moderate for climate change vulnerability, and 31 scored low.

Climate Change Vulnerability Scores for Significant Habitats

Significant Habitat Climate Change Vulnerability Scores were similarly composed of habitat-based vulnerability estimates for heat and solar exposure, aridification, and wildfire (Table 8). Sensitivity of SH was based on inherent habitat characteristics, while exposure was based on where they were located.

Sensitivity was first scored for each MCV alliance and then averaged by Significant Habitat occurrence, because information was available for sensitivity at the alliance level from the Manual of California. Each MCV alliance was scored for its intrinsic sensitivity to: heat and solar, aridification, and fire. Evidence came from alliance descriptions in the Manual of California Vegetation (unless otherwise noted).

> *Heat and Solar sensitivity:* If the MCV alliance is sensitive to increased heat solar exposure, scored 1, otherwise 0.
>
> *Aridification sensitivity:* If the MCV alliance is susceptible to increased aridity, scored 1. If the MCV alliance is drought resistant, scored 0. Additionally, wet habitat MCV alliances scored 1, unless otherwise noted as drought tolerant.
>
> *Fire sensitivity:* If the veg type is negatively affected by more frequent or more severe fires, scored 1, otherwise scored 0. If the MCV alliance benefits from fire, scored 0—unless if the MCV alliance is nonnative then scored a 1.

Exposure to climate change factors was scored at the Significant Habitat occurrence scale in a similar manner to how it was scored for rare plant populations. Exposure and average sensitivity scores were added to produce the Raw Climate Change Vulnerability score for each Significant Habitat. Hexagon-based values for Significant Habitat Climate Change Vulnerability Scores represent the maximum Significant Habitat score within each hexagon.

Table 8. Significant Habitat Climate Change Vulnerability Score inputs. Significant Habitat characteristics are highlighted in green. Classifications are noted in parentheses.

Vulnerability	Input Category	Input Data
Vulnerability to Heat and Solar Exposure	Heat and Solar Exposure	Topographic Wetness Index (Quartiles)
		Heat Load Index (Quartiles)
	Heat and Solar Exposure Sensitivity	Heat and Solar Exposure Sensitivity Average (Natural Breaks)
Vulnerability to Aridification	Aridification Exposure	Climatic Water Deficit (Standard Deviation)
		Fog and Low Cloud Cover (Quartiles)
	Aridification Sensitivity	Aridification Sensitivity Average (Natural Breaks)
Vulnerability to Wildfire	Wildfire Exposure	Wildfire Classification – Mean Fire Return Interval (MFRI) (Quantile)
	Wildfire Sensitivity	Wildfire Sensitivity Max (Natural Breaks)

Raw Climate Change Vulnerability Scores were again adjusted to a scale from 1 to 3 that could be added to the Invasive Plant Risk Score without overweighting climate change vulnerability.

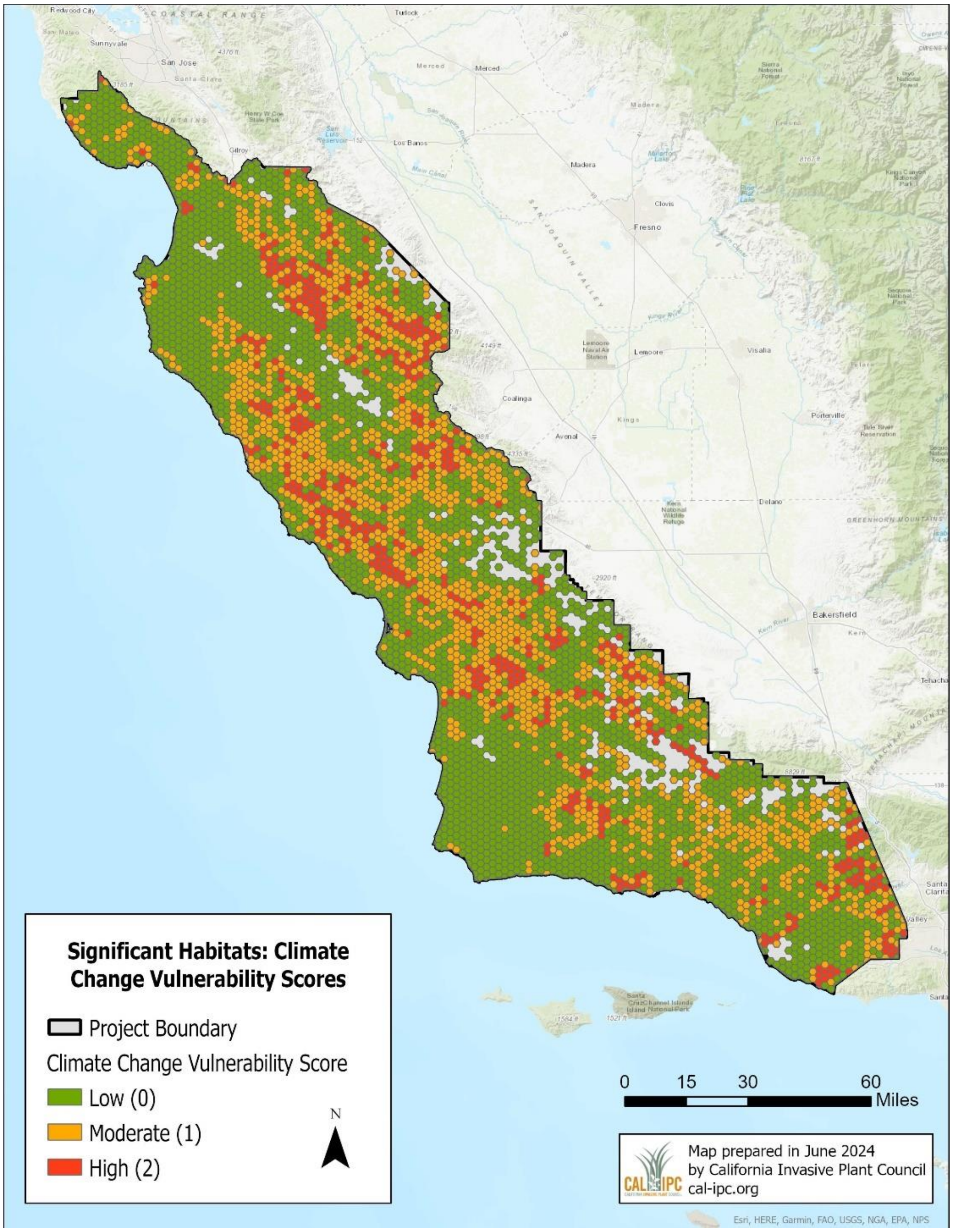

Figure 6. Significant Habitat Climate Change Vulnerability Scores for the project area.

The six highest scoring Significant Habitats for climate change vulnerability that had average adjusted scores of over 1.5 were predominantly riparian habitat types: *Prunus ilicifolia*, *Salix laevigata-Salix lasiolepis*, *Juniperus californica*, *Populus fremontii-Salix laevigata*, *Platanus racemose*, and *Salix breweri*. Geospatial (exposure) factors drove climate vulnerability scores more than inherent characteristics of habitats because many MCV alliances that were used to score them did not have documentation of their sensitivity to heat-solar, aridification, or fire.

Climate Change Vulnerability Score Confidence for Sensitive Habitats

As mentioned above, many MCV alliances had no documentation of sensitivity to fire, aridity, or heat and solar incidence. When we found no evidence available in the MCV for sensitivity to a factor or when the MCV was “PENDING,” the MCV alliance received a 0 for the sensitivity. If there was any evidence used to score a sensitivity, the MCV alliance received a 1 for confidence for that sensitivity. Confidence scores were averaged across the three sensitivities for each MCV alliance. Average confidence scores were then averaged again for each Significant Habitat Type. These in turn were averaged within hexagons. The resulting confidence ratio is displayed as a percentage and divided into classes based on natural breaks (Figure 7).

Confidence ratings for habitats were overall lower than those for rare populations and species because of the lack of information available on habitat sensitivity to stressors (Figures 4 and 7).

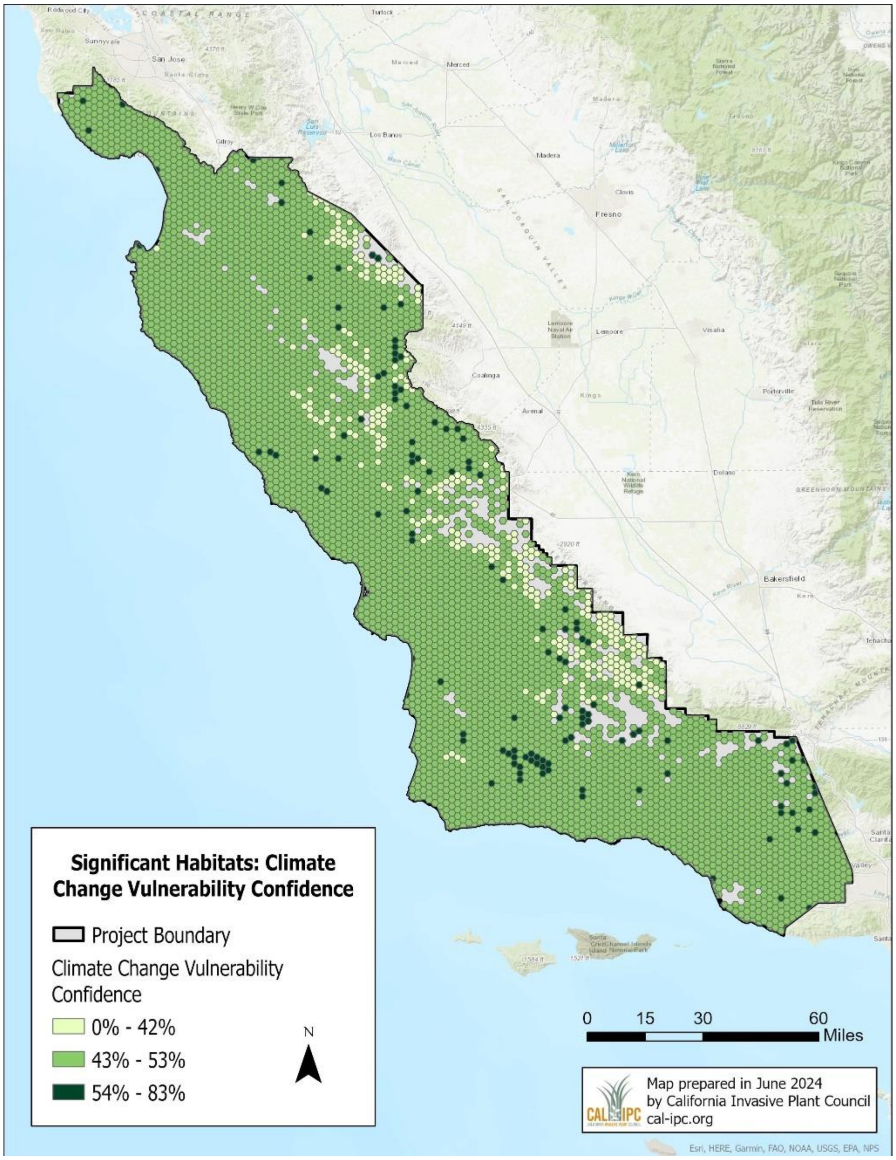

Figure 7. Significant Habitat Climate Change Vulnerability confidence ratings for the project area.

Invasive Plant Risk Scores and Climate Change Vulnerability Scores

Invasive Plant Risk Scores and Climate Vulnerability Scores were summed for rare plants to produce a Rare Plant Invasive Plant Risk and Climate Change Vulnerability Scores (RP IPRS + CCV). Similarly, both scores were added for Significant Habitats to produce Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores (SH IPRS + CCV). The original IPRS range of 1 to 10 was retained, with all scores higher than 10 truncated to 10.

Invasive Plant Risk and Climate Change Vulnerability Scores for Rare Plant Populations

A total of 121 rare plant populations had “high” IPRS + CCV scores. Of these, the top eleven that have the maximum score of 10 are shown in Table 9. Interestingly, five of these are Chorizanthe species. Only one population (*Deinandra increscens* ssp. *villosa*) scored low for climate change vulnerability. All species but two -- both of which are *Piperia* orchids – are relatively ephemeral annuals. Except for Deinandra, the highest scoring populations occur at the northern and southern edge of the project area (Figure 8).

Table 9. Rare Plant Populations with the highest Invasive Plant Risk and Climate Change Vulnerability Scores.

Population ID	Species	RP IPRS[1]	RP CCV[2]	RP IPRS + CCV[3]	RP Conf. %[4]
545	Chorizanthe pungens var. hartwegiana	10	1	10	67%
469	Chorizanthe robusta var. hartwegii	10	1	10	100%
96	Deinandra increscens ssp. villosa	10	0	10	100%
429	Chorizanthe robusta var. hartwegii	9	1	10	67%
368	Pentachaeta lyonia	9	1	10	100%
541	Piperia yadonii	9	1	10	100%
385	Pentachaeta lyonia	9	1	10	100%
526	Pentachaeta lyonia	9	1	10	100%
345	Piperia yadonii	9	1	10	100%
284	Chorizanthe robusta var. hartwegii	9	1	10	100%
243	Chorizanthe parryi var. Fernandina	8	2	10	100%

[1]Rare Plant Population Invasive Plant Risk Score
[2]Rare Plant Population Climate Change Vulnerability Score
[3]Rare Plant Population Invasive Plant Risk and Climate Change Vulnerability Scores
[4]Rare Plant Population Confidence

Rare plant populations along the coast tended to have greater combined invasive plant and climate change vulnerability than inland populations (Figure 8), however high scores for many were the result of spatial and species-specific patterns in invasive plant risk and not climate change vulnerability (see Figure 2). Climate change vulnerability did increase the combined vulnerability score for a few rare plant populations further inland, near the Carrizo Plain, and increased scores for the highest scoring populations (as described above).

When population-level scores for invasive plant risk and climate change vulnerability were averaged by hexagon across all extant species records, similar patterns remained, with high-risk locations occurring along the Santa Barbara, San Luis Obispo, and Monterey County coastlines, as well as further inland in the Santa Monica Mountains, Ventura Co., and Fort Hunter Liggett, Monterey Co. (Figure 9).

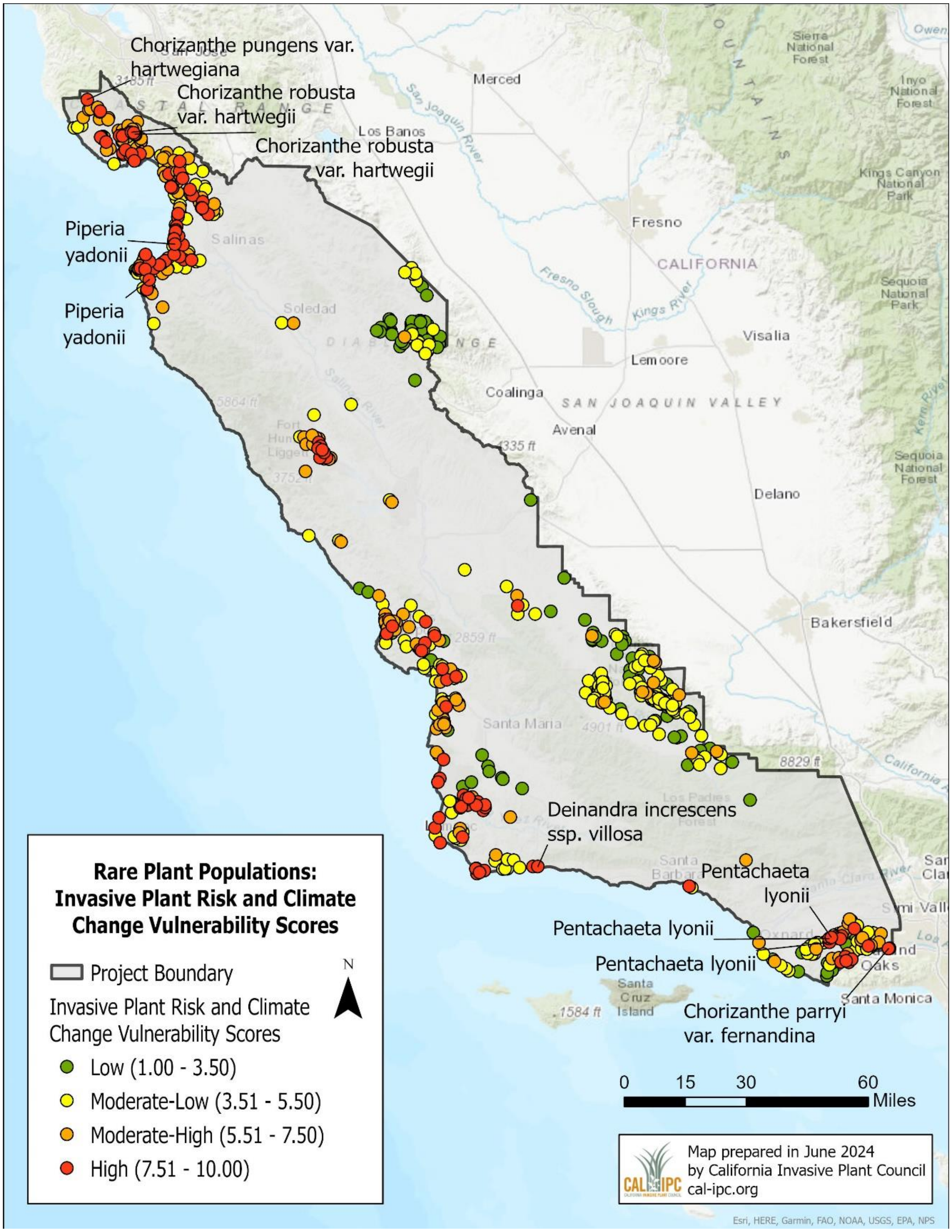

Figure 8. Rare Plant Invasive Plant Risk and Climate Change Vulnerability Score for the project area. Higher scoring populations are placed on top of lower scoring populations. The highest scoring populations were labelled by species.

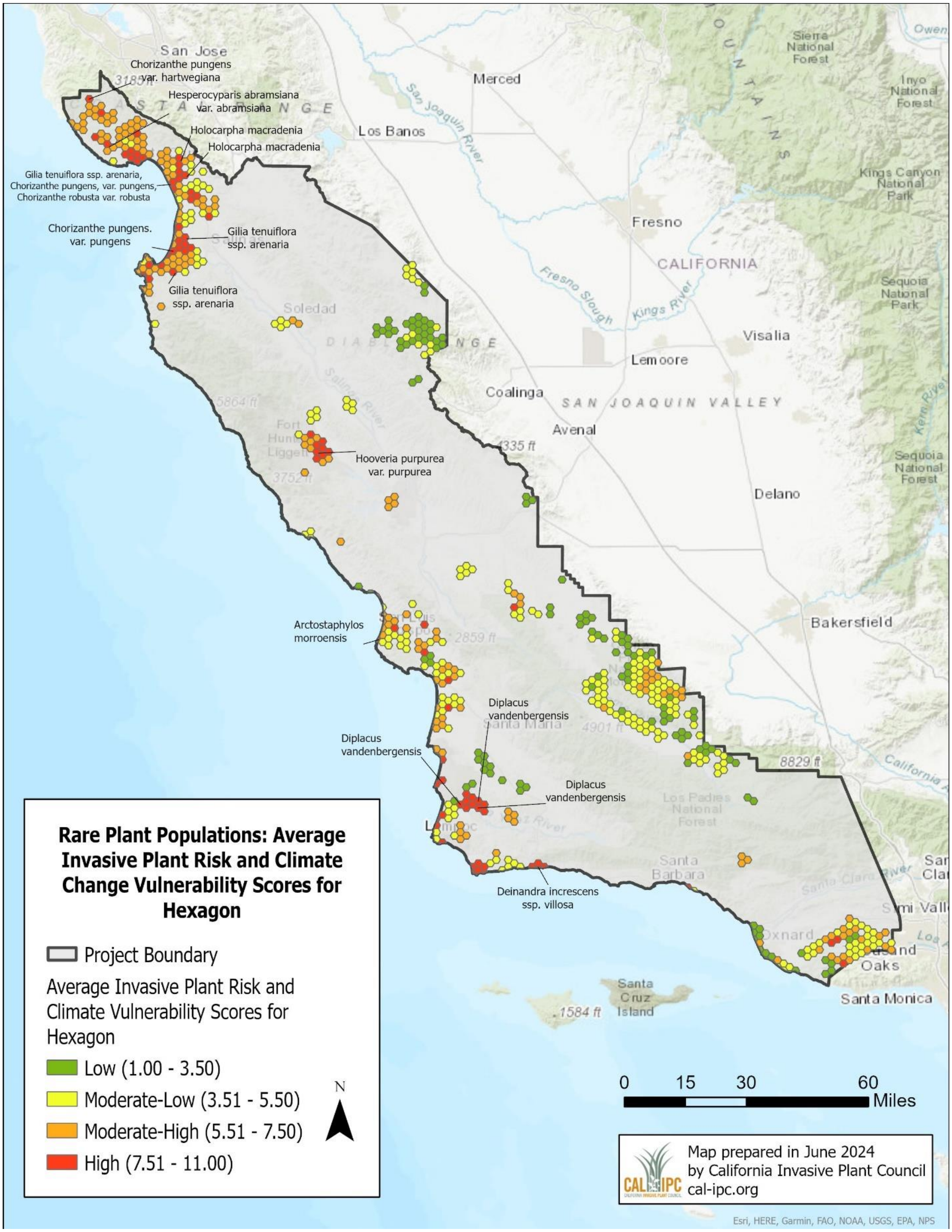

Figure 9. Average Rare Plant Population IPRS and CCV for hexagons. Hexagons with the highest scores are labelled by species occurring within.

Invasive Plant Risk and Climate Change Vulnerability Scores for Significant Habitats

Rare Plant Invasive Plant Risk and Climate Change Vulnerability and Significant Habitat Invasive Plant Risk and Climate Change Vulnerability scores were correlated (Figure 10). Habitat scores were influenced by population scores because the “Local Threat” factor for Significant Habitat IPRS was derived from the Rare Plant Population IPRS.

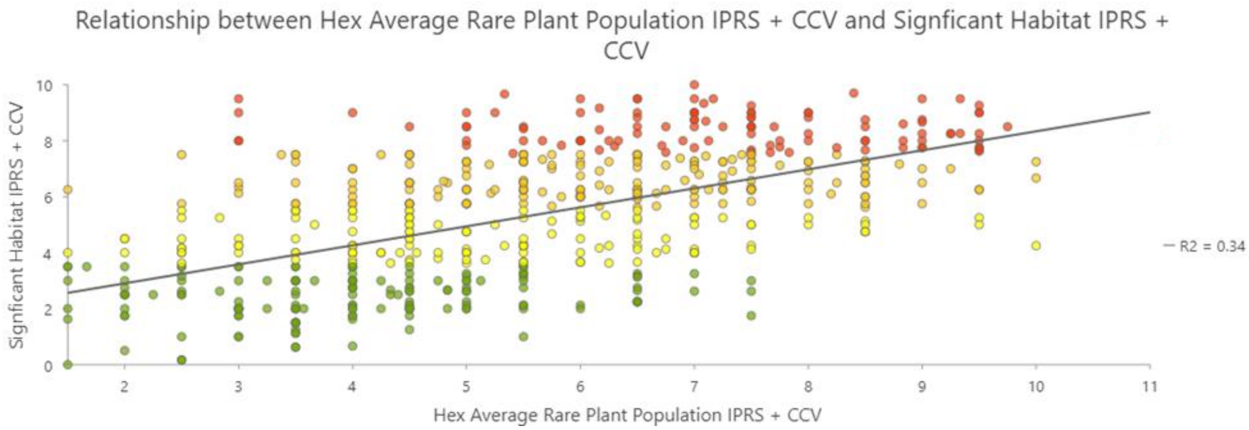

Figure 10. Scatterplot of rare plant IPRS + CCV and Significant Habitat IPRS + CCV across hexagons in project area.

Class ranking for SH Invasive Plant Risk Scores increased across hexagons with the addition of Climate Change Vulnerability Scores (Figure 11). Most notable the hexagons with “High” class ranking for Invasive Plant Risk Score more than doubled from 78 to 178 with the addition of Climate Change Vulnerability Scores. Predictably, both scores were highly correlated, since climate change vulnerability was only added as a maximum 2-point modifier on to IPRS.

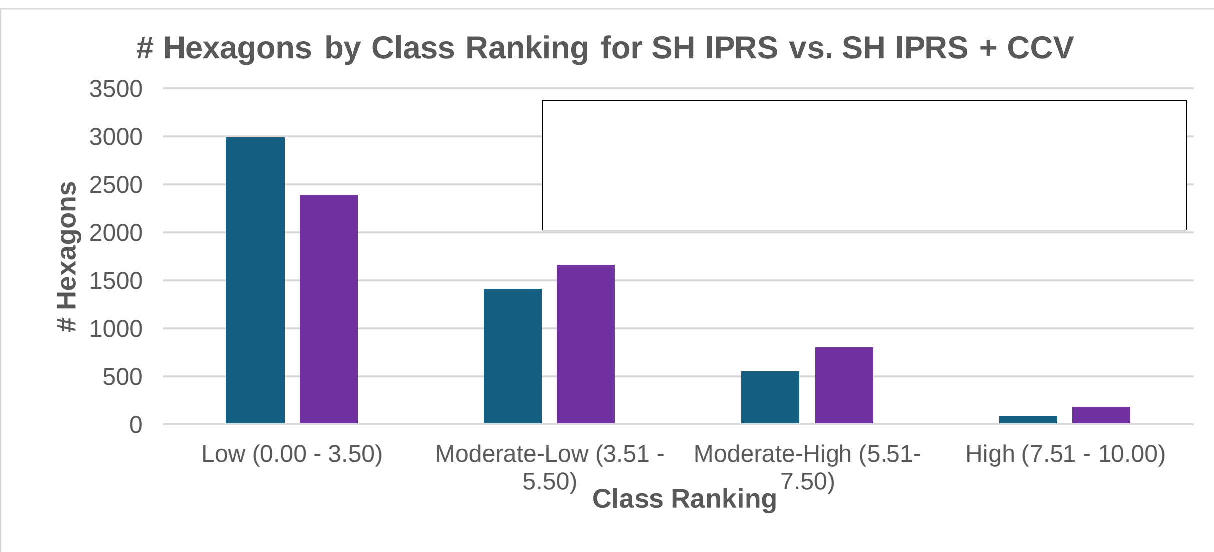

Figure 11. Number of hexes in each class ranking for SH Invasive Plant Risk Score and SH Invasive Plant Risk Score and Climate Vulnerability Scores.

