Protecting Rare Plants from Invasive Plants: Risk Assessment and Habitat Enhancement for Federally Listed Plants In the Central Coast Region of California

California Invasive Plant Council
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Camatta Canyon amole with flower-visiting bee and Festuca *in background. Photo: J. Burger*

Final Report for CDFW Grant Agreement Q1982003

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Executive Summary

This project seeks to strengthen our collective ability to protect rare native plant species in the central coast region of California. Currently, 50 rare plant species federally listed as either threatened or endangered occur within the central coast region encompassing Santa Cruz, Monterey, San Benito, San Luis Obispo, Santa Barbara, and Ventura counties. With rapid development and population growth along the state's coast, habitat that has not already been protected is becoming increasingly difficult to secure for species conservation. As a result, land managers and agencies are broadening their attention to management actions that can address other threats to listed plants beyond the threat of development. One of the top threats is invasive plants.

Competition from invasive plants is considered a primary threat 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 detailed spatial or cross-species analyses of the threats from invasive species, yet this information is critical when prioritizing management actions to protect rare plant species. Furthermore, land managers who directly manage lands where listed species occur are rarely provided with 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; (2) compiling existing listed plant data that included information on invasive species; and (3) calculating an Invasive Plant Risk Score (IPRS) for populations of all 50 federally listed plant species that