Climate change vulnerability, when based on modeling future change in terrestrial stressors such as aridification, heat and solar incidence, and fire, was largely uncorrelated with either RP IPRS or SH IPRS (Figure 12, 13). Invasive plant risk is highest in more urbanized and mesic coastal sites, whereas climate change vulnerability appears to be higher inland and in shrub- and forest-dominated landscapes with topography. A few locations and habitat types stand out as having high scores for both invasive plant risk and climate vulnerability, such as Elkhorn Slough, Goleta, Pinnacles National Park, Piru, Point Mugu, Santa Lucia Range, and Simi Hills.

Table 10. The ten highest SH IPRS + CCV scoring hexagons with associated IPRS and CCV component scores and RP IPRS scores. All hexes also contained rare plant populations.

Hex ID	No. Rare Pops[1]	SH IPRS[2]	RP Ave IPRS[3]	SH CCV[4]	RP Ave CCV[5]	SH IPRS + CCV[6]	RP Ave IPRS + CCV[7]
56483	2	8.00	5.50	2	3.50	10.00	9.00
56289	5	8.70	7.60	1	2.60	9.70	10.20
56387	3	7.67	4.33	2	3.00	9.67	7.33
56762	1	9.50	6.50	0	1.00	9.50	7.50
56572	1	9.50	6.00	0	2.00	9.50	8.00
45344	1	9.50	7.00	0	1.00	9.50	8.00
32129	3	9.50	9.33	0	1.00	9.50	10.33
56576	2	8.50	5.50	1	3.00	9.50	8.50
56857	6	8.50	5.67	1	3.50	9.50	9.17
56950	2	7.50	8.00	2	3.00	9.50	11.00

[1]Number of Rare Plant Populations within the hexagon
[2]Significant Habitat Invasive Plant Risk Score
[3]Rare Plant Population Invasive Plant Risk Score averaged for the hexagon
[4]Significant Habitat Climate Change Vulnerability Score
[5]Rare Plant Population Climate Change Vulnerability Score averaged for the hexagon
[6]Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores
[7]Rare Plant Population Invasive Plant Risk and Climate Change Vulnerability Scores averaged for the hexagon

Plant population-based spatial patterns for IPRS and CCV also showed the extreme north, south, and coastal regions of the project area supporting rare plant populations that had high scores for both invasive plant risk and climate change vulnerability (*Pentachaeta* and *Chorizanthe* populations) (Figure 12). There were also areas, such as Fort Hunter Liggett and Monterey Bay, that had high invasive plant risk but low climate change vulnerability.

Significant Habitat IPRS showed a fundamentally different pattern than CCV, in that SH IPRS scores were generally higher along the coast, whereas higher CCV scores occurred throughout the project area, especially including montane and inland sites (Figure 13). There are several areas with high CCV and low invasive plant risk, such as the San Benito Wilderness Area, where several low-IPRS *Camissonia benitensis* occur. Other hexes without federally listed plant species also had high CCV scores, especially those occurring in more mountainous areas with steep topography and high exposure, suggesting that geographic factors are contributing strongly to CCV.

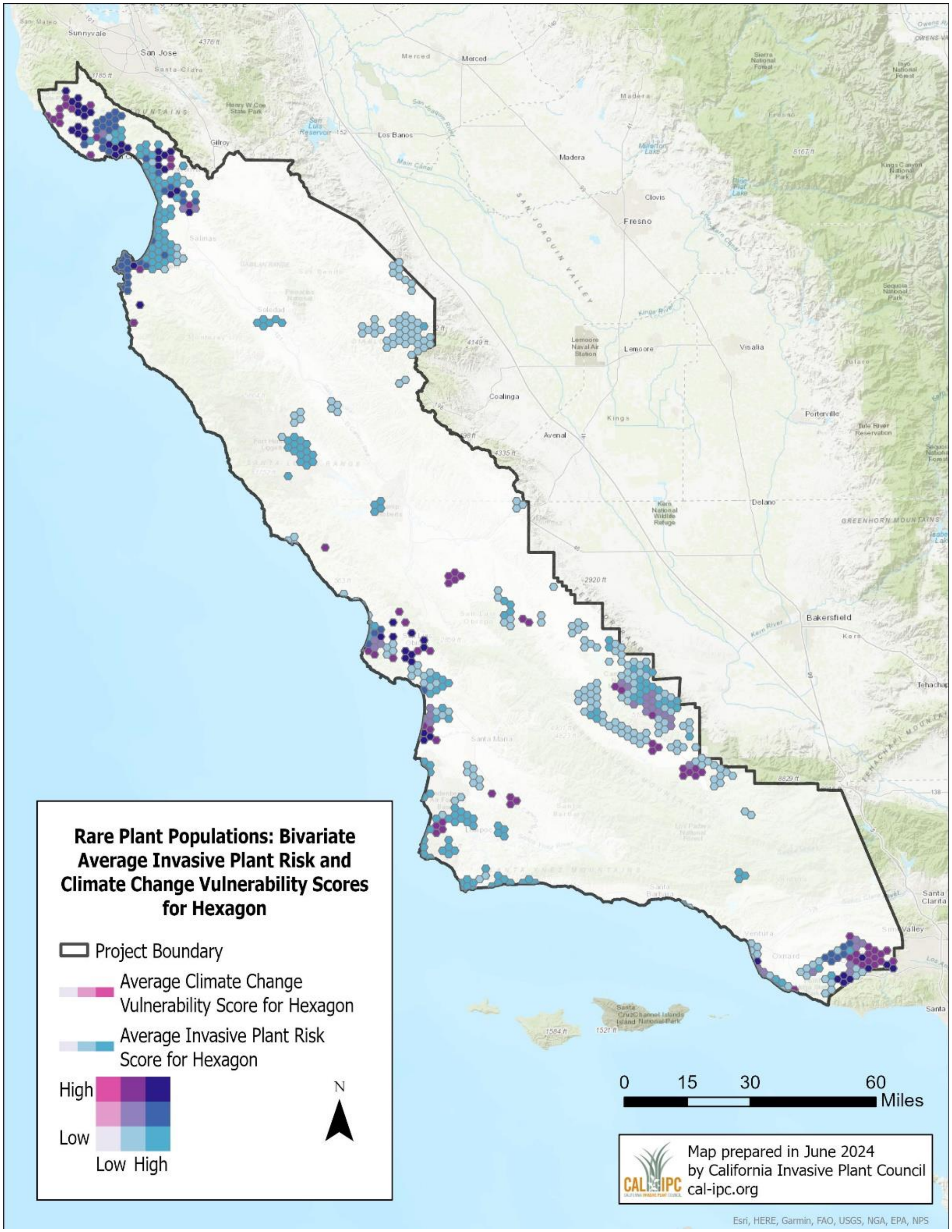

Figure 12. Rare Plant Population Invasive Plant Risk and Climate Change Vulnerability bivariate scores averaged by hexagon. Pink indicates high climate vulnerability but low invasive plant risk. Teal represents high invasive plant risk but low climate vulnerability. Dark purple indicates high climate vulnerability and climate risk.

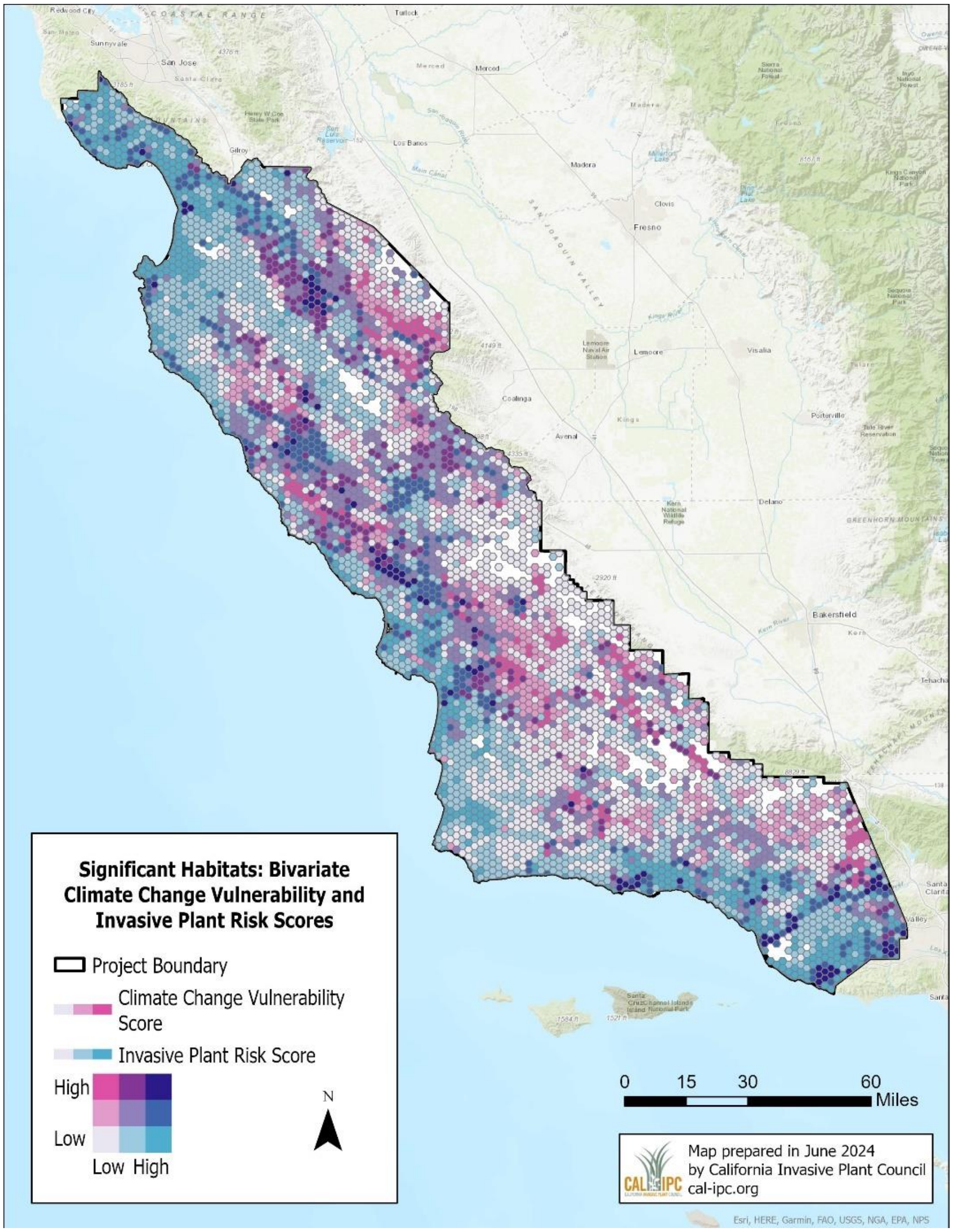

Figure 13. Significant Habitat Invasive Plant Risk and Climate Change Vulnerability bivariate scores by hexagon. Pink indicates high climate vulnerability but low invasive plant risk. Teal represents high invasive plant risk but low climate vulnerability. Dark purple indicates high climate vulnerability and climate risk.

When we added the Climate Change Vulnerability Score to the Invasive Plant Risk Scores for Significant Habitats, we were able to pinpoint locations where invasive plant management would be beneficial to protect habitats under both current and future conditions (Figure 14). High priority locations include Santa Cruz, Monterey, Fort Hunter Ligget, Morro Bay, Mission Hills, Goleta, and Simi Hills. Lower priority areas (green-filled) may alternatively benefit more from habitat protection against other stressors, such human disturbance.

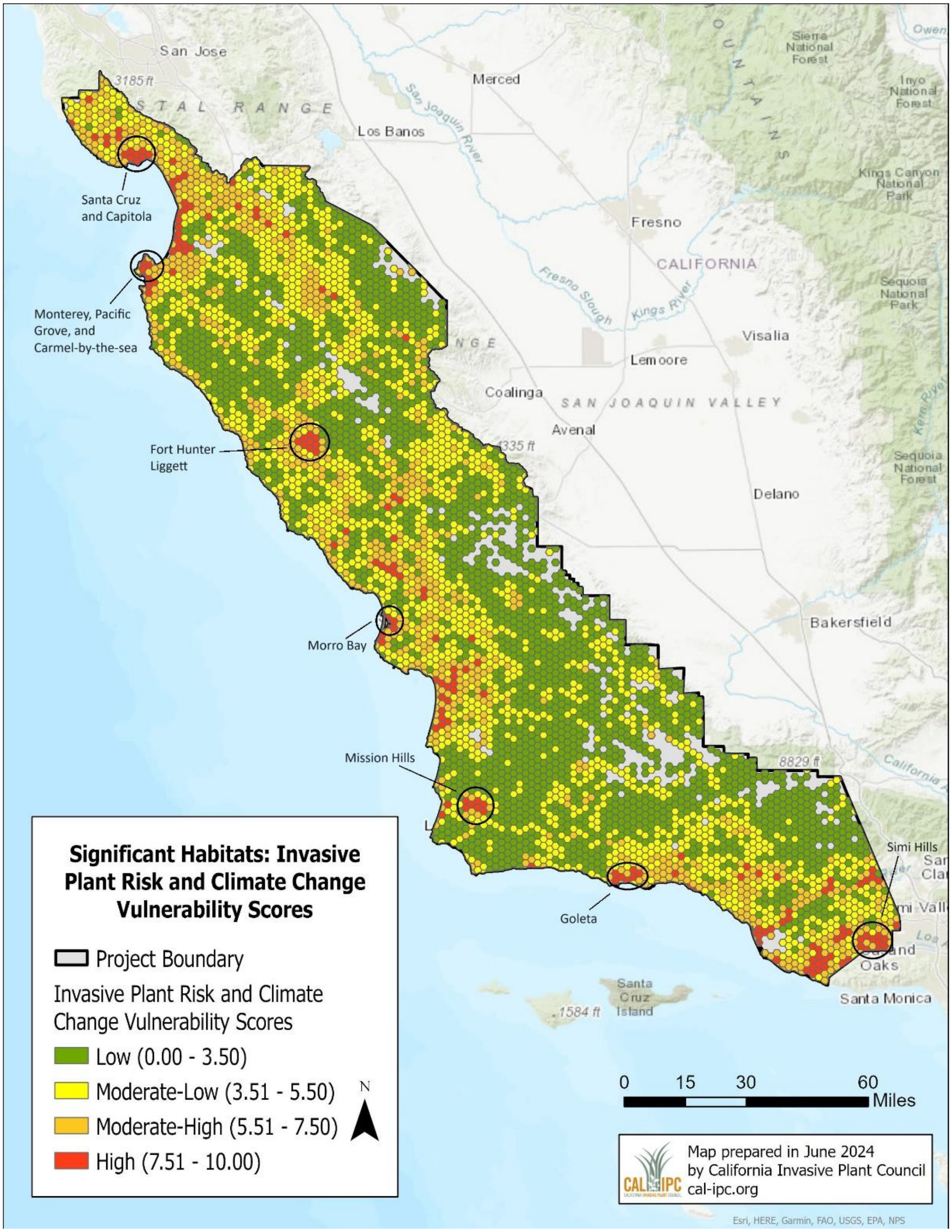

Figure 14. Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores for the project area. Select high-scoring clusters of interest are labelled.

California Protected Areas' Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores

California Protected Areas (CPAP) were overlayed onto hexagon-based SH IPRS + CCV scores. Several CPAP locations are identified in Figure 15 and Table 11 that occur in high scoring locations and represent good targets for focused invasive plant management for climate change resilience.

Table 11. The California Protected Areas Significant Habitats with the highest weighted average Invasive Plant Risk and Climate Change Vulnerability Scores.

UNIT ID[1]	Unit Name	Agency in Ownership	IPRS Wt. Ave[2]	IPRS+CCV Wt. Ave[3]	# SH Hexes in Unit[4]
17499	Lynnmere Open Space	Conejo Open Space Conservation Agency	8.70	9.70	1
15585	Conejo Recreation and Park District	Conejo Recreation and Park District	8.70	9.70	1
15583	Conejo Recreation and Park District	Conejo Recreation and Park District	8.70	9.70	1
1873	Wildflower Playfield	Conejo Recreation and Park District	8.62	9.62	2
17212	Lake Eleanor Open Space	Conejo Open Space Conservation Agency	8.50	9.50	1
5091	Cathedral Oaks Fire Center	Santa Barbara, County of	7.50	9.50	1
50985	Pacific View	United States National Park Service	7.50	9.50	1
44286	Morro Bay City Beach	Morro Bay, City of	9.50	9.50	1
13609	Dos Vientos Community Park	Conejo Recreation and Park District	9.50	9.50	1
13764	Del Prado Playfield	Conejo Recreation and Park District	9.50	9.50	1
44251	Coleman Park	Morro Bay, City of	9.50	9.50	1
1005	Southshore Hills Open Space	Conejo Open Space Conservation Agency	8.50	9.50	1
15403	Indian Springs Park	Rancho Simi Recreation and Park District	8.50	9.50	1
14972	Valley View Park	Rancho Simi Recreation and Park District	8.50	9.50	1
15467	Chaparral Park	Rancho Simi Recreation and Park District	8.50	9.50	1
1259	Sunset State Beach	Santa Cruz, County of	9.50	9.50	1
2651	Canilla Corp.	United States National Park Service	9.50	9.50	1
1439	Tuckers Grove Park	Santa Barbara Flood Control and Water Conserv. District	7.50	9.50	1
7085	Medea Creek Open Space	Agoura Hills, City of	8.50	9.50	1
15569	Conejo Open Space Conservation Agency	Conejo Open Space Conservation Agency	8.50	9.50	1
27020	Anchor Memorial Park	Morro Bay, City of	9.50	9.50	1

[1]Unit ID is unique. Often multiple units with the same park name and agency have different Unit IDs.
[2]Significant Habitat Invasive Plant Risk Score weighted area average for the hexagons with significant habitat that the unit occurs within.
[3]Significant Habitat Invasive Plant Risk Score and Climate Change Vulnerability Class weighted area average for the hexagons with significant habitat that the unit occurs within.
[4]The number of hexagons with significant habitat that the unit occurs within.

Figure 15. Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores for California Protected Areas.

Task 4: Plan Management Implementation

Cal-IPC worked with the Land Conservancy of SLO County (LCSLO) to support a single-year pulse of targeted invasive plant management at two sites in San Luis Obispo County: Black Lake Ecological Preserve and Guadalupe- Nipomo Dunes National Wildlife Refuge. Black Lake Ecological Preserve supports populations of the federally listed Nipomo Mesa lupine (*Lupinus nipomensis*), which scored “High” for Invasive Plant Risk. The hexagon that it occurs in scored Moderate-High for Significant Habitat Invasive Plant Risk and Climate Change Vulnerability and is surrounded by “High” scoring hexagons, though its climate change vulnerability was low (Table 12). Guadalupe-Nipomo Dunes was selected because it scored moderately for Significant Habitat Invasive Plant Risk and Climate Vulnerability. Both sites are managed by LCSLO, which is committed to ongoing rare species and habitat management and therefore was well suited to make optimal use of an additional infusion of funds as a pilot project for climate smart invasive plant management. Having a willing, committed, and engaged land manager was key to project success. Both sites and management actions are described below.

Cal-IPC had originally planned to pursue CEQA permitting for a willing land manager on high priority lands. However, we did not find a natural fit between a management partner and a site need of permitting that would be viable long-term with the funds available through this grant.

Lupinus nipomensis in the Black Lake Ecological Preserve

Invasive plants are listed as the primary threat to *Lupinus nipomensis* at a species-level (USFWS 2021; Cal-IPC 2023). The Nipomo Mesa lupine population at Black Lake Ecological Area has a high IPRS and IPRS+CCV (Table 12 and Figure 16). Perennial veldtgrass (*Ehrharta calycina*), narrowleaf ice plant (*Conicosia pugioniformis*), and Sahara mustard (*Brassica tournefortii*) occur on site and have been listed as threats to this population by experts. Nipomo Mesa lupine is most directly threatened by competition with perennial veldtgrass. Perennial veldgrass removal is considered necessary to provide space for Nipomo lupine to perpetuate itself at this site.

Under contract with Cal-IPC, LCSLO hand-pulled invasive plants out of 20 ft. buffer zones surrounding each of the 173 Nipomo Mesa lupine plots, resulting in 0.25 acres being treated for nonnative species across one full day in early March 2024 and one-half day in late March 2024. All target species were completely removed with most plots having 1-5% cover of nonnative species. The most common species removed were perennial veldt grass (*Ehrharta calycina*), iceplant (*Carpobortus* spp.), annual grasses, and narrowleaf iceplant (*Conicosia pugioniformis*). Several late spring storms initiated additional perennial veldt grass germination, making follow-up visits necessary. Follow-up hand pulling was completed in April using limited matching funding. Supplemental funding to control plants was critical in 2024. As a result, invasive species around this Nipomo lupine population are on a downward trajectory and Nipomo Mesa Lupine is likely to have had a high seed production year to increase its population-level resilience (see Appendix D).

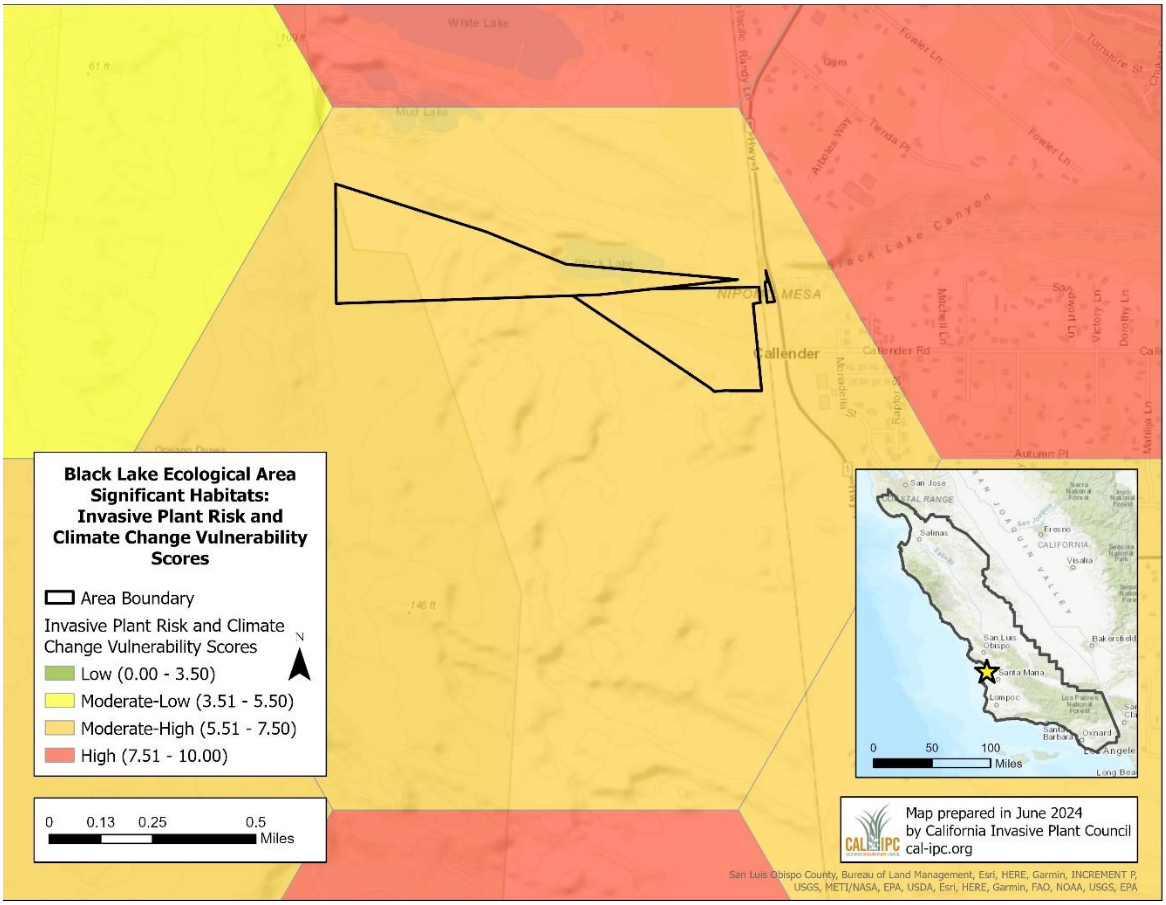

Figure 16. Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores for the Black Lake Ecological Area.

Table 12. Rare plant population scores for the *Lupinus nipomensis* population in the Black Lake Ecological Area.

Population ID	Species	RP IPRS[1]	RP CCV[2]	RP IPRS + CCV[3]	RP Confidence [4]
452	Lupinus nipomensis	7.5	0	7.5	High

[1] Rare Plant Population Invasive Plant Risk Score
[2] Rare Plant Population Climate Change Vulnerability Score
[3] Rare Plant Population Invasive Plant Risk and Climate Change Vulnerability Scores
[4] Rare Plant Population Confidence

Sensitive Habitat Protection in the Guadalupe-Nipomo Dunes National Wildlife Refuge

Guadalupe-Nipomo Dunes National Wildlife Refuge has been a priority for invasive plant management by LCSLO (Figure 17). Cal-IPC's IPRS + CCV scoring also supports this prioritization, by ranking the hexagon where much of the management work that occurs, when funded, as “HIGH” vulnerability. The State-listed species beach spectaclepod (*Dithyrea maritima*) and surf thistle (*Cirsium rhothophilum*) are both present in the Guadalupe-Nipomo Dunes National Wildlife Refuge. The Refuge also contains four Significant Habitats. Among these, Central Dune Scrub, which occurred in all of the hexagons in the Guadalupe-Nipomo Dunes National Wildlife Refuge, scored “HIGH” for invasive plant risk and, consequently, also “HIGH” for IPRS + CCV (Figure 17 and Table 13). Again, CCV was low, but irrelevant if current invasive plant risks are persistent. Although the data are still unpublished, the Refuge also falls within a high value CNPS Important Plant Area (CNPS, unpublished data).

LCSLO considers red-purple ragwort (*Senecio elegans*) to be one of the primary threats to the Central Dune Scrub habitat of Guadalupe-Nipomo Dunes. Red-purple ragwort, a Cal-IPC “Watch” species, is an especially aggressive colonizer of coastal dune habitat that prolifically seeds and can carpet dunes, excluding other species. Removing purple ragwort is essential for the reproductive success of beach spectaclepod and surf thistle as well as for protecting Western Snowy Plover nesting areas.

Some portions of the red-purple ragwort population have been managed using USFWS Coastal program funds, but the additional WCB funding has allowed for treatment expansion. Additionally, both neighboring properties (California State Parks and Chevron) have been managing invasive plant species, making this a strategic management opportunity.

Under contract with Cal-IPC, LCSLO treated red-purple ragwort at Central Dune Scrub and Central Foredunes habitats of the Guadalupe-Nipomo Dunes National Wildlife Refuge. This funding directly helped manage red-purple ragwort in areas where both surf thistle and Dune spectaclepod are prevalent and other management strategies are not permitted. Red-purple ragwort (*Senecio elegans*) was hand-pulled for a total of 5.5 days across the first half of February, mid-March, and late April. It was abundant in 2024 due to winter rains, so the goal was to maintain and decrease the population’s footprint. LCSLO preliminarily concluded that significant progress was made in decreasing the footprint of red-purple ragwort, but can only confirm this when they see the returning population size next spring.

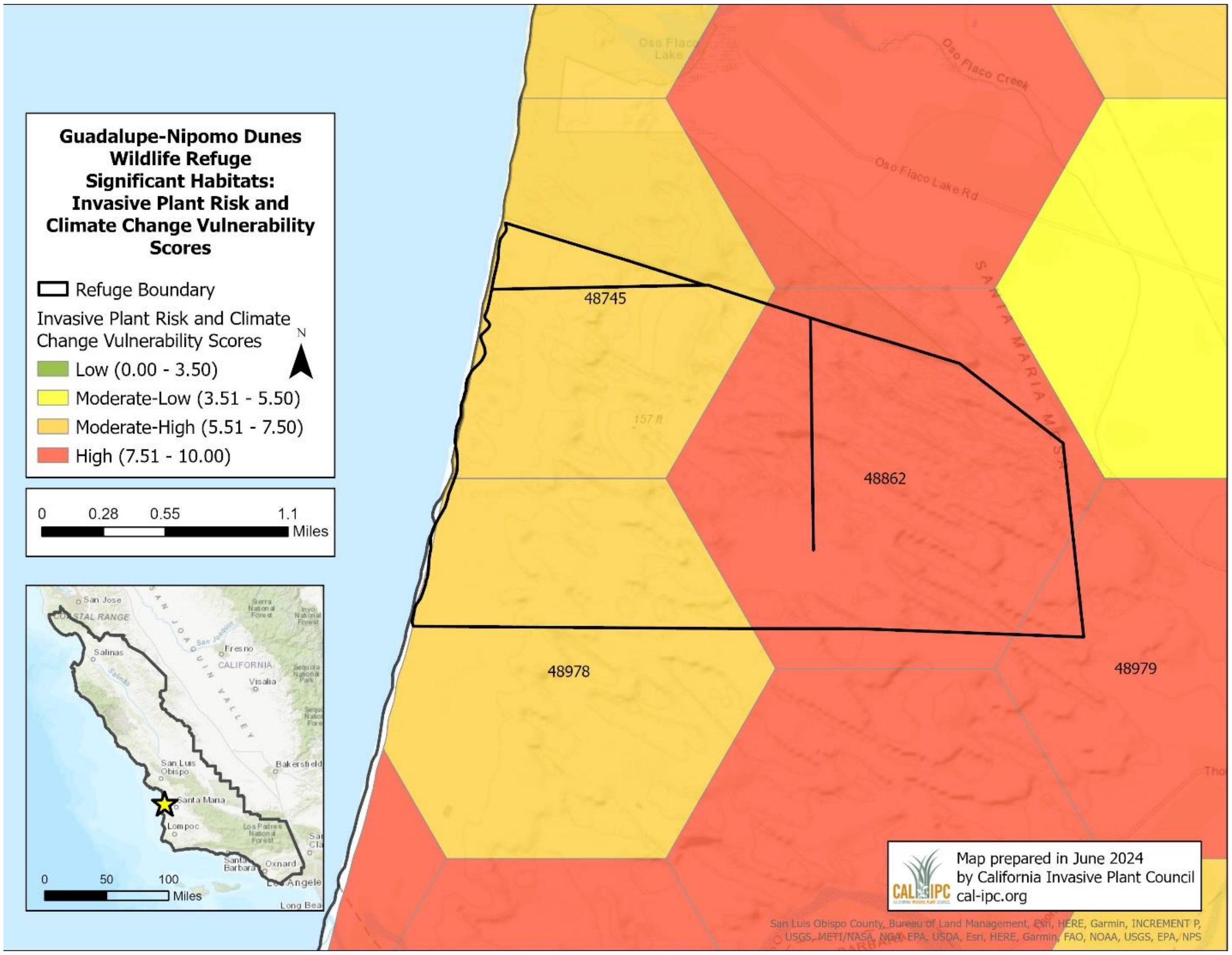

Figure 17. Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores for the Guadalupe-Nipomo Dunes National Wildlife Refuge. Hexagons within the Refuge are labelled by Hex ID for reference in Table 13.

Table 13. Significant habitat types and scores by hexagon in the Guadalupe-Nipomo Dunes National Wildlife Refuge.

Hex ID	Significant Habitat Type	Inv Vuln.[1]	IPRS[2]	IPRS Confidence[3]	CCV[4]	CCV Confidence[5]	IPRS + CCV[6]
48745	Central Dune Scrub Central Foredunes Coastal and Valley Freshwater Marsh Fresh Emergent Wetland Freshwater Forested/Shrub Wetland	2.00 2.00 0.78 0.75 0.63	7.00	55%	0	52%	7.00
48862	Central Dune Scrub Fresh Emergent Wetland	2.00 0.75	9.00	52%	0	52%	9.00

	Freshwater Forested/Shrub Wetland	0.63					
	Valley Foothill Riparian	0.75					
48978	Central Dune Scrub	2.00	7.00	55%	0	53%	7.00
	Central Foredunes	2.00					
	Fresh Emergent Wetland	0.75					
	Freshwater Forested/Shrub Wetland	0.63					
	Freshwater Forested/Shrub Wetland	0.63					
48979	Central Dune Scrub	2.00	7.00	51%	1	52%	8.00
	Coastal Oak Woodland	0.17					
	Fresh Emergent Wetland	0.75					
	Freshwater Forested/Shrub Wetland	0.63					
	Valley Foothill Riparian	0.75					

[1] Invasive vulnerability for the Significant Habitat Type (averaged from the MCV Classifications)
[2] Significant Habitat Invasive Plant Risk Score
[3] Significant Habitat Invasive Plant Risk Score Confidence
[4] Significant Habitat Climate Change Vulnerability Score
[5] Significant Habitat Climate Change Vulnerability Confidence
[6] Significant Habitat Invasive Plant Risk and Climate Change Vulnerability Scores

Conclusions

As conditions change across our protected lands, so do priorities. The goal of this project was to help strategically address invasive plant issues for important conservation resources in the central coast region of California in light of climate change and ongoing introductions of invasive plants. We have developed invasive plant risk and climate change vulnerability scores that can be used to help land managers prioritize species and sites from the adverse effects of invasive plants in the face of changing climate. Products of this work include combined invasive plant risk and climate change vulnerability scores (IPRS + CCV) for 50 rare species, their extant populations, CDFW ACE hexagons based on rare species populations, 171 Significant Habitats, and CDFW ACE hexagons based on Significant Habitats occurring therein, summarized here and available as geodata. Our risk analysis suggests species, habitats, and areas to focus conservation efforts and scores to refer to when planning conservation-based invasive plant management on the central coast.

We collected available information on co-occurring invasive plants in areas where invasive species were considered a high threat for rare plants. The most commonly cited invasive plants were invasive annual grasses (and their thatch), iceplant(s), and perennial veldtgrass. Rather than focus on predicting future introductions and expansions, we focused on the current and future risks that these and other species could pose based on current level of invasion, identity of co-occurring invasive plants, and geographic location. Of the 50 rare plant species evaluated, 17 were considered at high risk of being impacted by the effects of invasive plants. Management actions including invasive plant management and further study of its effects are strongly recommended for these species. Of these, a subset of annuals and two perennial orchids appeared to have especially high combined invasive plant risk and climate change vulnerability. Invasive plant management actions could be paired with conservation seed collection at these sites to ensure that local populations are not lost to the combined effects of both factors.

Generally, populations of rare plants along the coast scored higher for invasive plant risk than those occurring inland. This pattern may be due both to the greater amount of documentation that exists for more accessible coastal sites, but also to the larger level of invasive of many species, such as perennial veldtgrass and iceplant, and newer invaders like Sahara mustard, and red-purple ragwort, mentioned elsewhere in this report. Management actions controlling invasive plants near high priority rare plant populations are recommended and may be relatively feasible, due to greater accessibility. The Task 4 pilot project described in this report provides a useful model for targeted invasive plant management for the purpose of encouraging seed production, recruitment and expansion of rare plant species and habitats.

The Significant Habitats that scored most highly for the combined effects of invasive plant risk and climate vulnerability were Salix laevigata-Salix lasiolepis and Populus fremontii-Salix laevigata. In both cases, climate change vulnerability moved these habitat types up from a moderate-high to a high score. Both are riparian habitats, and *Salix laevigata* (red willow) has a greater water requirement than other willow species, such as *Salix lasiolepis* (arroyo willow). Future drying trends may imperil this species disproportionately, especially in the face of competition with riparian invaders.

Several locations in the central coast supported Significant Habitat that scored highly for the combined effects of invasive plant risk and climate change (see Figure 14, in part). These locations should be studied more closely and, to the extent possible, managed with an eye to maintaining habitat resilience in the face of both stressors. High combined risk locations include several owned and managed by the Conejo Recreation and Park District, Morro Bay, and Rancho Simi Recreation and Parks District. The Black Lake Ecological Area and Guadalupe-Nipomo National Wildlife Reserve that the Task 4 pilot project occurred on also represent locations with high to moderately high combined invasive plant and climate change vulnerability risk.

Taking invasive plant management actions to protect listed species and sensitive habitats is sometimes difficult due to regulatory hurdles. If federally listed species are involved, land managers should contact their regions USFWS office for consultation. Given that management is an action listed in many federally listed recovery plans, federal and state agency representatives may be very willing to facilitate permitting management activities.

In the process of completing the analysis described here, we identified several logical next steps to furthering progress on rare plant and habitat protection through invasive plant management prioritization. More work on documenting success and describing appropriate protocols for invasive plant management around rare plants is needed. Currently, expert assessments of invasive plant impacts are largely based on observation. It is highly likely, and has been documented in some cases, that regular – or even periodic – invasive plant management around rare plants can result in improved recruitment and increases in a species soil seed bank, but currently data are largely lacking. It is important to correctly evaluate the risk of inaction, especially under rapidly changing environmental, human disturbance conditions and novel introductions such as California is experiencing. Additional efforts to promote the work conducted here and ensure its use by a wider audience is needed to make full use of the products produced. Lastly, a similar study in another region would both strengthen the current geodata set and allow other regions to improve invasive plant management strategy geared towards sensitive resources.

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Appendix A. Species Average Rare Plant Population Scores

Average Rare Plant Populations Scores by Species. Sorted by Sum of Average Subscores

Species-level IPRS were calculated by first averaging each of the eight score components across populations and then summing the averages. IPRS were averaged in this manner to better reflect populations where we had data and thereby avoiding a situation where missing data would unduly depress scores (because missing data do not affect individual factor averages but do depress population-level scores). Species averages are as a result higher using this methodology than they would have been by merely averaging population scores.

Although scores were calculated for all populations, only occurrence records for populations presumed to be extant (ie. those not reported as “extirpated” or assumed to be extirpated because they were listed as “possibly extirpated” with a polygon size larger than a quarter quad) were used in calculations and are presented in maps. Extirpated populations were excluded because current invasive plant co-occurrence and threat cannot be ascertained for them.

Table A.1. Average IPRS scores for the rare plant species in the project area. The three surveyed species are emboldened.

Species	Average Population IPRS[1]	Sum of Average IPRS Subscores[2]	Sum of Average IPRS Subscores with CCV Score[3]	Ave Confidence[4]	# Pops[5]
Chorizanthe robusta var. hartwegii	8.75	8.92	9.92	2.50	4
Erysimum menziesii	6.78	8.89	8.89	1.67	9
Chorizanthe robusta var. robusta	7.03	8.87	8.87	1.60	15
Potentilla hickmanii	8.75	8.75	8.75	3.00	2
Diplacus vandenbergensis	8.74	8.74	8.74	2.94	17
Gilia tenuiflora ssp. arenaria	5.90	8.70	8.70	1.44	25
Chorizanthe pungens var. pungens	6.77	8.61	8.61	1.58	50
Hooveria purpureum var. purpureum	6.67	8.48	8.48	1.50	26
Layia carnosa	7.19	8.20	8.20	2.38	8
Clarkia speciosa ssp. immaculata	5.35	8.15	8.15	1.27	26
Holocarpha macradenia	6.82	8.09	9.09	1.94	17
Hooveria purpureum var. reductum	5.50	8.00	8.00	1.75	4
Chorizanthe parryi var. fernandina	8.00	8.00	10.00	3.00	1
Lupinus nipomensis	8.00	8.00	8.00	3.00	2

Chorizanthe pungens var. hartwegiana	6.22	7.89	8.89	1.17	18
Polygonum hickmanii	7.67	7.67	7.67	3.00	3
Piperia yadonii	5.88	7.54	8.54	1.65	26
Astragalus tener var. titi	7.50	7.50	7.50	3.00	1
Trifolium trichocalyx	7.00	7.50	7.50	2.00	2
Suaeda californica	5.00	7.42	7.42	1.63	8
Pentachaeta lyonia	7.26	7.26	8.26	2.67	21
Eremalche parryi ssp. kernensis	4.16	7.19	7.19	1.04	100
Lasthenia conjugens	7.17	7.17	7.17	3.00	3
Cirsium fontinale var. obispoense	5.52	7.12	8.12	1.77	22
Monolopia congdonii	4.41	7.00	7.00	1.10	29
Chloropyron maritimum ssp. maritimum	5.50	6.98	6.98	2.00	13
Dudleya parva	5.23	6.86	6.86	1.69	13
Deinandra increscens ssp. villosa	6.84	6.84	6.84	2.24	29
Arctostaphylos morroensis	6.83	6.83	7.83	2.50	6
Erysimum teretifolium	4.64	6.55	6.55	1.29	14
Astragalus pycnostachyus var. lanosissimus	4.50	6.50	7.50	2.00	2
Orcuttia californica	4.50	6.50	6.50	1.33	3
Eriodictyon capitatum	4.00	6.25	6.25	1.50	8
Lupinus tidestromii	5.83	6.17	6.17	2.00	6
Hesperocyparis abramsiana var. abramsiana	5.11	6.17	8.17	1.67	9
Arenaria paludicola	5.00	6.14	7.14	1.43	7
Dudleya cymosa ssp. marcescens	3.70	6.10	6.10	1.20	5
Nasturtium gambelii	4.33	5.83	5.83	2.17	6
Dudleya verityi	4.81	5.69	5.69	2.00	8
Hesperocyparis goveniana	4.50	5.63	6.63	2.00	5
Cirsium scariosum var. loncholepis	3.81	5.17	6.17	2.14	21
Pentachaeta bellidiflora	5.00	5.00	6.00	1.00	3
Astragalus brauntonii	3.98	4.50	5.50	1.81	27
Caulanthus californicus	3.35	4.08	5.08	1.00	30
Thysanocarpus conchuliferus	3.67	3.67	3.67	1.00	3
Navarretia fossalis	3.50	3.50	4.50	1.00	1
Dudleya cymosa ssp. agourensis	2.83	2.83	4.83	3.00	3
Camissonia benitensis	2.66	2.66	2.66	2.06	50
Eriodictyon altissimum	2.00	2.00	2.00	1.00	6
Eriastrum hooveri	1.50	1.50	1.50	1.00	1

[1]The Average Rare Plant Population Invasive Plant Risk Score for Species
[2]The Summed Average Rare Plant Population Subscores for Invasive Plant Risk Score for Species

[3] The Summed Average Rare Plant Population Subscores for Invasive Plant Risk Score and Climate Change Vulnerability for Species
[4]The average confidence score for species (scores from 1-3)
[5]The number of rare plant populations for the species

Appendix B. Significant Habitat Types

Significant Terrestrial Habitats included in analysis, sorted by most prevalent habitat type.

Significant Habitat Types	No. Occurrences in Hex[1]	Average IPRS[2]	Average CCV Score[3]	Average IPRS + CCV[4]	IPRS Confidence[5]	CCV Confidence[6]
Coastal Oak Woodland	3280	3.74	0.53	4.26	33%	50%
Freshwater Forested/Shrub Wetland	3247	3.76	0.59	4.34	48%	51%
Blue Oak Woodland	2135	2.89	0.70	3.59	50%	33%
Valley Foothill Riparian	1975	4.04	0.55	4.59	50%	54%
Fresh Emergent Wetland	1718	4.16	0.50	4.66	58%	52%
Valley Oak Woodland	1169	4.45	1.07	5.52	100%	67%
Blue Oak-Foothill Pine	1029	3.18	0.99	4.17	50%	67%
Vernal Pools	229	3.66	0.60	4.26	86%	52%
Montane Riparian	221	3.04	0.74	3.79	27%	53%
Wet Meadow	122	4.30	0.70	4.99	65%	48%
North Central Coast Drainage Sacramento Sucker/Roach River	92	4.50	0.78	5.28	45%	51%
Southern Coast Live Oak Riparian Forest	91	4.76	0.73	5.48	0%	67%
Ephedra californica	77	2.35	0.65	3.00	100%	33%
Southern California Steelhead Stream	74	4.72	0.36	5.08	48%	51%
Populus fremontii	73	4.65	1.07	5.72	0%	33%
Saline Emergent Wetland	73	6.03	0.38	6.42	71%	49%
Southern Sycamore Alder Riparian Woodland	70	4.52	1.53	6.05	50%	83%
Central Dune Scrub	69	6.42	0.09	6.51	100%	83%
Central Maritime Chaparral	69	5.83	0.16	5.99	14%	33%
Adenostoma fasciculatum	68	3.39	1.18	4.57	100%	67%
Quercus lobata	68	4.85	1.10	5.95	100%	67%
Aesculus californica	48	4.68	0.96	5.63	0%	33%
Quercus douglasii/grass	45	4.40	0.91	5.31	100%	33%
Baccharis salicifolia	44	4.55	0.93	5.48	100%	67%
Gutierrezia californica	43	2.48	0.70	3.17	0%	33%
Southern Cottonwood Willow Riparian Forest	43	3.75	0.67	4.42	50%	56%
Southern Willow Scrub	42	4.80	0.67	5.47	60%	60%
Atriplex spinifera	41	2.56	1.12	3.68	100%	33%
Quercus agrifolia	41	4.85	0.71	5.55	0%	67%
Salix laevigata	38	5.87	1.21	7.08	100%	67%
Southern Riparian Scrub	36	6.06	0.92	6.97	100%	50%

Monterey Pine Forest	32	5.87	0.41	6.27	100%	67%
California Walnut Woodland	30	4.13	0.80	4.93	0%	33%
Quercus douglasii-Pinus sabiniana	29	3.78	1.03	4.81	100%	33%
Desert Riparian	27	3.24	1.00	4.24	67%	41%
Pinus coulteri	27	2.51	1.26	3.77	0%	67%
Valley Needlegrass Grassland	26	6.29	0.42	6.72	100%	67%
Coastal and Valley Freshwater Marsh	25	6.36	0.36	6.72	56%	48%
Arctostaphylos glauca	24	1.88	1.38	3.25	0%	33%
Central Foredunes	20	5.53	0.00	5.53	100%	67%
Northern Coastal Salt Marsh	20	6.91	0.30	7.21	70%	50%
Pinus sabiniana	19	3.63	1.16	4.79	0%	100%
Prunus ilicifolia	19	4.26	1.84	6.11	0%	67%
Southern Mixed Riparian Forest	19	3.37	0.89	4.26	48%	58%
Lepidospartum squamatum	18	4.75	1.17	5.91	0%	67%
Platanus racemosa	18	5.17	1.56	6.72	100%	100%
Poa secunda	18	2.61	0.72	3.33	100%	33%
Quercus douglasii	18	4.72	0.72	5.44	100%	33%
Southern Coastal Salt Marsh	17	6.80	0.59	7.39	67%	56%
Artemisia californica	16	5.63	0.44	6.06	100%	33%
Salix breweri	16	2.28	1.56	3.84	100%	33%
Valley Sink Scrub	16	2.88	1.06	3.94	100%	67%
Krascheninnikovia lanata	15	2.48	1.00	3.48	100%	33%
Quercus durata	15	2.37	1.47	3.83	0%	33%
Juniperus californica	14	1.39	1.57	2.96	100%	67%
Populus fremontii–Salix laevigata	14	6.14	1.57	7.71	0%	33%
Southern California Threespine Stickleback Stream	14	3.75	0.36	4.11	48%	51%
Northern Maritime Chaparral	13	5.89	0.38	6.28	50%	44%
Maritime Coast Range Ponderosa Pine Forest	12	6.03	0.50	6.53	0%	67%
Leymus triticoides	11	3.20	1.00	4.20	0%	67%
Pluchea sericea	11	3.64	0.91	4.55	100%	33%
Salix laevigata–Salix lasiolepis	11	6.50	1.64	8.14	100%	67%
Acer macrophyllum	10	5.53	1.10	6.63	0%	0%
Northern Interior Cypress Forest	10	6.17	0.30	6.47	100%	67%
Quercus agrifolia /Adenostoma fasciculatum (-Salvia mellifera)??mellifera)	10	5.30	0.80	6.10	0%	67%
Quercus lobata-Quercus agrifolia /grass	10	5.50	0.90	6.40	100%	67%

Ribes quercetorum	10	2.30	1.00	3.30	0%	67%
Allenrolfea occidentalis	9	3.17	1.33	4.50	100%	67%
North Central Coast Short-Run Coho Stream	9	5.14	0.67	5.81	45%	51%
Quercus agrifolia /Toxicodendron diversilobum	9	5.72	0.89	6.61	0%	67%
Quercus lobata/grass	9	5.72	0.89	6.61	100%	67%
Salix lucida	9	6.44	1.11	7.56	0%	67%
Southern Vernal Pool	9	3.39	0.22	3.61	86%	52%
Sycamore Alluvial Woodland	9	4.56	1.44	6.00	100%	100%
Adenostoma fasciculatum-Salvia leucophylla	8	5.63	1.00	6.63	100%	67%
Frankenia salina	8	5.88	0.13	6.00	0%	33%
Populus trichocarpa	8	6.44	1.00	7.44	0%	67%
Populus trichocarpa–Salix laevigata	8	6.56	1.38	7.94	0%	67%
Sarcocornia pacifica - Frankenia salina	8	7.25	0.00	7.25	100%	67%
Arctostaphylos (crustacea, tomentosa)	7	4.59	0.71	5.30	0%	33%
Coastal Brackish Marsh	7	5.66	0.86	6.52	44%	48%
Quercus wislizeni (shrub)	7	4.64	1.00	5.64	0%	33%
Sarcocornia pacifica	7	7.21	0.00	7.21	100%	67%
Baccharis pilularis	6	5.83	0.83	6.67	100%	33%
Central Coast Arroyo Willow Riparian Forest	6	5.33	0.00	5.33	100%	67%
Forestiera pubescens	6	2.75	1.00	3.75	100%	33%
North Central Coast Fall-Run Steelhead Stream	6	5.58	0.67	6.25	45%	51%
Schoenoplectus americanus	6	2.83	1.00	3.83	100%	67%
Sequoia sempervirens	6	4.69	1.00	5.69	0%	67%
Ambrosia chamissonis - Abronia maritima - Cakile maritima	5	7.30	0.00	7.30	100%	100%
Arthrocnemum subterminale	5	7.30	0.00	7.30	100%	67%
Distichlis spicata - Jaumea carnosa	5	7.50	0.00	7.50	100%	67%
Distichlis spicata - Sarcocornia pacifica	5	7.10	0.00	7.10	100%	67%
Lupinus albifrons	5	6.50	0.60	7.10	0%	33%
Pseudotsuga menziesii–Umbellularia californica	5	4.58	0.80	5.38	0%	67%
Sarcocornia pacifica - Frankenia salina - Suaeda taxifolia	5	7.30	0.00	7.30	100%	67%
Suaeda moquinii	5	3.00	1.40	4.40	100%	67%

Abronia latifolia–Ambrosia chamissonis	4	7.13	0.75	7.88	100%	100%
Arthrocnemum subterminale - Monanthochloe littoralis	4	7.25	0.00	7.25	100%	67%
Arthrocnemum subterminale - Sarcocornia pacifica	4	7.50	0.00	7.50	100%	67%
Distichlis spicata - Ambrosia chamissonis	4	7.25	0.00	7.25	100%	67%
Frankenia salina - Distichlis spicata	4	7.00	0.00	7.00	0%	33%
Lepidospartum squamatum–Baccharis salicifolia	4	6.25	2.00	8.25	0%	67%
Monterey Pygmy Cypress Forest	4	7.68	0.25	7.93	100%	33%
Nassella cernua	4	3.50	0.50	4.00	100%	67%
Prunus fasciculata	4	1.56	1.75	3.31	0%	67%
Quercus chrysolepis (tree)	4	3.16	0.75	3.91	0%	67%
Quercus chrysolepis-Arbutus menziesii-Lithocarpus??densiflorus var. densiflorus	4	3.16	0.75	3.91	0%	67%
Serpentine Bunchgrass	4	6.08	0.25	6.33	100%	44%
Southern California Coastal Lagoon	4	6.32	0.00	6.32	71%	49%
Southern Riparian Forest	4	7.55	0.25	7.80	100%	56%
Walnut Forest	4	2.75	1.50	4.25	0%	33%
Branchinecta conservatio	3	3.17	0.00	3.17	86%	52%
Canyon Live Oak Ravine Forest	3	1.75	0.67	2.42	0%	67%
Hazardia squarrosa	3	3.38	1.33	4.71	0%	33%
Leymus condensatus	3	6.50	1.67	8.17	0%	33%
Lithocarpus densiflorus	3	5.83	0.67	6.50	0%	67%
Monterey Cypress Forest	3	6.89	0.00	6.89	100%	33%
Northern Bishop Pine Forest	3	7.98	0.00	7.98	100%	67%
Populus fremontii–Quercus agrifolia	3	5.83	1.00	6.83	0%	33%
Populus trichocarpa–Salix lasiolepis	3	6.50	1.33	7.83	0%	67%
Sambucus nigra	3	6.50	1.33	7.83	100%	33%
Sarcocornia pacifica - Brassica nigra	3	7.50	0.00	7.50	100%	67%
Sarcocornia pacifica / algae	3	7.17	0.00	7.17	100%	67%
Alkali Seep	2	3.69	1.00	4.69	50%	67%
Arbutus menziesii	2	3.50	0.50	4.00	100%	33%
Eriogonum wrightii	2	2.25	1.00	3.25	100%	67%
Northern Claypan Vernal Pool	2	2.00	0.50	2.50	33%	56%
Populus fremontii–Salix lasiolepis	2	6.50	1.00	7.50	0%	33%

Quercus douglasii-Quercus agrifolia	2	6.00	0.50	6.50	100%	33%
Salix lasiolepis	2	7.00	0.00	7.00	100%	67%
Sarcocornia pacifica - Jaumea carnosa - Batis maritima	2	7.50	0.00	7.50	100%	67%
Sarcocornia pacifica - Jaumea carnosa - Distichlis spicata	2	7.50	0.00	7.50	100%	67%
Umbellularia californica	2	4.50	1.00	5.50	0%	67%
Branchinecta campestris	1	3.00	1.00	4.00	86%	52%
Carex serratodens	1	4.50	2.00	6.50	100%	67%
Cismontane Alkali Marsh	1	6.50	1.00	7.50	64%	50%
Encelia californica	1	6.50	2.00	8.50	100%	33%
Encelia californica - Artemisia californica	1	7.50	0.00	7.50	100%	33%
Eriodictyon crassifolium	1	1.63	1.00	2.63	0%	33%
Eriogonum heermannii	1	7.50	1.00	8.50	100%	67%
Juglans californica	1	6.50	1.00	7.50	0%	33%
Lycium andersonii	1	4.00	2.00	6.00	100%	67%
N. Central Coast Calif. Roach/Stickleback/Steelhead Stream	1	3.63	1.00	4.63	45%	51%
Platanus racemosa–Populus fremontii	1	6.50	2.00	8.50	100%	100%
Platanus racemosa–Quercus agrifolia	1	6.50	2.00	8.50	100%	100%
Platanus racemosa–Salix laevigata	1	6.50	2.00	8.50	100%	100%
Populus fremontii–Juglans californica	1	6.50	1.00	7.50	0%	33%
Populus fremontii–Sambucus nigra	1	6.50	2.00	8.50	0%	33%
Populus trichocarpa–Quercus agrifolia	1	4.25	1.00	5.25	0%	67%
Populus trichocarpa–Salix lucida	1	6.50	1.00	7.50	0%	67%
Sarcocornia pacifica - Jaumea carnosa	1	7.50	0.00	7.50	100%	67%
Sarcocornia pacifica (Salicornia depressa)	1	7.00	1.00	8.00	100%	67%
Spartina foliosa	1	7.50	0.00	7.50	100%	33%

[1] The number of hexagons the significant habitat type occurs in the project area.
[2] The significant habitat Invasive Plant Risk Score averaged for the hexagons the significant habitat type occurs in.
[3] The Climate Change Vulnerability Score averaged for the hexagons the significant habitat type occurs in.
[4] The Invasive Plant Risk and Climate Change Vulnerability Scores averaged for the hexagons the significant habitat type occurs in.
[5] The significant habitat Invasive Plant Risk Score confidence averaged for the hexagons the significant habitat type appears within.
[6] The significant habitat Climate Change Vulnerability confidence averaged for the hexagons the significant habitat type appears within.

Appendix C. Raw Climate Change Vulnerability Score Maps.

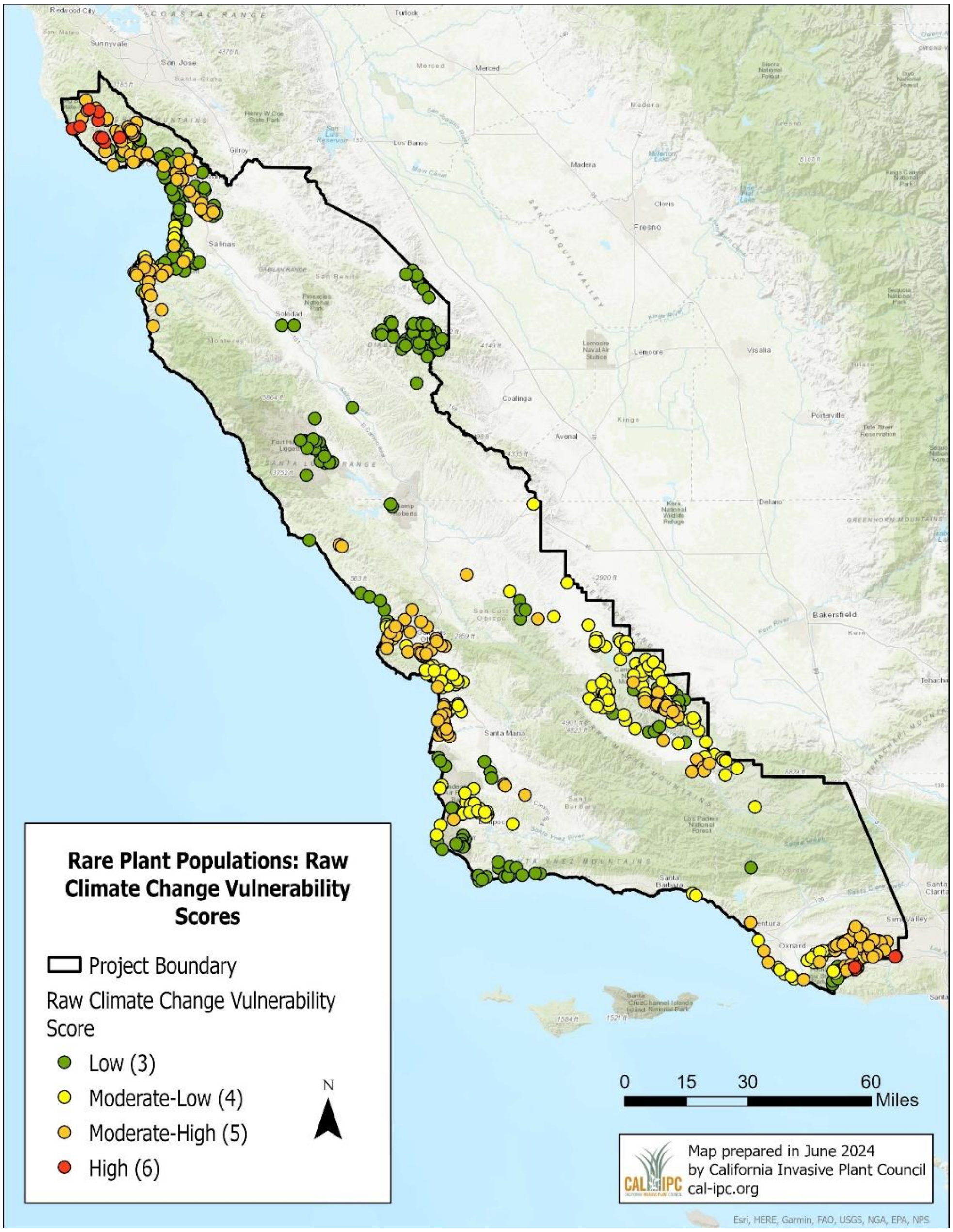


Figure C-1. Rare Plant Population Raw Climate Change Vulnerability Scores for rare plant populations in the project area. Higher scoring populations are placed on top of lower scoring populations.

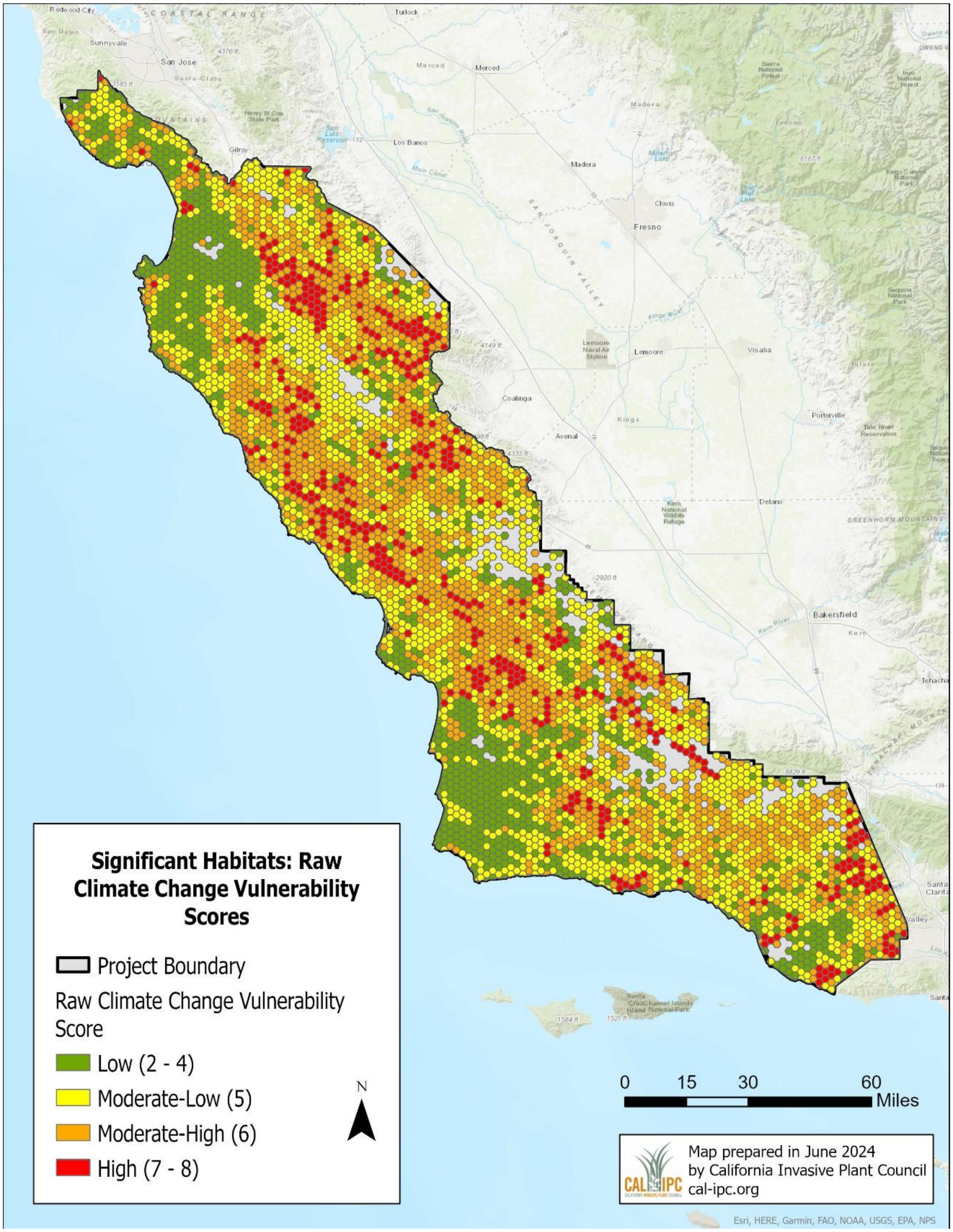


Figure C-2. Significant Habitat Raw Climate Change Vulnerability Scores for the project area.

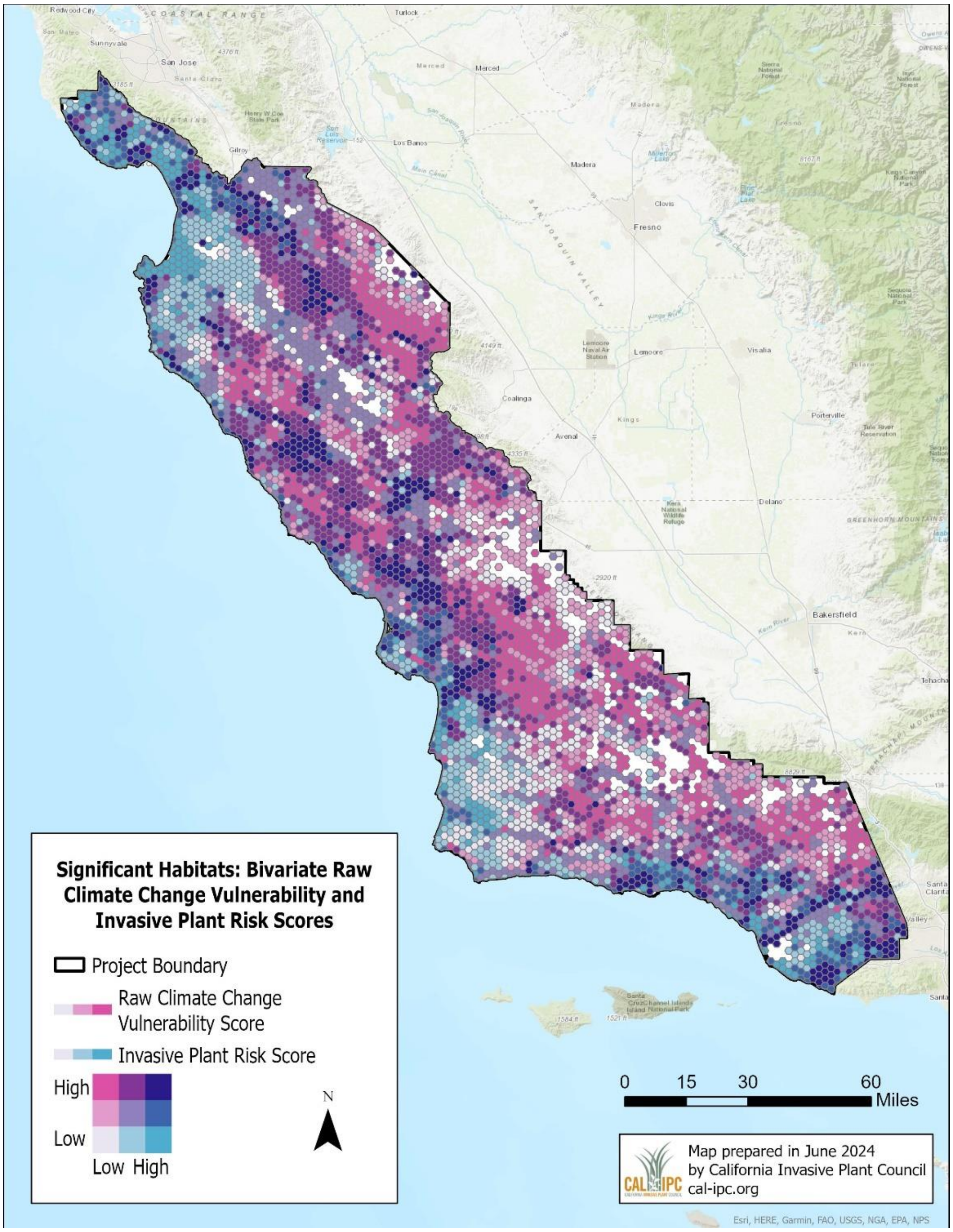


Figure C-3. Sensitive Habitat bivariate scores for Invasive Plant Risk Score and Raw Climate Change Vulnerability Scores in the project area. Pink indicates high climate vulnerability but low invasive plant risk. Teal represents high invasive plant risk but low climate vulnerability. Dark purple indicates high climate vulnerability and climate risk.

Appendix D. Work report from Land Conservancy of San Luis Obispo

Appendix E. Tom Robinson Consulting 2024 Analysis Summary

THE LAND CONSERVANCY of San Luis Obispo County
Mailing: PO Box 12206, San Luis Obispo, CA 93406
Office: 1137 Pacific Street, Suite A, San Luis Obispo, CA 93401
805 544 9096
805 544 5122
lc@lcslo.org
lcslo.org

Appendix D: Work report from Land Conservancy of San Luis Obispo

June 25, 2024

Jutta Burger
Science Program Director
California Invasive Plant Council
1442-A Walnut Street, #462
Berkeley, CA 94709

RE: INVOICE #2 AND FINAL REPORT
AGREEMENT NUMBER: CAL-IPC.01.15.2024

Please find enclosed an invoice for work performed in **April and May 2024**, for the California Invasive Plant Council, under the "Rare Habitat Protection through Invasive Plant Management Demonstration Project" The following final report describes the activities that were performed through funding period (January – May 2024). This is the final invoice and the remaining balance will not be billed for.

Budget	Costs Incurred this Period	Total Cost to Date	Remaining Balance
$ 15,014.20	$ 4,591.05	$ 15,014.17	$ 0.03

Thank you for your continued support,

Sincerely,

Lindsey Roddick
Restoration Program Manager
The Land Conservancy of San Luis Obispo County

Final Report

The following update includes all invasive species work throughout the life of the funding (January – May 2024). All tasks set in the agreement have been met. This funding has directly supported rare plant habitats in the Guadalupe Nipomo Dunes Complex and allowed additional work to be completed in an extremely wet year when invasive species were especially prevalent.

<u>Task 1:</u> *Lupinus nipomensis* at Black Lake Ecological Area

Invasive species surrounding locations of *L. nipomensis* were hand pulled on one full day (3/1/2024) and one-half day (3/28/2024) (Figure 1). Most common invasive species threats were perennial veldt grass (*Ehrharta calycina*) and narrowleaf iceplant (*Conicosia pugioniformis*). The sites were visited again in April and hand weeded using limited matching funding.

<u>Task 2:</u> Rare habitat protection at Guadalupe-Nipomo Dunes National Wildlife Refuge (Refuge)

Purple ragwort (*Senecio elegans*) was hand pulled within the foredune habitat of the Guadalupe-Nipomo Dunes National Wildlife Refuge 5.5 days (2/8, 2/9, 2/15, 3/18, 4/29, amd 4/30). This funding directly helped manage purple ragwort in areas where both Surf thistle (*Cirsium rhothophilum*) and Dune spectaclepod *(Dithyrea martima*) are prevalent and other management strategies are not permitted. Other portions of the population were managed using both herbicide and hand pulling treatment using matching USFW Service's Coastal program funds (Figure 2). Initial funding for this work was secured through the USFWS Coastal Program, but this additional funding has allowed us to expand our work area to protect additional areas, specifically in areas of high percent cover of rare plant species.

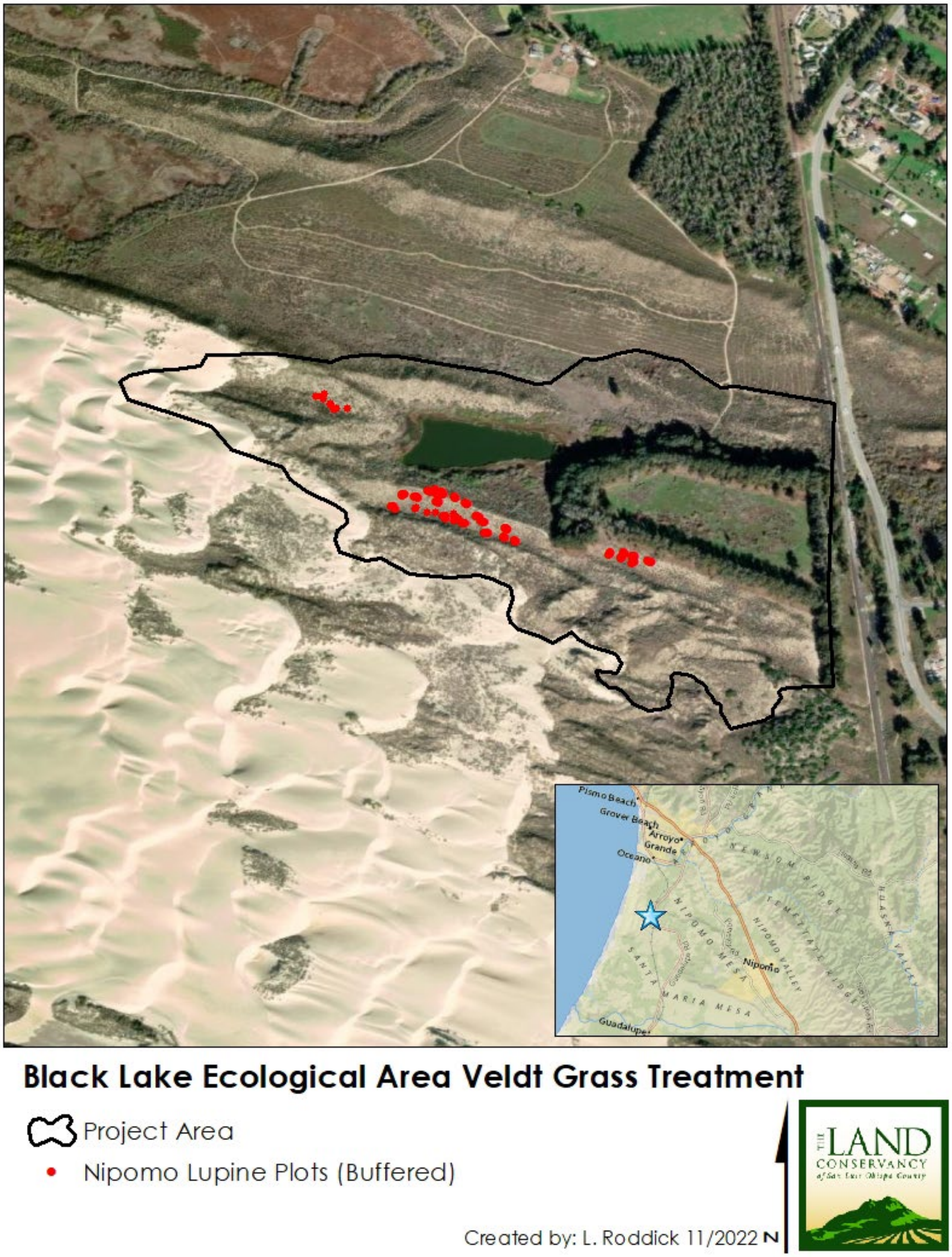


Figure 1. Nipomo Lupine plots at Black Lake Ecological Area.

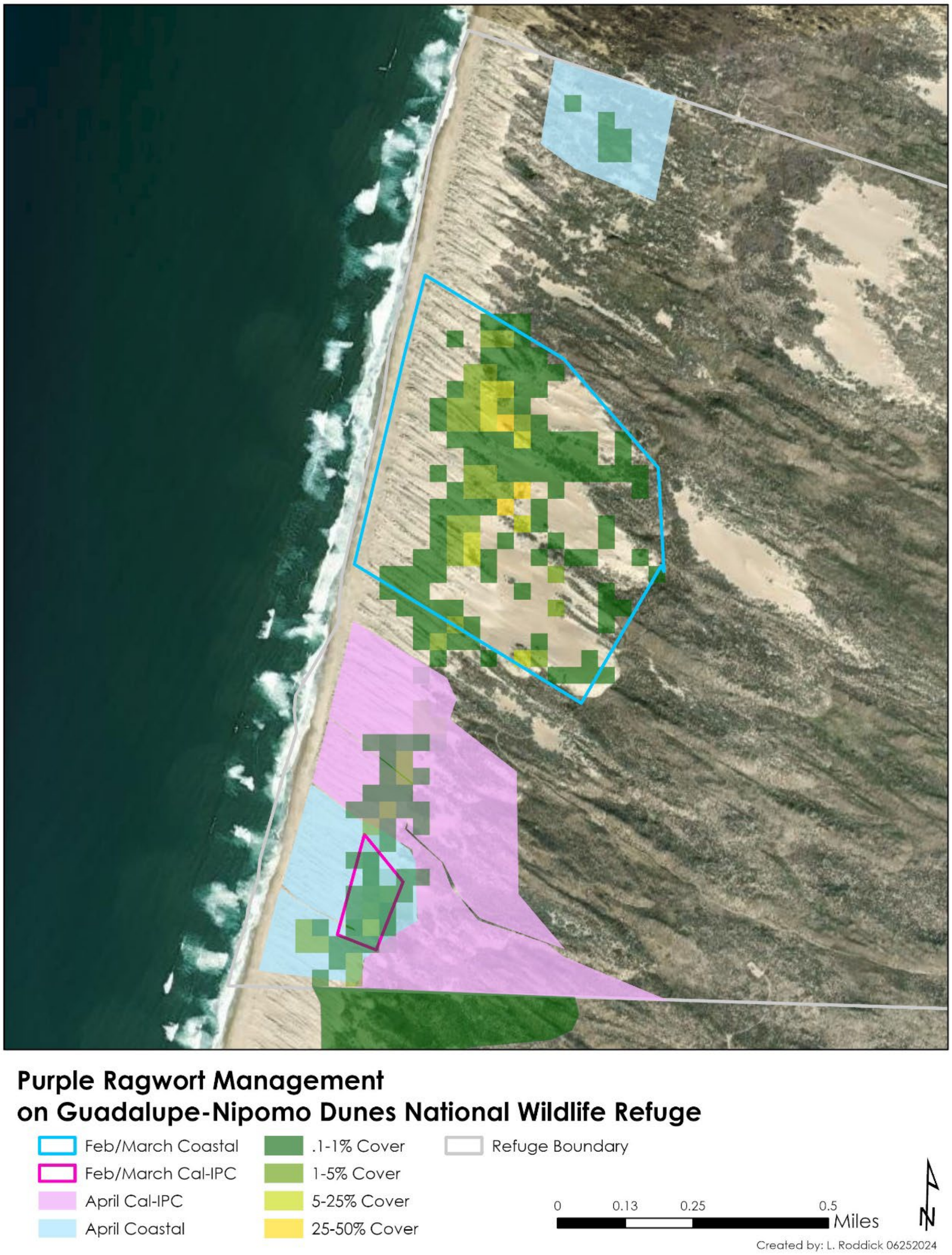


Figure 2: Purple ragwort mechanical removal on the Wildlife Refuge.

Land Conservancy of San Luis Obispo County
1137 Pacific St.
San Luis Obispo, CA 93401

Invoice

Invoice #: 24-294-03
Invoice Date: 4/30/2024

Bill To:
California Invasive Plant Council
Attn: Jutta Berger
1442-A Walnut St. #462
Berkeley, CA 94709

Item	Description	Date	Hours/Qty	Rate	Amount
	LABOR				
Lindsey - Cal-IPC Rare Hab Prot	project management	4/5/2024	0.5	95.00	47.50
Lindsey - Cal-IPC Rare Hab Prot	project management	4/8/2024	3	95.00	285.00
Lindsey - Cal-IPC Rare Hab Prot	field call with crew, map, game plan moving forward	4/23/2024	2.25	95.00	213.75
Lindsey - Cal-IPC Rare Hab Prot	plan forward, outreach to Kimi and Chevron	4/24/2024	0.75	95.00	71.25
Francisco - Cal-IPC Rare Hab Pr	Purple ragwort mechanical treatment	4/29/2024	4	80.00	320.00
Francisco - Cal-IPC Rare Hab Pr	Purple ragwort mechanical treatment	4/29/2024	4	80.00	320.00
Chris - Cal-IPC Rare Hab Protec	Ragwort mechanical removal	4/29/2024	4	80.00	320.00
Chris - Cal-IPC Rare Hab Protec	Purple ragwort mech removal	4/29/2024	4	80.00	320.00
Field Tech - Cal-IPC Rare Hab	Ragwort mech removal	4/29/2024	4	75.00	300.00
Field Tech - Cal-IPC Rare Hab	Ragwort removal	4/29/2024	4	75.00	300.00
Lindsey - Cal-IPC Rare Hab Prot	project management- maps for crew	4/30/2024	0.25	95.00	23.75
Francisco - Cal-IPC Rare Hab Pr	Purple ragwort mechanical treatment	4/30/2024	4	80.00	320.00
Francisco - Cal-IPC Rare Hab Pr	Purple ragwort mechanical treatment	4/30/2024	4	80.00	320.00
Chris - Cal-IPC Rare Hab Protec	Ragwort mech removal	4/30/2024	4	80.00	320.00
Chris - Cal-IPC Rare Hab Protec	Ragwort mech removal	4/30/2024	4	80.00	320.00
	EQUIPMENT				
Service Truck #294	Service Truck $200/day	4/29/2024	1	200.00	200.00
Mule UTV #294	UTV - Mule @ $165/day	4/29/2024	1	165.00	165.00
Service Truck #294	Service Truck $200/day	4/30/2024	1	200.00	200.00
Mule UTV #294	UTV - Mule @ $165/day	4/30/2024	1	165.00	165.00
	MILEAGE				
Fleet Mileage #294	Fleet Mileage @ $0.67		89.25	0.67	59.80

Total	$4,591.05
Payments/Credits	$0.00
Balance Due	$4,591.05

Job	Cal-IPC Rare Habitat Protection
Job Number	294
Billing Period	April 2024
Reported by	Lindsey Roddick
Reported Date	5/13/2024

Equipment

Date	Description	Name	Equipment	Amount	Rate	Total
4/29/2024	Refuge Ragwort	Chris Lobdell	Service Truck	1	$ 200.00	$ 200.00
4/29/2024	Refuge Ragwort	Chris Lobdell	UTV	1	$ 165.00	$ 165.00
4/30/2024	Refuge Ragwort	Wyatt Michener	Service Truck	1	$ 200.00	$ 200.00
4/30/2024	Refuge Ragwort	Wyatt Michener	UTV	1	$ 165.00	$ 165.00
					Total	**$ 730.00**

Mileage

Date	Description	Name	Vehicle	Starting Odometer	Ending Odometer	Total Mileage	Rate	Total
4/29/2024	Ragwort mech removal	Chris Lobdell	White Truck	72328	72383	55	$ 0.670	$ 36.85
4/30/2024	Ragwort removal	Wyatt Michener	White Truck	72383	72417.25	34.25	$ 0.670	$ 22.95
					Total	**89.25**	**$ 0.670**	**$ 59.80**

APPROVED FOR PAYMENT

Payment Method: ______________________

Job#: 294

Job Name: Cal-IPC Rare Habitat Protection

Expense Acct: ______________________

Notes: CEM logs

Approved By: Lindsey Roddick

Approval Date: 06/24/2024

Analysis Summary

Central California Rare Plant Climate Change Vulnerability Analysis
Performed by Tom Robinson Consulting for California Invasive Plant Council
March 6, 2023 (revised July 8, 2024)

TABLE OF CONTENTS

1. Classify Vulnerability Factors

A. Vulnerability to Heat & Solar

Topographic Wetness Index (potential ground wetness)

- Many studies have found that the topographic wetness index (TWI) is significantly correlated to spatial patterns of soil moisture (Moore et al., 1988; Western et al., 1999) and tree mortality (Kaiser et al., 2013). TWI is a spatial distribution function that can be used to describe lateral subsurface water flow along hillslopes (Beven, 1995). It is a physically based index of hydrological similarity, with areas having similar index values likely to respond in hydrologically similar ways (Beven, 1997). TWI is defined as loge(ac/tan(b)), where ac is the upslope contributing area per unit contour length and tan(b) is the local land surface slope. The index assumes that the hydraulic gradient (i.e. a metric controlling the capacity of accumulated water to pass through the grid cell) is approximated by the local slope, and that lateral discharge (i.e. the water volume passing through a grid cell) is proportional to upslope contributing area (Quinn et al., 1995; Beven, 1997).
- Topographically convergent areas (e.g. valleys) tend to be associated with higher than average values of TWI, greater upslope contributing area (e.g. greater lateral discharge) and lower slopes (e.g. low hydraulic gradient).
- An increase in moisture content decreases the soil temperature differences between day-time and night-time, which provides protection to the plant root system against sharp and sudden changes of soil temperature. (link)
- For each species, calculate average TWI diversity

TWI Diversity Classification:
Quartiles

Class	Upper Value	Label
Very Low	9.384815	7.928 - 9.385
Low	9.919378	9.386 - 9.919
Moderate	11.085695	9.92 - 11.086
High	20.319044	11.087 - 20.319

Heat Load Index

- Heat Load Index (HLI), is a direct measure of incident radiation calculated from a Digital Elevation Model (DEM).

HLI Classification: Quartiles

Class	Upper Value	Label
Very Low	0.838025	0.406 - 0.838
Low	0.840822	0.839 - 0.841
Moderate	0.877182	0.842 - 0.877
High	1.117715	0.878 - 1.118

Query:

```
# Heat Load Index classification

def reclass(MEAN_HLI_from_JE_toolbox_Clipped_10Miles):
if (MEAN_HLI_from_JE_toolbox_Clipped_10Miles < 0.838025):
return "Very Low"
elif (MEAN_HLI_from_JE_toolbox_Clipped_10Miles >= 0.838025 and
MEAN_HLI_from_JE_toolbox_Clipped_10Miles < 0.840822):
return "Low"
elif (MEAN_HLI_from_JE_toolbox_Clipped_10Miles >= 0.840822 and
MEAN_HLI_from_JE_toolbox_Clipped_10Miles < 0.877182):
return "Moderate"
elif (MEAN_HLI_from_JE_toolbox_Clipped_10Miles >= 0.877182):
return "High"
```

```
reclass(!MEAN_HLI_from_JE_toolbox_Clipped_10Miles!)
```

Scoring

Heat/Solar Exposure					
	Very Low	Moderate	Moderate	High	High

Topographic Wetness Index (TWI)	Low	Low	Moderate	High	High
	Moderate	Low	Moderate	Moderate	High
	High	Low	Low	Moderate	Moderate
		Very Low	Low	Moderate	High
	Heat Load Index (HLI)				

Query:

```
# Heat-Solar Exposure

def myCalc(Variable1,Variable2):
if (Variable1=='Very Low')and(Variable2=='Very Low'):
return 'Moderate'
elif (Variable1=='Very Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Very Low')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='Very Low')and(Variable2=='High'):
return 'High'
elif (Variable1=='Low')and(Variable2=='Very Low'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='Low')and(Variable2=='High'):
return 'High'
elif (Variable1=='Moderate')and(Variable2=='Very Low'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'High'
elif (Variable1=='High')and(Variable2=='Very Low'):
return 'Low'
elif (Variable1=='High')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='High'):
return 'Moderate'
else:
return 'NoData'
```

```
myCalc(!TWI_Class!,!HeatLoadIndex_spp!)
```

	Heat/Solar Species Sensitivity				
Dispersal Distance	Limited (<5m)	Moderate	Moderate	High	High
	Intermediate	Low	Moderate	Moderate	High
	Long distance (>30m)	Low	Low	Moderate	Moderate
		>10yr	3-10yr	1-3yr	Limited/None
	Seed Dormancy				

	Heat/Solar Vulnerability			
Heat/Solar Exposure	High	Moderate	High	High
	Moderate	Low	Moderate	High
	Low	Low	Low	Moderate
		Low	Moderate	High
	Heat/Solar Sensitivity			

Query:

```
# Heat-Solar Vulnerability

def myCalc(Variable1,Variable2):
if (Variable1=='Low')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='High'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
```

```
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'High'
elif (Variable1=='High')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='High')and(Variable2=='High'):
return 'High'
else:
return 'NoData'
```

```
myCalc(!HeatSolarExposure!, !HeatSolarSensitivity!)
```

Processing steps

- TWI diversity = Low pass (Focal Stats) on 30-m TWI (15x153, mean)
- Sample TWI and TWI diversity (compare with percent change; good example is OBJECTID = 120)
- Calculate average TWI by species
- Classify TWI
- Combine TWI and HLI to produce Climate Exposure Class
- Calculate Heat/Solar Species Sensitivity per species
- Combine exposure and sensitivity to produce Heat/Solar Vulnerability

B. Vulnerability to Aridification

Climatic Water Deficit

- Proxy for drought tolerance
- Increase in CWD = greater risk
- Used HadGEM2-ES (warm/dry) model for RCP 8.5 emissions scenario projected for end of century (2070- 2099)

Fog and Low Cloud Cover

- Fog and low clouds have a moderating effect on solar radiation. One is shading, which keeps the temperatures cooler and the soil moisture higher. The other is fog drip, which is a water input into the soil. Assumption: Plants existing within fog and low cloud cover have evolved with this moderating effect.
- Assuming less fog cover in the future. Therefore high historic averages of presence of fog = greater risk (assumed decrease).
- Cloud Fraction: Cloud fraction is the percentage of each pixel in satellite imagery or each gridbox in a weather or climate model that is covered with clouds. A cloud fraction of one means the pixel is completely covered with clouds, while a cloud fraction of zero represents a totally cloud free pixel.

- Source: NASA Earth Observations & MODIS

Climatic Water Deficit data processing:

HadGEM2-ES (warm/dry)

Calculated percent change in the CWD 30-year average from 1990-2019 to a future CWD 30-year average (HadGEM ES RCP85 2070- 2099), averaged by species. Percent change in CWD is calculated as:

$\Delta CWD = [(CWDx – CWD1981\text{-}2010)/ CWD1981\text{-}2010]*100$

Where:

ΔCWD = percent change in CWD
CWDx = average CWD for 2070-2099, averaged by species
CWD1990-2019 = average CWD for climate period 1990-2019, averaged by species

ΔCWD Classification:
Quintiles

Class	Upper Value	Label
Slight Decrease	-2	-7 - -2
Presumed Stable	2	-1.9 - 2.0
Low	6	2.1 - 6.0
Moderate	12	6.1 - 12
High	350	12.1 - 350

Cloud Fraction data processing:

Fill NoData:
Con(IsNull("MYDAL2_M_CLD_FR_2003_06_01_gs_3600x1800"), FocalStatistics("MYDAL2_M_CLD_FR_2003_06_01_gs_3600x1800", NbrRectangle(3,3, "CELL"), "MEAN"), "MYDAL2_M_CLD_FR_2003_06_01_gs_3600x1800")

```
Con(IsNull("raster"), FocalStatistics("raster", NbrRectangle(5,5, "CELL"), "MEAN"),
"raster")
```

Did not use (too much missing):

- MYDAL2_M_CLD_FR_2010_08_01_gs_3600x1800

Average calculation:

```
((("MYDAL2_M_CLD_FR_2012_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2012_08_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2012_07_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2012_06_01_gs_3600x1800_filled2")/4) +
(("MYDAL2_M_CLD_FR_2011_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2011_08_01_gs_3600x1800_filled2" +
"MYDAL2_M_CLD_FR_2011_07_01_gs_3600x1800_filled2" +
"MYDAL2_M_CLD_FR_2011_06_01_gs_3600x1800")/4) +
(("MYDAL2_M_CLD_FR_2010_09_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2010_07_01_gs_3600x1800_filled3" +
"MYDAL2_M_CLD_FR_2010_06_01_gs_3600x1800")/3) +
(("MYDAL2_M_CLD_FR_2009_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2009_08_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2009_07_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2009_06_01_gs_3600x1800")/4) +
(("MYDAL2_M_CLD_FR_2008_09_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2008_08_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2008_07_01_gs_3600x1800_filled2" +
"MYDAL2_M_CLD_FR_2008_06_01_gs_3600x1800_filled2")/4) +
(("MYDAL2_M_CLD_FR_2007_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2007_08_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2007_07_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2007_06_01_gs_3600x1800")/4) +
(("MYDAL2_M_CLD_FR_2006_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2006_08_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2006_07_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2006_06_01_gs_3600x1800")/4) +
(("MYDAL2_M_CLD_FR_2005_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2005_08_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2005_07_01_gs_3600x1800_filled2" +
"MYDAL2_M_CLD_FR_2005_06_01_gs_3600x1800")/4) +
(("MYDAL2_M_CLD_FR_2004_09_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2004_08_01_gs_3600x1800" +
"MYDAL2_M_CLD_FR_2004_07_01_gs_3600x1800_filled" +
"MYDAL2_M_CLD_FR_2004_06_01_gs_3600x1800_filled")/4) +
(("MYDAL2_M_CLD_FR_2003_09_01_gs_3600x1800_filled2" +
"MYDAL2_M_CLD_FR_2003_08_01_gs_3600x1800" + "MYDAL2_M_CLD_FR_2003_07_01_gs_3600x1800"
+ "MYDAL2_M_CLD_FR_2003_06_01_gs_3600x1800_filled2")/4))/10
```

Standardization calculation:

```
(("decadal_ave_03_12_b" -0 ) / (255 - 0))
```

Classification: Quartiles

Class	Upper Value	Label

Very Low	0.085973	0.063 - 0.086
Low	0.100263	0.087 - 0.1
Moderate	0.162186	0.101 - 0.162
High	0.669477	0.163 - 0.669

Scoring

	Aridification Exposure				
Change in Climatic Water Deficit (ΔCWD)	High	Moderate	Moderate	High	High
	Moderate	Low	Moderate	High	High
	Low	Low	Moderate	Moderate	High
	Stable or Sm Decrs	Low	Low	Moderate	Moderate
		High	Moderate	Low	Very Low
	Cloud Fraction (CF)				

Query:

```
# Aridification Exposure

def myCalc(Variable1,Variable2):
if (Variable1=='Sm Decrs')and(Variable2=='Very Low'):
return 'Moderate'
elif (Variable1=='Stable')and(Variable2=='Very Low'):
return 'Moderate'
elif (Variable1=='Low')and(Variable2=='Very Low'):
return 'High'
elif (Variable1=='Moderate')and(Variable2=='Very Low'):
return 'High'
elif (Variable1=='High')and(Variable2=='Very Low'):
return 'High'
elif (Variable1=='Sm Decrs')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Stable')and(Variable2=='Low'):
```

```
return 'Moderate'
elif (Variable1=='Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'High'
elif (Variable1=='High')and(Variable2=='Low'):
return 'High'
elif (Variable1=='Sm Decrs')and(Variable2=='Moderate'):
return 'Low'
elif (Variable1=='Stable')and(Variable2=='Moderate'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Sm Decrs')and(Variable2=='High'):
return 'Low'
elif (Variable1=='Stable')and(Variable2=='High'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='High'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'Low'
elif (Variable1=='High')and(Variable2=='High'):
return 'Moderate'
else:
return 'NoData'
```

```
myCalc(!CWDChg_Class!,!MEAN_CF_Class!)
```

Aridification Species Sensitivity					
Moisture Requirement (MR)		Root Storage (RS)		Leaf Size (LS)	
Class	Score	Class	Score	Class	Score
moist/wet	3	shallow	3	very large (>100cm2)	3
vernal/mesic	2	deep/taproot	2	medium (5-30cm2) or large (30-100cm2)	2

dry	1	rhizome-bulb -tuber	1	very small (<1cm2) or small (1-5cm2)	1
Species sensitivity score (weighted sum) = $MR_{score} + RS_{score} + LF_{score}$ 3-4 (Low), 5-6 (Moderate), 7-9 (High)					

	Aridification Vulnerability			
Aridification Exposure	High	Moderate	High	High
	Moderate	Low	Moderate	High
	Low	Low	Low	Moderate
		Low	Moderate	High
	Aridification Sensitivity			

Query:

```
# Aridification Vulnerability

def myCalc(Variable1,Variable2):
if (Variable1=='Low')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='High'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'High'
elif (Variable1=='High')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='High')and(Variable2=='High'):
return 'High'
else:
return 'NoData'
```

```
myCalc(!AridificationExposure!,!AridificationSensitivity!)
```

Processing steps

- Calculate percent change in CWD (historic vs future)
- Classify CWD delta as High, Moderate, Low, Assumed Stable
- Download 2003-2012 JJAS fog maps
- Fill NoData gaps
- Average JJAS rasters (clip at the same time)
- Combine CWD and CF to produce Aridification Class
- Calculate Aridification Species Sensitivity per species
- Combine exposure and sensitivity to produce Aridification Vulnerability

C. Vulnerability to Wildfire

Wildfire Classification:
Mean Fire Return Interval (MFRI) from Mann et al. (2016) 2026–2050 under the GFDL A2 climate scenario. Negative values = greater fire frequency.

Change in MFRI	Exposure Class
-150,-100 | 100,150	High
-100,-50 | 50,100	Moderate
-50,0 | 0,50	Low

Change in MFRI	
Class	Score
High	3
Moderate	2
Low	1
Prsm Stbl	1

Species ΔMRFI score (average of observation scores) 1 - 1.59 (Low), 1.6 - 2.59 (Moderate), 2.6 - 3 (High)

```
# ΔMRFI scoring

def myCalc(Variable1):
if (Variable1=='High'):
return 3
elif (Variable1=='Moderate'):
return 2
elif (Variable1=='Low'):
return 1
elif (Variable1=="Prsm Stbl"):
return 1
else:
return 'NoData'
```

```
myCalc(!MFRI_Class!)
```

```
# ΔMRFI classification

def reclass(Variable1):
if (Variable1 < 1.599999):
return "Low"
elif (Variable1 >= 1.6 and Variable1 < 2.599999):
return "Moderate"
elif (Variable1 >= 2.6):
return "High"
```

```
myCalc(!MEAN_MFRI_score!)
```

Scoring

	Wildfire Regime Change Vulnerability

Exposure to wildfire regime change (Change in MFRI)	High	""Moderate	High	High
	Moderate	Low	Moderate	High
	Low	Low	Low	Moderate
		None	Some	Obligate
	Fire Dependency			

Query:

```
# Wildfire Regime Change Vulnerability

def myCalc(Variable1,Variable2):
if (Variable1=='Low')and(Variable2=='none'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='some'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='obligate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='none'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='some'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='obligate'):
return 'High'
elif (Variable1=='High')and(Variable2=='none'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='some'):
return 'High'
elif (Variable1=='High')and(Variable2=='obligate'):
return 'High'
else:
return 'NoData'
```

```
myCalc(!MFRI_Class_spp!,!Fire_Resilience_Class!)
```

2. Combine Vulnerabilities to Produce Climate Vulnerability Index Per Species

Scoring

Climate change vulnerability was calculated by summing numerical scores that correspond to the scores (i.e., Low, Moderate, High) of the three Vulnerability Factors. The table below shows the the numerical scores for each

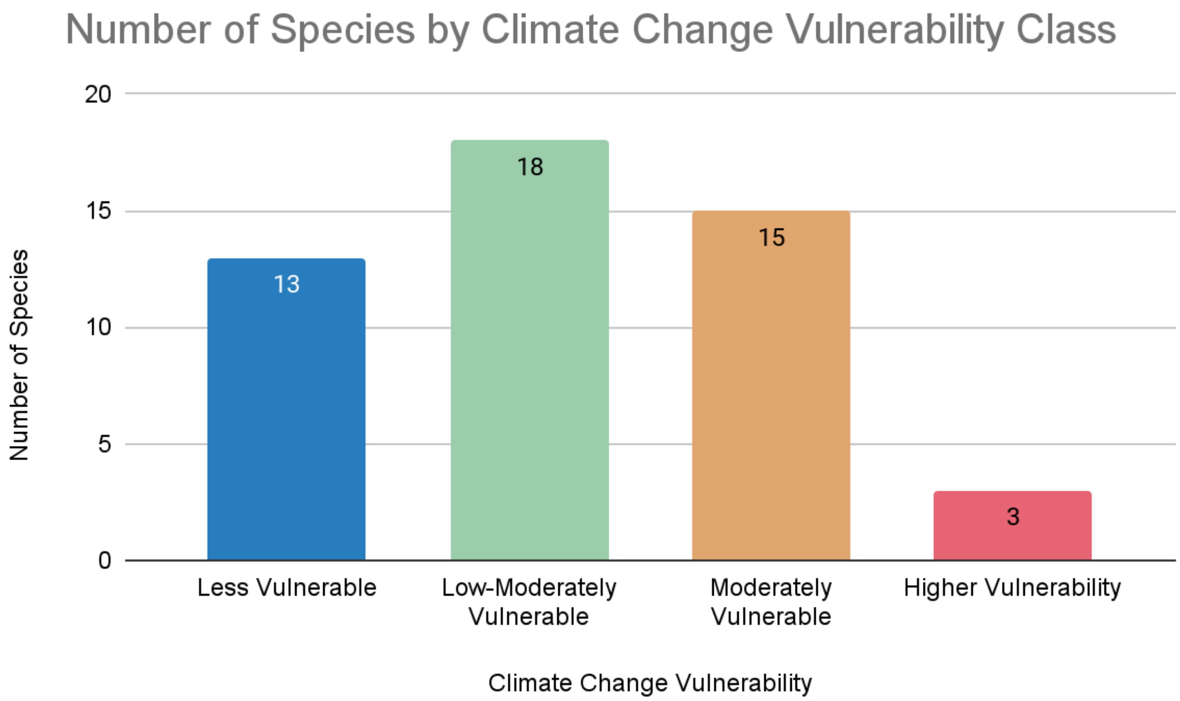
	Vulnerability Factors		
	Heat/Solar Vulnerability (HS)	Aridification Vulnerability (A)	Fire Vulnerability (F)
Vulnerability Factor Score	Corresponding Numerical Score	Corresponding Numerical Score	Corresponding Numerical Score
High	3	3	3
Moderate	2	2	2
Low	1	1	1

Climate change vulnerability score = $HS_{score} + A_{score} + L_{score}$

Climate change vulnerability scores ranged from 3 to 6. Scores were assigned descriptive vulnerability classes accordingly:

3 = Less Vulnerable
4 = Low-Moderately Vulnerable
5 = Moderately Vulnerable
6 = Higher Vulnerability

The distribution of species within each vulnerability class is shown in the chart below.




```
# Vulnerability scores

def myCalc(Variable1):
if (Variable1=='High'):
return 3
elif (Variable1=='Moderate'):
return 2
elif (Variable1=='Low'):
return 1
```

```
myCalc(<vulnerability field>)
```

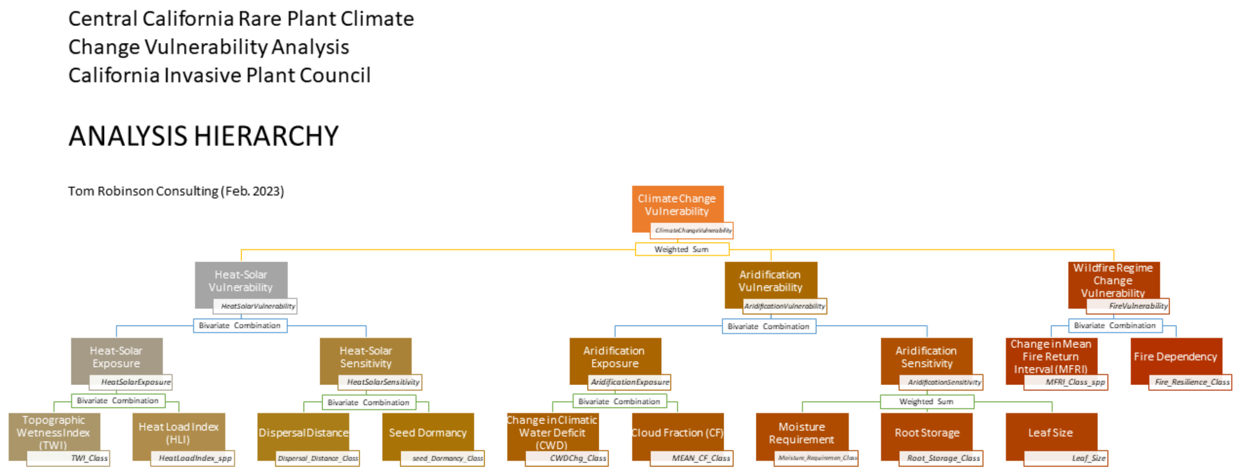
```
!HeatSolarVulnerabilityScore! + !AridVulnerabilityScore! + !FireVulnerabilityScore!
```

```
# Climate Change Vulnerability classification

def reclass(Variable1):
if (Variable1 < 4):
return "Less"
if (Variable1 == 4):
return "Low"
elif (Variable1 == 5):
return "Moderate"
elif (Variable1 >= 6):
return "High"
```

```
reclass(!ClimateVulnerabilityScore!)
```

Analysis Hierarchy



Modifiers to the Climate Change Vulnerability Score

- Range Restriction: Highlight which moderately and highly vulnerable species are range restricted.
- Apply weights to vulnerability factors prior to calculating the overall Climate Change Vulnerability score. E.g., if one vulnerability factor is thought to be more important or threatening than the others. It is not clear whether the change in fire regime is as much a threat as heat and solar radiation.

Analysis Tabular Values

Central CA rare plant climate vulnerability analysis

3. Summarize Environmental Variables to USGS Quarter Quads

Data values for the five environmental variables used to produce climate change exposures described above were summarized to USGS Quarter Quads.

Methods

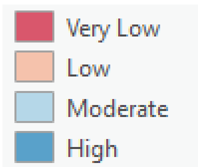
Data for the five environmental variables were in raster (or gridded) format. The ArcGIS Pro 'Zonal Statistics' tool was used to summarize raw values to Quarter Quad. Zonal Statistics considers all grid cell values that fall within each Quarter Quad, calculating a full suite of statistics per quad. The table below shows the environmental variables, their grid cell length (resolution), the summary statistic method used, and the class breaks.

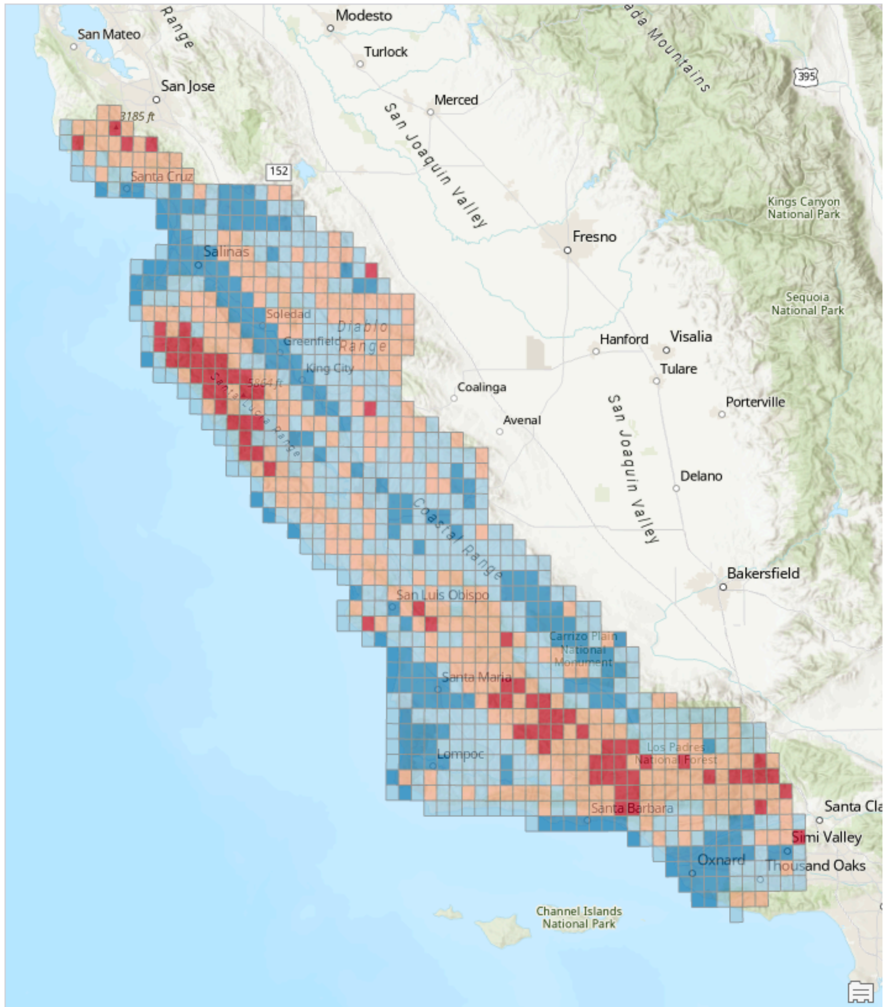
Environmental Variable	**Data Type**	**GIS Summarizing Method**	**Classification**
Topo-graphic Wetness Index	Raster (30m)	Zonal Statistics: Mean value for the quarter quad	Quartiles 9.384815 = Very Low 9.919378 = Low 11.085695 = Moderate 20.319044 = High
Heat Load Index	Raster (30m)	Zonal Statistics: Mean value for the quarter quad	Quartiles 0.845219 = Very Low 0.852503 = Low 0.859651 = Moderate 0.890881 = High
% Change in CWD	Raster (270m)	Zonal Statistics: Mean value for the quarter quad	Standard Deviations < -1.5 Std. Dev. = Moderately Large % decrease -1.5 - -0.50 Std. Dev. = Low-Moderate % decrease -0.50 - 0.50 Std. Dev. = Low/No % change 0.50 - 1.5 Std. Dev. = Low-Moderate % increase 1.5 - 2.5 Std. Dev. = Moderately Large % increase

			> 2.5 Std. Dev. = Large % increase
Cloud Fraction	Raster (10km)	Average of 5 random sample points per quarter quad	Quartiles 0.076412 = Very Low 0.090792 = Low 0.133497 = Moderate 0.669477 = High
Change in Mean Fire Return Interval	Raster (3.6km)	Zonal Statistics: Majority class for the quarter quad	-150 to -100; 150; Over 150 = High change -100 to -50; 50 to 100 = Moderate change -50 to 0; 0 to 50 = Low change

Maps

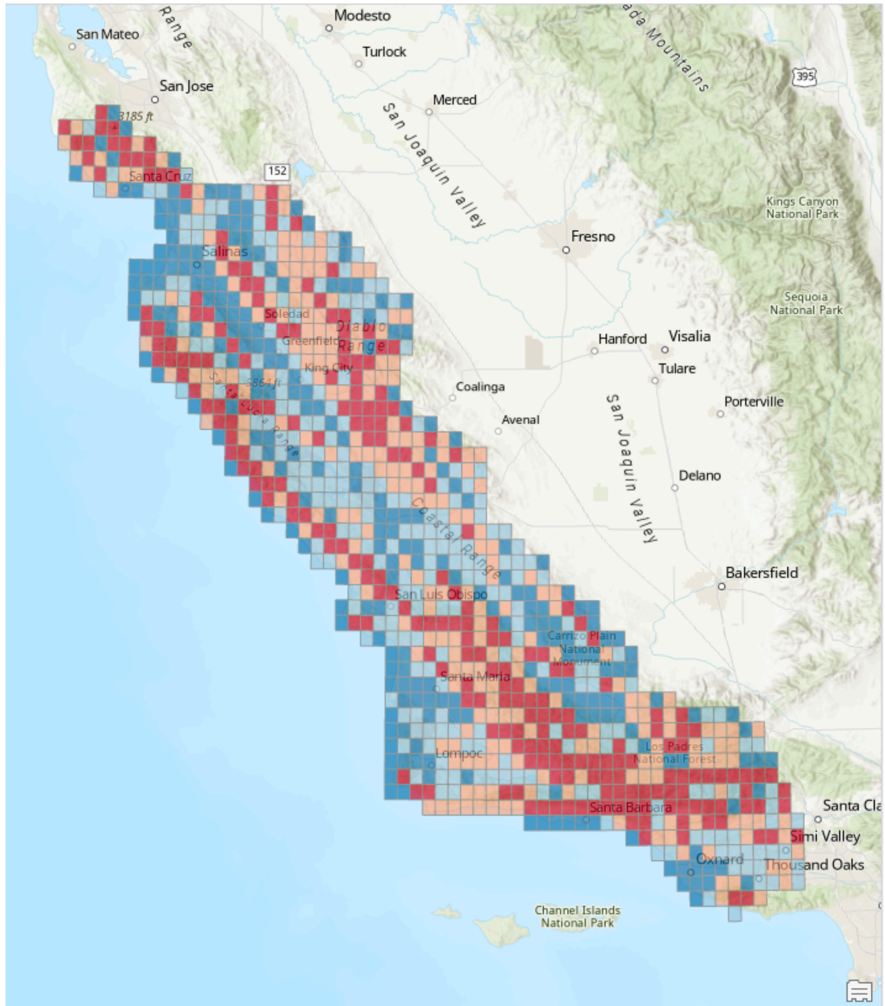
Topo-graphic Wetness Index





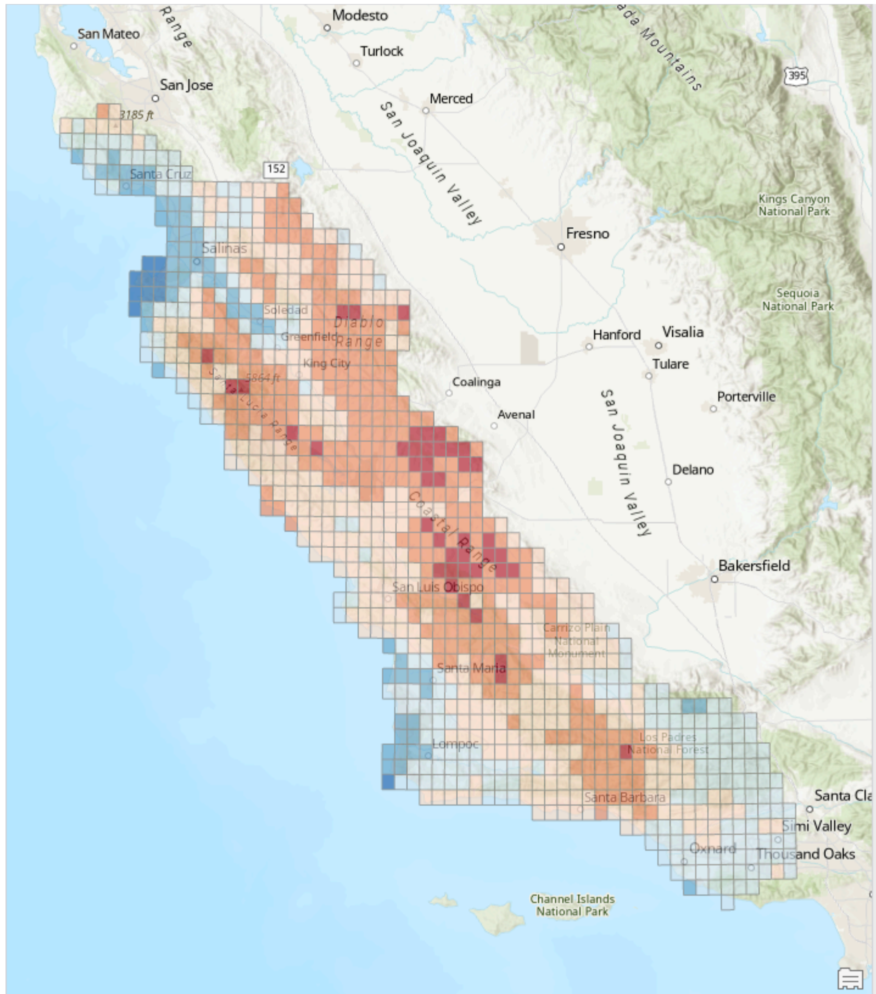
Heat Load Index

- Very Low
- Low
- Moderate
- High

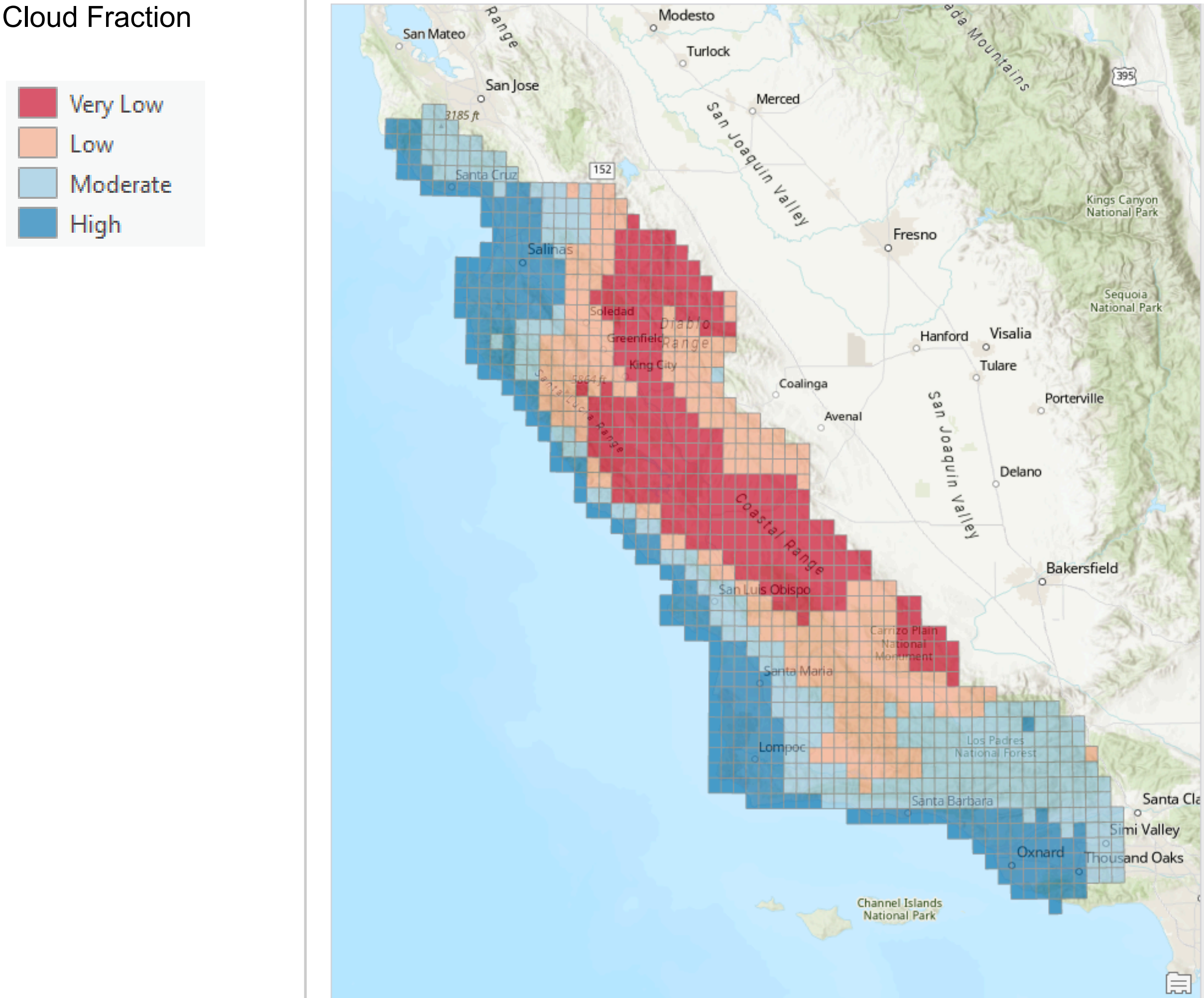


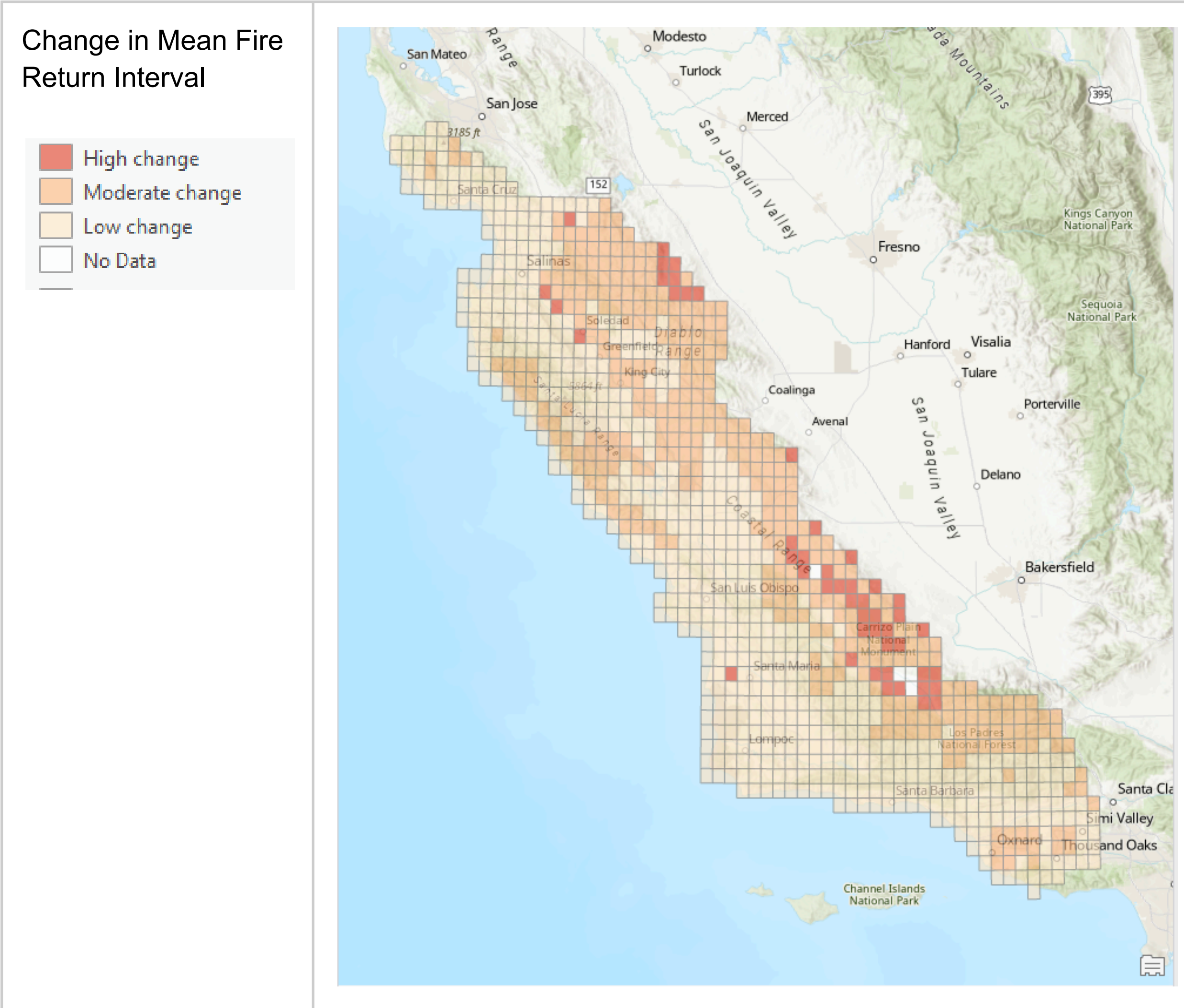
% Change in CWD

- Moderately Large % decrease
- Low-Moderate % decrease
- Low/No % change
- Low-Moderate % increase
- Moderately Large % increase
- Large % increase



Cloud Fraction



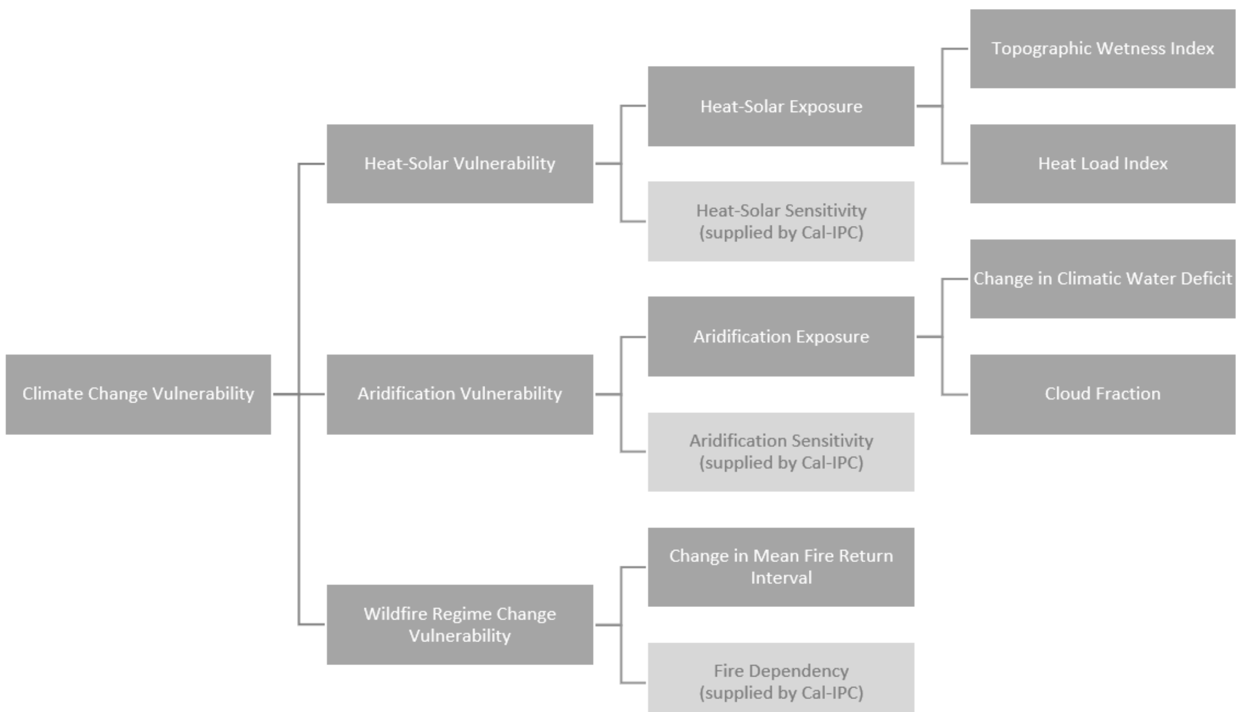


4. Climate Change Vulnerability Analysis for Sensitive Habitats

A scoring system was developed to assess climate change vulnerability of sensitive habitats as defined by CDFW's significant terrestrial habitats (STHs) and rare vegetation types (RVTs). The method used followed the model previously developed (see above) for scoring climate change vulnerability of rare plant populations in the central coast region of California. That model combined *exposure* and *sensitivity* scores to determine *vulnerability*. The exposure factors included Heat-Solar, Aridification, and Wildfire Regime Change.

For the sensitive habitats vulnerability analysis, climate change vulnerability index scores were assigned to individual CDFW Areas of Conservation Emphasis (ACE) hexagons. Each of the three vulnerabilities were defined by a combination of exposure and sensitivity (see Analysis Hierarchy below). Cal-IPC staff supplied STH and RVT sensitivity scores that were averaged (habitat area-weighted) to the ACE hexagons. Heat-Solar exposure was defined by combining two environmental factors: Topographic Wetness Index and Heat Load Index. Aridification exposure was defined by combining two environmental factors: Change in Climatic Water Deficit and Cloud Fraction. Wildfire Regime Change exposure was defined by one environmental factor: Change in Mean Fire Return Interval. See ‘Classify Vulnerability Factors’ above for data sources of the environmental factors.

Analysis Hierarchy



Analysis hierarchy for the Climate Change Vulnerability Analysis for Sensitive Habitats. All items in the boxes were summarized to CDFW ACE Hexagons and combined using the methods below. Items in light gray boxes were supplied by Cal-IPC.

Methods

Data for the five environmental variables associated with exposure were in raster (or gridded) format. The ArcGIS Pro ‘Zonal Statistics’ tool was used to summarize raw values to ACE hexagons. Zonal Statistics considers all grid cell values that fall within each hexagon, calculating a full suite of statistics per quad. The table below shows the environmental variables, their grid cell length (resolution), the summary statistic method used, and the class breaks.

Element	**Description**	**Attribute Field**
Topographic Wetness Index Class	Quartiles 9.384815 = Very Low 9.919378 = Low 11.085695 = Moderate 20.319044 = High	TWI_CLASS
Heat Load Index Class	Quartiles 0.845219 = Very Low 0.852503 = Low 0.859651 = Moderate 0.890881 = High	HLI_CLASS
Climatic Water Deficit Class	Standard Deviations < -1.5 Std. Dev. = Moderately Large % decrease -1.5 - -0.50 Std. Dev. = Low-Moderate % decrease -0.50 - 0.50 Std. Dev. = Low/No % change 0.50 - 1.5 Std. Dev. = Low-Moderate % increase 1.5 - 2.5 Std. Dev. = Moderately Large % increase > 2.5 Std. Dev. = Large % increase	CWD_CLASS *
Cloud Fraction Class	Quartiles 0.076412 = Very Low 0.090792 = Low 0.133497 = Moderate 0.669477 = High	CF_CLASS
Mean Fire Return Interval Class	-150 to -100; 150; Over 150 = High change -100 to -50; 50 to 100 = Moderate change -50 to 0; 0 to 50 = Low change	MFR_CLASS
Aridification **Exposure** Class	Combination of CWD and CF	ARID_EXP_CLASS

Heat/Solar **Exposure** Class	Combination of TWI and HLI	HEAT_SOL_EXP_CLASS
Wildfire Regime Change **Exposure** Class	Same as Mean Fire Return Interval Class	FIRE_CHG_EXP_CLASS
Aridification **Sensitivity** Class	Average (3 classes, Natural Breaks)	ARID_SENS_CLASS
Heat/Solar **Sensitivity** Class	Average (3 classes, Natural Breaks)	HEAT_SOL_SENS_CLASS
Wildfire Regime Change **Sensitivity** Class	Max (3 classes, Natural Breaks)	FIRE_CHG_SENS_CLASS
Aridification **Vulnerability** Score	Combination of Aridification exposure and sensitivity	ARID_SCORE
Heat/Solar **Vulnerability** Score	Combination of Heat/Solar exposure and sensitivity	HEAT_SOL_SCORE
Wildfire Regime Change **Vulnerability** Score	Combination of Wildfire Regime Change exposure and sensitivity	FIRE_CHG_SCORE
Climate Change **Vulnerability** Score by hexagon	Combination of Aridification, Heat/Solar, Wildfire Regime Change vulnerabilities 3 classes, Natural Breaks: High = 8-9 Moderate = 7 Low = 2-6	CLIM_CHG_VUL_SCORE
Aridification Vulnerability Score (**numerical**)	High = 3 Med = 2 Low = 1 NoData = 0	Arid

Heat/Solar Vulnerability Score (**numerical**)	High = 3 Med = 2 Low = 1 NoData = 0	Heat
Wildfire Regime Change Vulnerability Score (**numerical**)	High = 3 Med = 2 Low = 1 NoData = 0	Fire
Climate Change Vulnerability Score (**numerical**)	Range = 2-9	Vulnerability

Scoring

Vulnerability to each of the exposures were determined using the following combination method:

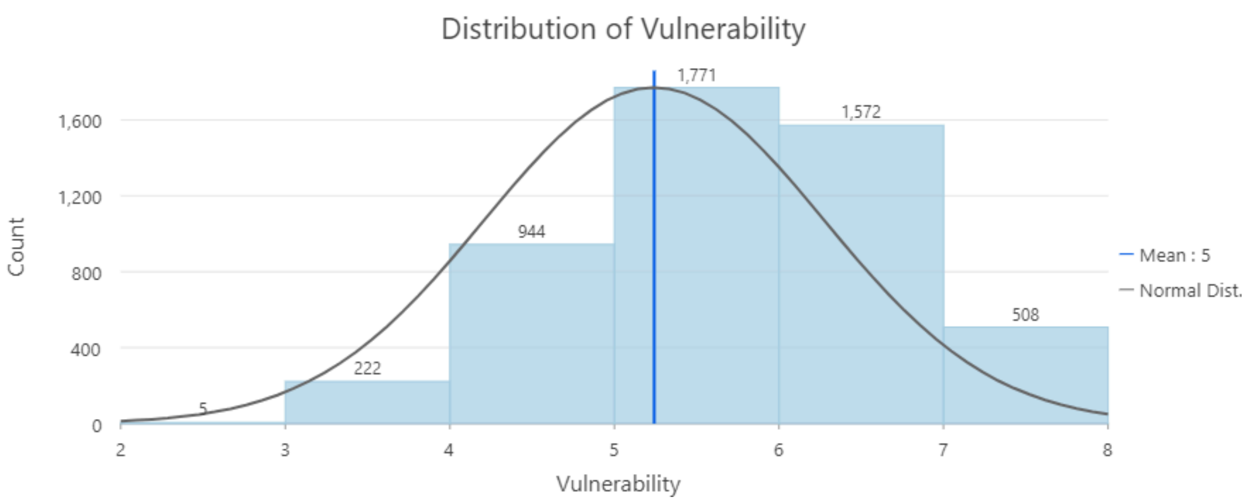
		Scoring		
Exposure Score	High	Moderate	High	High
	Moderate	Low	Moderate	High
	Low	Low	Low	Moderate
		Low	Moderate	High
	Sensitivity Score			

Overall vulnerability was determined by summing a numerical ranking of each of the exposure vulnerabilities. For example:

Aridification Vulnerability	Heat/Solar Vulnerability	Wildfire Regime Δ Vulnerability	Overall Vulnerability
High (3)	Moderate (2)	Low (1)	6
Low (1)	Moderate (2)	Low (1)	4

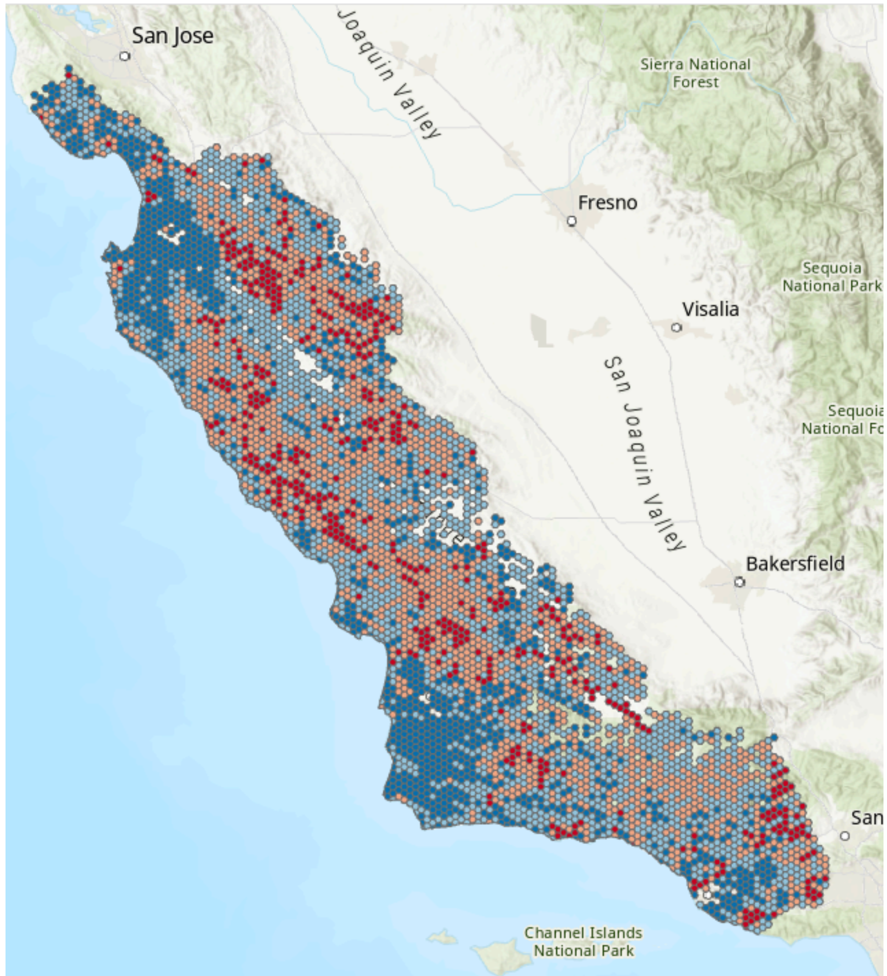
The class breaks for nominal ranking (e.g., Very Low, Low, etc.) were determined using the Natural Breaks (Jenks) method.

Overall Vulnerability Score	Nominal Ranking
7-8	High
6	Moderate
5	Low
2-4	Very Low



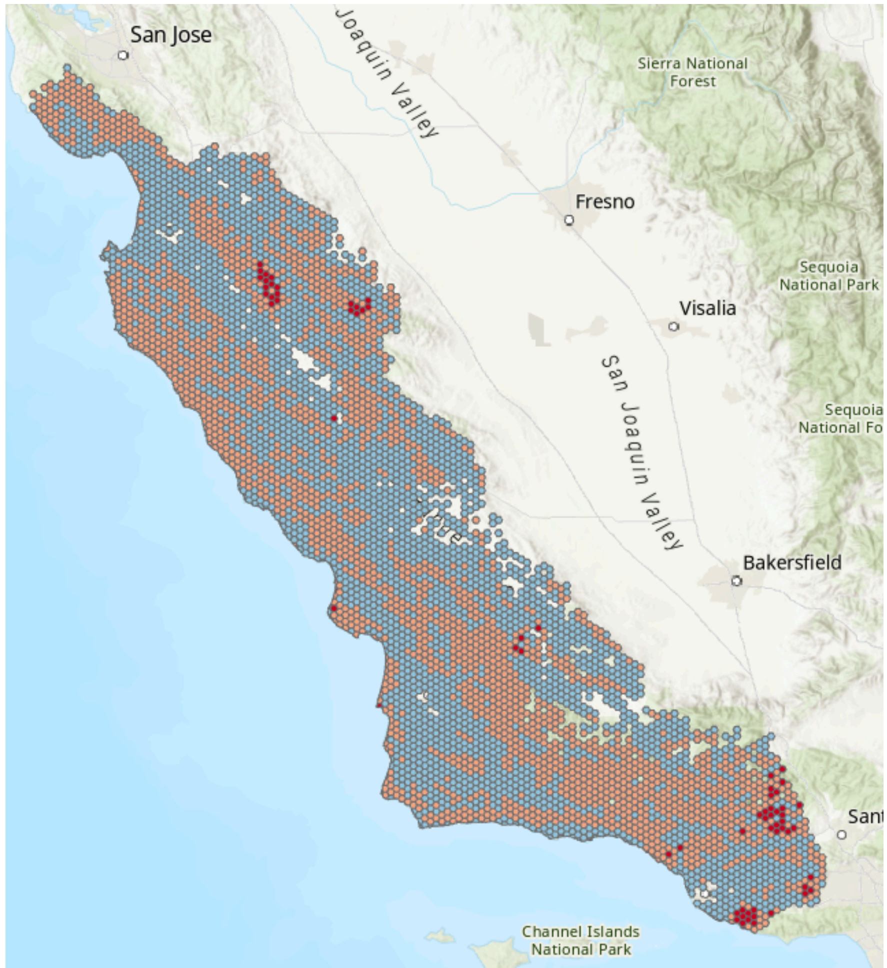
Maps

Climate Change Vulnerability Index for significant terrestrial habitats (STHs) and rare vegetation types (RVTs)



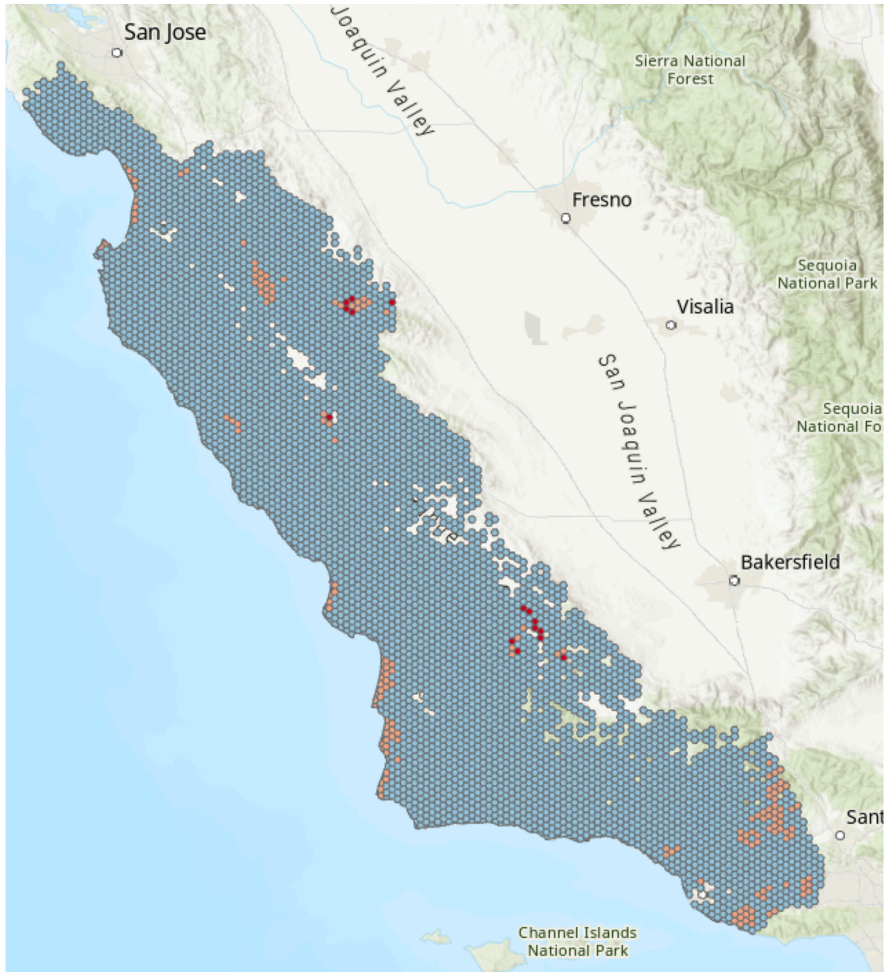
Heat-Solar Vulnerability

- High
- Moderate
- Low

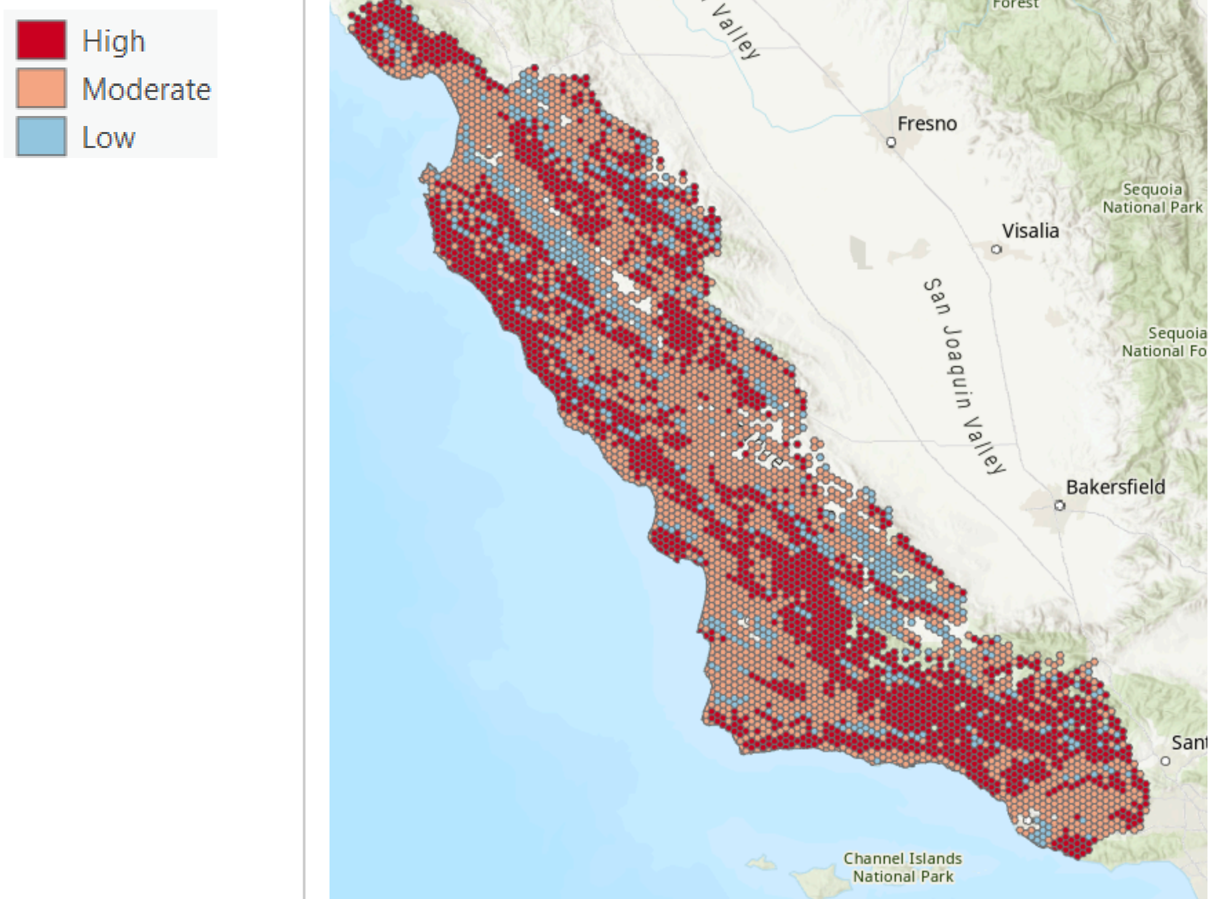


Heat-Solar Sensitivity

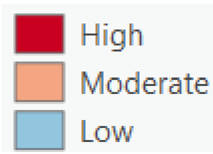
High	
Moderate	
Low	

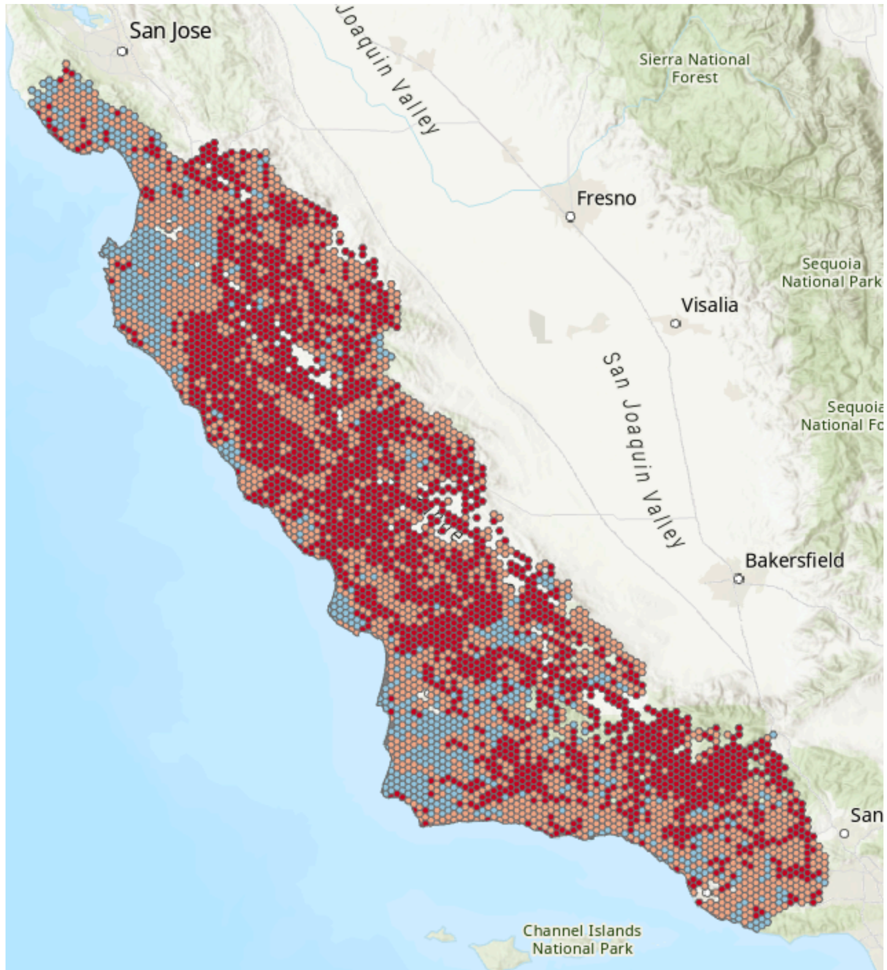


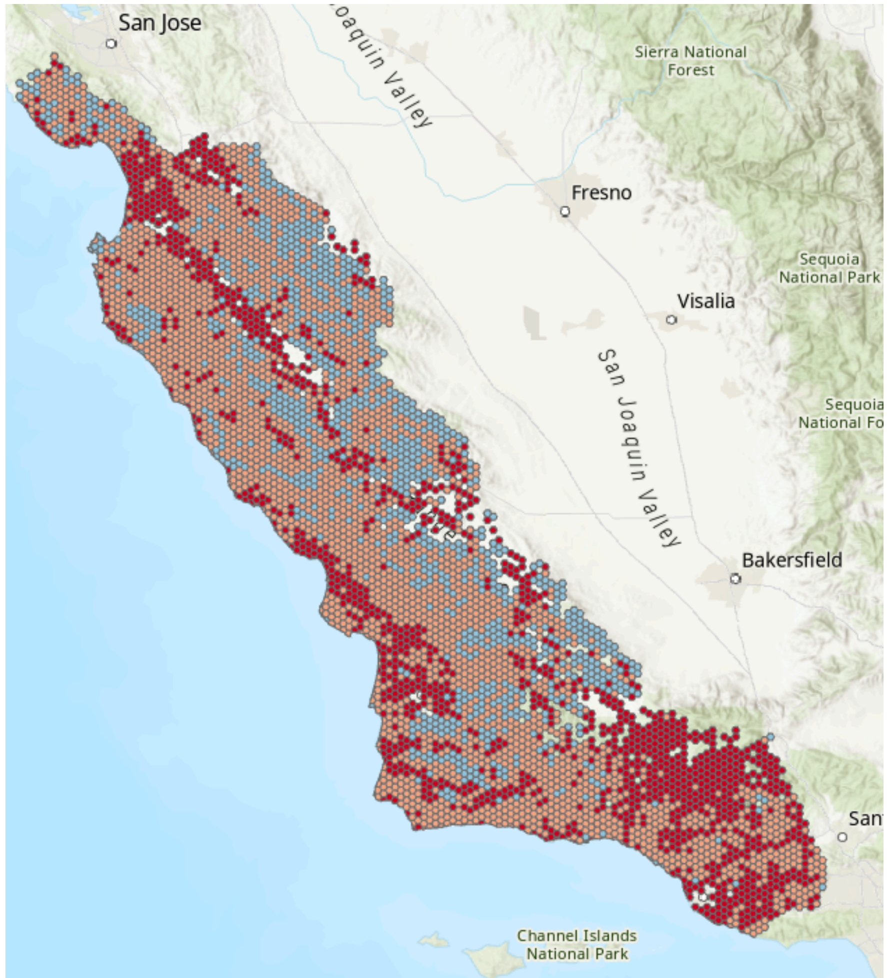
Heat-Solar Exposure

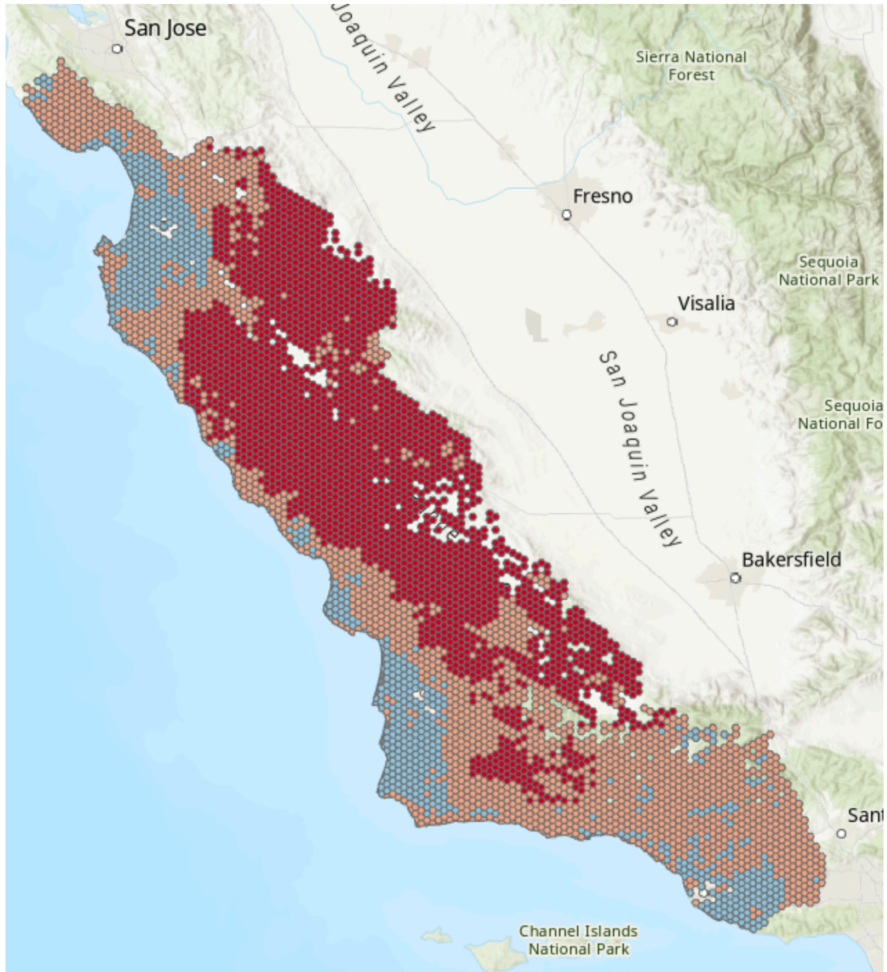


Aridification Vulnerability



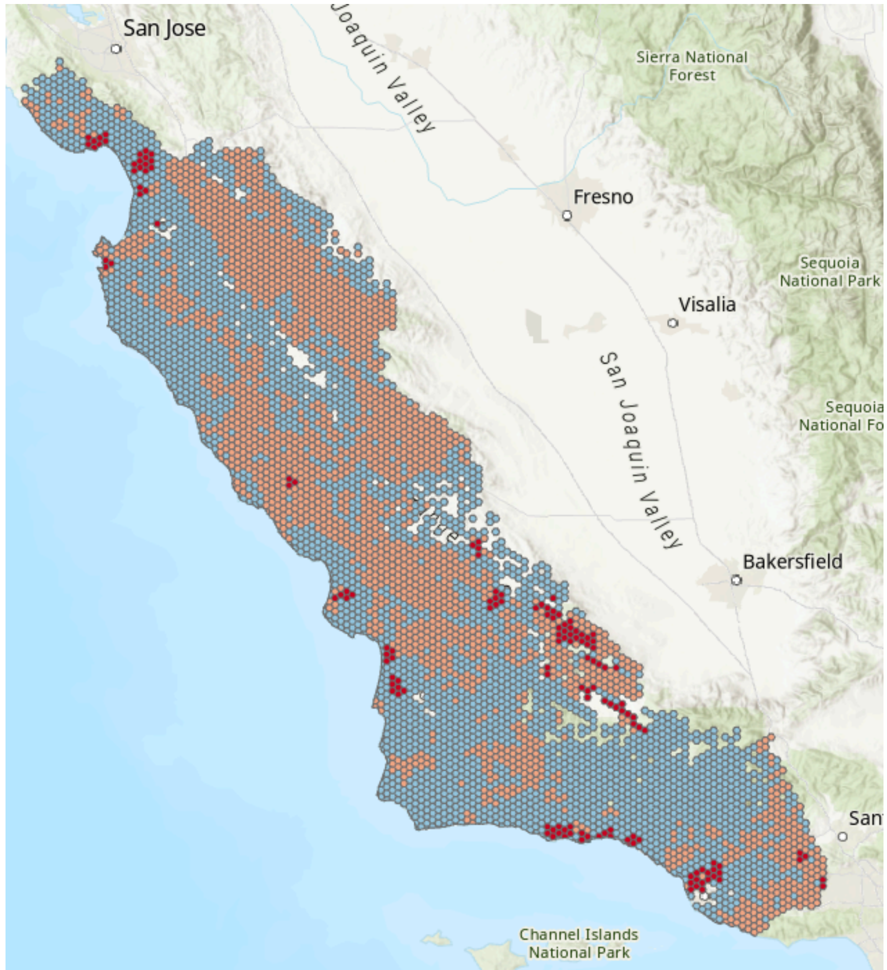


Aridification Sensitivity High Moderate Low	

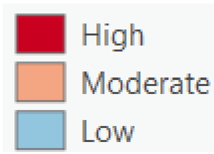
Aridification Exposure High Moderate Low	

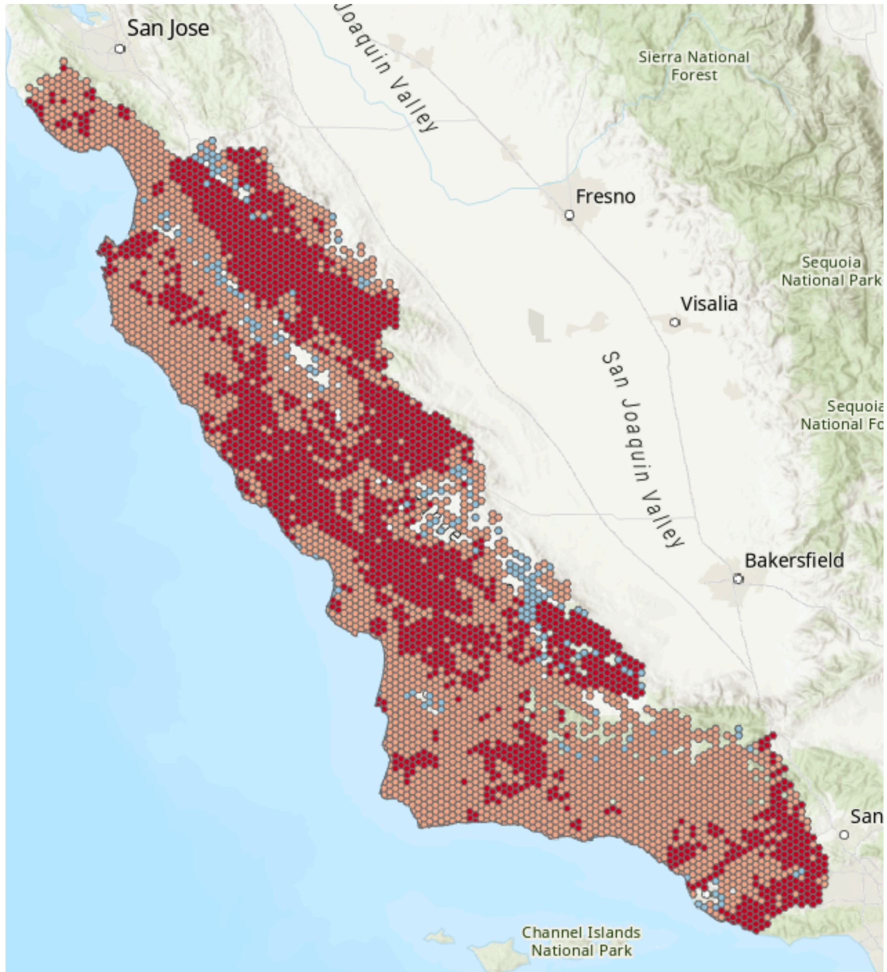
Fire Regime Change Vulnerability

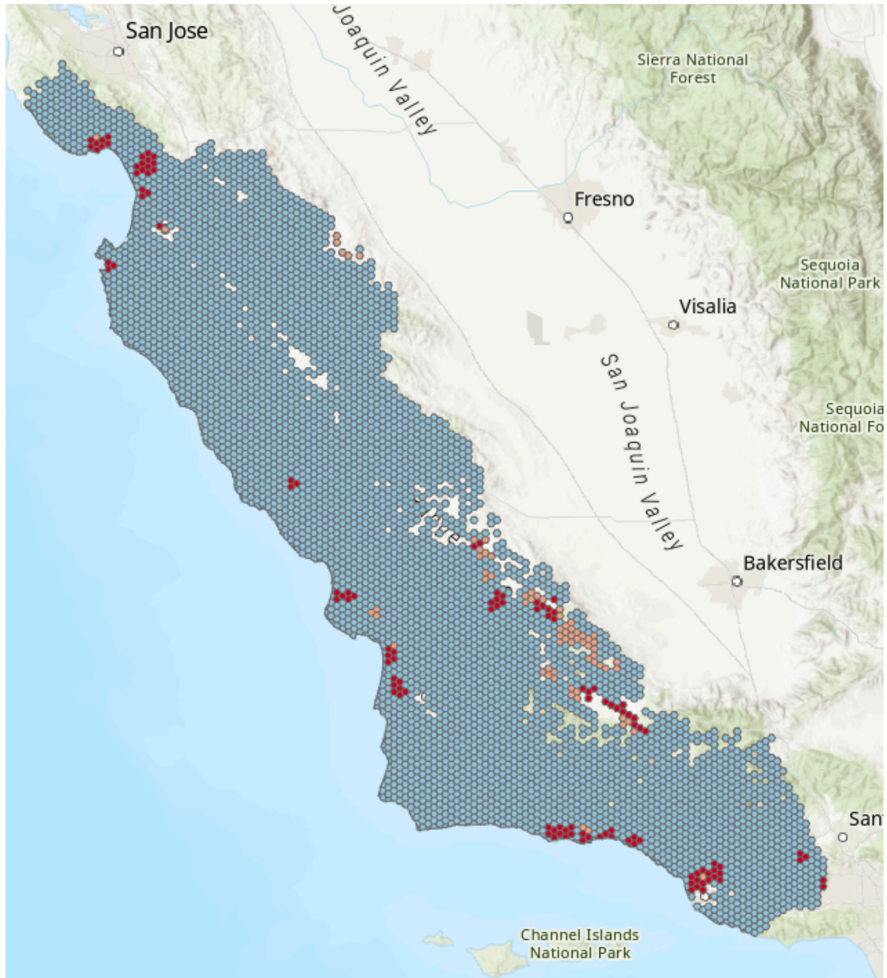
High
Moderate
Low



Fire Regime Change Sensitivity

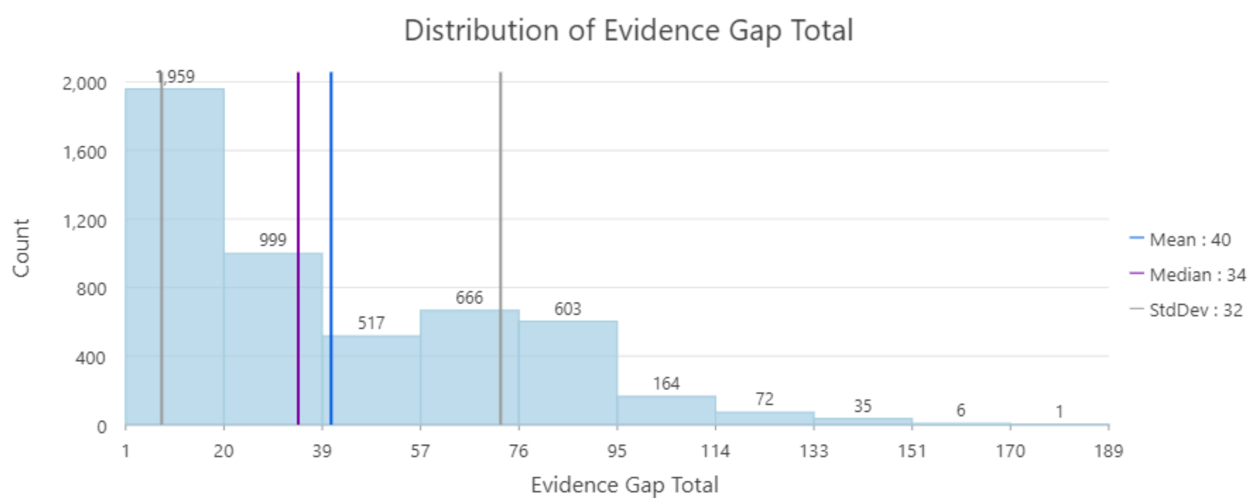




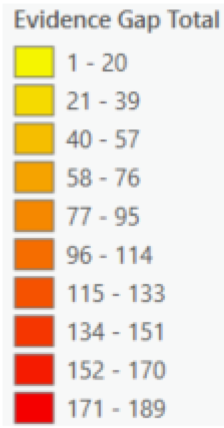
Fire Regime Change Exposure High Moderate Low	

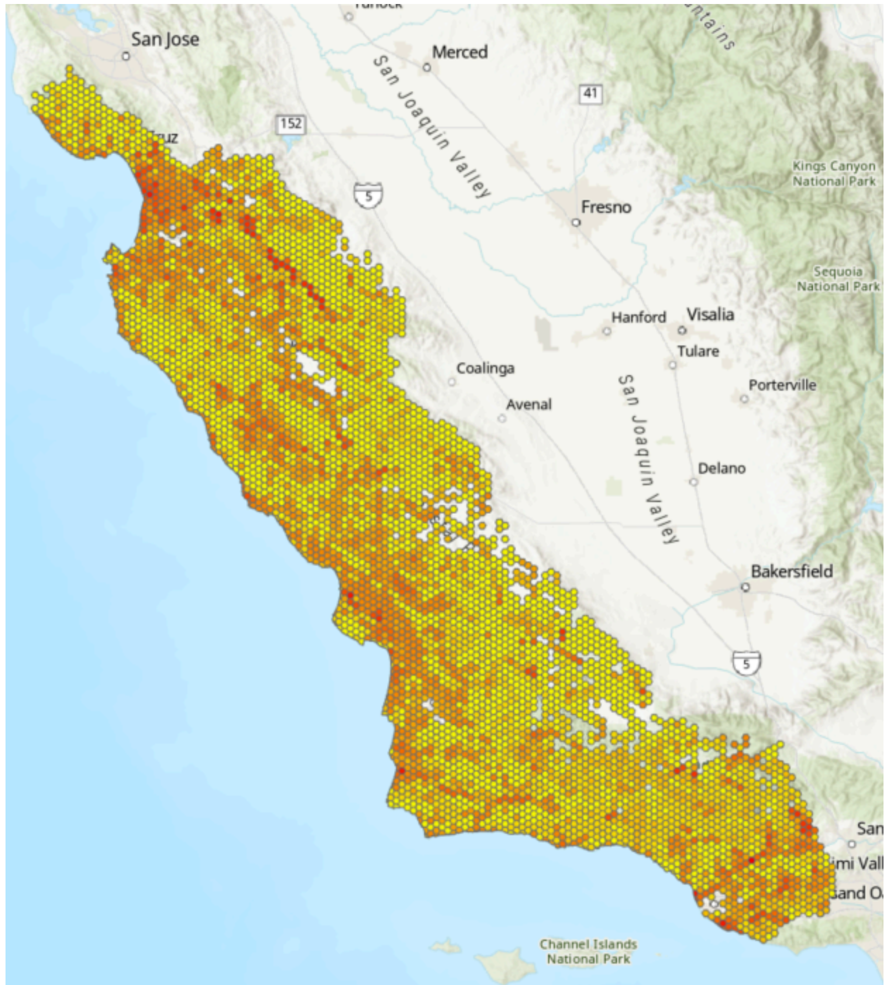
Confidence Estimation

As a proxy for confidence estimation, a method was developed to show where a low vulnerability score may be the result of little or little sensitivity data. Habitats were flagged by Cal-IPC staff that needed more evidence data in order to determine sensitivity to one or more of the exposures. These resulted in “no data” for those sensitivity scores. Thus, vulnerability scores for those hexagons were more heavily based on exposure. The number of Manual of California Vegetation alliance types that lacked sensitivity data to the exposures were summed by hexagon (see map below). For example, if a hexagon contained two (2) habitats that lacked evidence data for Aridification and four (4) habitats that lacked evidence data for Fire Regime Change, the total for that hexagon would be six (6). The mean number of evidence gaps was 40. The minimum was one, and the maximum was 189.



Total number of MCV alliances that lacked sensitivity data





Scoring Queries

Heat-Solar Exposure

- Topographic Wetness Index
- Heat Load Index

```
# Heat Load Index classification
```

```
def reclass(MEAN):
if (MEAN < 0.838025):
return "Very Low"
elif (MEAN >= 0.838025 and MEAN < 0.840822):
return "Low"
elif (MEAN >= 0.840822 and MEAN < 0.877182):
return "Moderate"
elif (MEAN >= 0.877182):
return "High"
```

```
reclass(!MEAN!)
```

```
# Heat-Solar Exposure

def myCalc(Variable1,Variable2):
if (Variable1=='Very Low')and(Variable2=='Very Low'):
return 'Moderate'
elif (Variable1=='Very Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Very Low')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='Very Low')and(Variable2=='High'):
return 'High'
elif (Variable1=='Low')and(Variable2=='Very Low'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='Low')and(Variable2=='High'):
return 'High'
elif (Variable1=='Moderate')and(Variable2=='Very Low'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'High'
elif (Variable1=='High')and(Variable2=='Very Low'):
return 'Low'
```

```
elif (Variable1=='High')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='High'):
return 'Moderate'
else:
return 'NoData'
```

```
myCalc(!TWI_Class!,!HeatLoadIndex_spp!)
```

Aridification Exposure

- Climatic Water Deficit (Field name:)
- Cloud Fraction (Field name:)

```
# Aridification Exposure

def myCalc(Variable1,Variable2):
if (Variable1=='Very Low')and(Variable2=='Very Low'):
return 'Moderate'
elif (Variable1=='Low')and(Variable2=='Very Low'):
return 'High'
elif (Variable1=='Moderate')and(Variable2=='Very Low'):
return 'High'
elif (Variable1=='High')and(Variable2=='Very Low'):
return 'High'
elif (Variable1=='Very Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Low')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'High'
elif (Variable1=='High')and(Variable2=='Low'):
return 'High'
elif (Variable1=='Very Low')and(Variable2=='Moderate'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Very Low')and(Variable2=='High'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='High'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'Low'
elif (Variable1=='High')and(Variable2=='High'):
return 'Moderate'
```

```
else:
return 'NoData'
```

```
myCalc(!CWD_CLASS!,!CF_CLASS!)
```

Wildfire Regime Change Exposure

- Change in Mean Fire Return Interval (Field name:)

```
# Vulnerability

def myCalc(Variable1,Variable2):
if (Variable1=='Low')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='Moderate'):
return 'Low'
elif (Variable1=='Low')and(Variable2=='High'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='Low'):
return 'Low'
elif (Variable1=='Moderate')and(Variable2=='Moderate'):
return 'Moderate'
elif (Variable1=='Moderate')and(Variable2=='High'):
return 'High'
elif (Variable1=='High')and(Variable2=='Low'):
return 'Moderate'
elif (Variable1=='High')and(Variable2=='Moderate'):
return 'High'
elif (Variable1=='High')and(Variable2=='High'):
return 'High'
else:
return 'NoData'
```

```
myCalc(!AridificationExposure!,!AridificationSensitivity!)
```

```
# Total scoring

def myCalc(Variable1):
if (Variable1=='High'):
return 3
elif (Variable1=='Moderate'):
return 2
elif (Variable1=='Low')
return 1
elif (Variable1=="NoData"):
return 0
else:
return 'NoData'
```

```
myCalc(!MFRI_Class!)
```

Appendix F: Rare plant raw climate vulnerability scores and components.

		Heat-Solar Vulnerability							Aridification Vulnerability								Wildfire Regime Change Vulnerability			Climate Δ
		Exposure			Sensitivity			Vulnerability	Exposure			Sensitivity				Vulnerability	Exposure	Sensitivity	Vulnerability	Vulnerability
Species	N	Topographic Wetness Index	Heat Load Index	Heat-Solar Exposure	Dispersal Distance	Seed Dormancy	Heat-Solar Sensitivity	Heat-Solar Vulnerability	Change in CWD	Cloud Fraction	Aridification Exposure	Moisture Requirement	Root Storage	Leaf Size	Sensitivity Score	Aridification Vulnerability	Exposure to Change in MFRI	Fire Depen-dency	Wildfire Regime Change	Raw CCV
Dudleya cymosa ssp. agourensis	3	Low	Moderate	High	intermediate	3-10 yr	Moderate	High	Low	Moderate	Moderate	dry	shallow	medium	6	Moderate	Low	none	Low	6
abramsiana	9	Moderate	Moderate	Moderate	limited (<5m)	limited/none	High	High	Low	High	Low	dry	deep/taproot	very small	4	Low	Low	obligate	Moderate	6
Chorizanthe parryi var. fernandina	1	Moderate	High	High	intermediate	limited/none	High	High	Low	Moderate	Moderate	dry	shallow	small	5	Moderate	Low	none	Low	6
Arctostaphylos morroensis	6	Moderate	Very Low	Low	intermediate	>10 yr	Low	Low	Moderate	High	Low	dry	deep/taproot	medium	5	Low	High	obligate	High	5
hartwegiana	18	Moderate	Moderate	Moderate	Long distance (	limited/none	Moderate	Moderate	Moderate	Moderate	Moderate	dry	shallow	very small	5	Moderate	Low	some	Low	5
Chorizanthe robusta var. hartwegii	4	Moderate	High	High	Long distance (	3-10 yr	Low	Moderate	Stable	Low	Moderate	dry	shallow	small	5	Moderate	Low	none	Low	5
Cirsium fontinale var. obispoense	22	Moderate	Very Low	Low	limited (<5m)	3-10 yr	Moderate	Low	Low	Moderate	Moderate	moist/wet	deep/taproot	very large	8	High	Low	none	Low	5
Hesperocyparis goveniana	5	Moderate	Very Low	Low	limited (<5m)	limited/none	High	Moderate	High	High	Moderate	dry	deep/taproot	very small	4	Low	Low	obligate	Moderate	5
Piperia yadonii	26	Moderate	Moderate	Moderate	Long distance (	1-3 yr	Moderate	Moderate	High	High	Moderate	dry	rhizome-bulb-t	large	4	Low	Moderate	some	Moderate	5
Astragalus brauntonii	27	Moderate	Moderate	Moderate	limited (<5m)	>10 yr	Moderate	Moderate	Low	Moderate	Moderate	dry	deep/taproot	medium	5	Moderate	Low	some	Low	5
lanosissimus	4	High	Moderate	Moderate	limited (<5m)	>10 yr	Moderate	Moderate	High	High	Moderate	vernal/mesic	deep/taproot	medium	6	Moderate	Low	none	Low	5
Caulanthus californicus	34	High	Very Low	Low	intermediate	>10 yr	Low	Low	Low	Very Low	High	dry	deep/taproot	medium	5	High	Moderate	none	Low	5
Cirsium scariosum var. loncholepis	23	High	Moderate	Moderate	Long distance (	1-3 yr	Moderate	Moderate	High	High	Moderate	vernal/mesic	deep/taproot	large	6	Moderate	Low	none	Low	5
Holocarpha macradenia	19	Moderate	Moderate	Moderate	limited (<5m)	3-10 yr	Moderate	Moderate	Moderate	High	Low	dry	deep/taproot	small	4	Low	Moderate	some	Moderate	5
Pentachaeta bellidiflora	4	Low	High	High	intermediate	3-10 yr	Moderate	High	Moderate	High	Low	dry	shallow	very small	5	Low	Low	some	Low	5
Pentachaeta lyonii	21	Moderate	Moderate	Moderate	intermediate	3-10 yr	Moderate	Moderate	Low	Moderate	Moderate	dry	shallow	small	5	Moderate	Low	none	Low	5
Arenaria paludicola	15	High	Moderate	Moderate	limited (<5m)	3-10 yr	Moderate	Moderate	High	High	Moderate	moist/wet	rhizome-bulb-t	small	5	Moderate	Low	none	Low	5
Navarretia fossalis	1	High	Moderate	Moderate	limited (<5m)	3-10 yr	Moderate	Moderate	Sm Decrs	Very Low	Moderate	vernal/mesic	deep/taproot	small	5	Moderate	Low	none	Low	5
Clarkia speciosa ssp. immaculata	27	Moderate	Moderate	Moderate	intermediate	3-10 yr	Moderate	Moderate	Low	High	Low	dry	shallow	very small	5	Low	Low	none	Low	4
Diplacus vandenbergensis	17	High	Moderate	Moderate	intermediate	3-10 yr	Moderate	Moderate	Moderate	High	Low	dry	shallow	small	5	Low	Low	none	Low	4
Dudleya verityi	8	Low	Very Low	Low	intermediate	3-10 yr	Moderate	Low	High	High	Moderate	dry	shallow	medium	6	Moderate	Low	none	Low	4
Eriodictyon altissimum	6	Moderate	Very Low	Low	intermediate	>10 yr	Low	Low	Low	High	Low	dry	rhizome-bulb-t	small	3	Low	Low	some	Moderate	4
Erysimum teretifolium	15	Moderate	Moderate	Moderate	limited (<5m)	3-10 yr	Moderate	Moderate	Moderate	Moderate	Moderate	dry	deep/taproot	small	4	Low	Low	some	Low	4
Lupinus nipomensis	3	Moderate	Moderate	Moderate	intermediate	>10 yr	Low	Low	High	High	Moderate	dry	deep/taproot	medium	5	Moderate	Moderate	none	Low	4
Polygonum hickmanii	3	Moderate	Moderate	Moderate	intermediate	3-10 yr	Moderate	Moderate	Low	Low	Moderate	dry	rhizome-bulb-t	very small	3	Low	Low	none	Low	4
Astragalus tener var. titi	1	High	Moderate	Moderate	intermediate	>10 yr	Low	Low	High	High	Moderate	vernal/mesic	deep/taproot	small	5	Moderate	Low	none	Low	4
Eremalche parryi ssp. kernensis	100	High	Moderate	Moderate	intermediate	3-10 yr	Moderate	Moderate	Stable	Very Low	Moderate	dry	deep/taproot	small	4	Low	High	none	Low	4
Erysimum menziesii	9	High	Moderate	Moderate	intermediate	1-3 yr	Moderate	Moderate	High	High	Moderate	dry	deep/taproot	small	4	Low	Low	none	Low	4
Lasthenia conjugens	4	High	Very Low	Low	limited (<5m)	3-10 yr	Moderate	Low	High	High	Moderate	vernal/mesic	shallow	small	6	Moderate	High	none	Low	4
Layia carnosa	8	High	Moderate	Moderate	Long distance (	3-10 yr	Low	Low	High	High	Moderate	dry	shallow	very small	5	Moderate	Low	none	Low	4
Lupinus tidestromii	7	High	Moderate	Moderate	limited (<5m)	>10 yr	Moderate	Moderate	Moderate	High	Low	dry	deep/taproot	medium	5	Low	Low	none	Low	4
Potentilla hickmanii	2	High	Low	Low	limited (<5m)	3-10 yr	Moderate	Low	High	High	Moderate	vernal/mesic	deep/taproot	medium	6	Moderate	Low	none	Low	4
Thysanocarpus conchuliferus	3	Very Low	Very Low	Moderate	limited (<5m)	3-10 yr	Moderate	Moderate	Sm Decrs	High	Low	dry	rhizome-bulb-t	small	3	Low	Low	none	Low	4
Chloropyron maritimum ssp. maritimum	13	High	Very Low	Low	Long distance (	3-10 yr	Low	Low	Low	High	Low	moist/wet	shallow	very small	7	Moderate	Low	none	Low	4
Nasturtium gambelii	9	High	Moderate	Moderate	intermediate	3-10 yr	Moderate	Moderate	Moderate	High	Low	moist/wet	rhizome-bulb-t	medium	6	Low	Moderate	none	Low	4
Orcuttia californica	3	High	Low	Low	limited (<5m)	3-10 yr	Moderate	Low	Low	Moderate	Moderate	vernal/mesic	shallow	small	6	Moderate	Low	none	Low	4
Camissonia benitensis	50	Moderate	Moderate	Moderate	Long distance (	>10 yr	Low	Low	Stable	Very Low	Moderate	dry	deep/taproot	very small	4	Low	Low	none	Low	3
Chlorogalum purpureum var. purpureum	26	High	Low	Low	limited (<5m)	3-10 yr	Moderate	Low	Sm Decrs	Very Low	Moderate	dry	rhizome-bulb-t	medium	4	Low	Low	none	Low	3
Chlorogalum purpureum var. reductum	4	Moderate	Very Low	Low	limited (<5m)	3-10 yr	Moderate	Low	Sm Decrs	Very Low	Moderate	dry	rhizome-bulb-t	medium	4	Low	Low	none	Low	3
Deinandra increscens ssp. villosa	29	Moderate	Moderate	Moderate	Long distance (	3-10 yr	Low	Low	Low	High	Low	dry	shallow	small	5	Low	Low	none	Low	3
Dudleya cymosa ssp. marcescens	5	Moderate	Very Low	Low	Long distance (	>10 yr	Low	Low	Low	High	Low	dry	shallow	medium	6	Low	Low	none	Low	3
Dudleya parva	13	Low	Very Low	Low	intermediate	3-10 yr	Moderate	Low	High	Moderate	Moderate	dry	rhizome-bulb-t	medium	4	Low	Low	none	Low	3
Eriodictyon capitatum	8	High	Moderate	Moderate	intermediate	>10 yr	Low	Low	High	High	Moderate	dry	rhizome-bulb-t	small	3	Low	Low	some	Low	3
Gilia tenuiflora ssp. arenaria	29	Moderate	Moderate	Moderate	Long distance (	>10 yr	Low	Low	Moderate	High	Low	dry	deep/taproot	small	4	Low	High	some	Low	3
Chorizanthe pungens var. pungens	51	High	Moderate	Moderate	Long distance (	3-10 yr	Low	Low	Moderate	High	Low	dry	shallow	very small	5	Low	High	none	Low	3
Chorizanthe robusta var. robusta	15	Moderate	Moderate	Moderate	Long distance (	3-10 yr	Low	Low	Moderate	High	Low	dry	shallow	small	5	Low	High	none	Low	3
Monolopia congdonii	29	High	Low	Low	intermediate	3-10 yr	Moderate	Low	Stable	Very Low	Moderate	dry	deep/taproot	small	4	Low	Moderate	none	Low	3
Suaeda californica	8	High	Moderate	Moderate	Long distance (	3-10 yr	Low	Low	Sm Decrs	High	Low	moist/wet	rhizome-bulb-t	very small	5	Low	Low	none	Low	3
Trifolium trichocalyx	2	Moderate	Very Low	Low	intermediate	>10 yr	Low	Low	High	High	Moderate	vernal/mesic	rhizome-bulb-t	small	4	Low	Low	some	Low	3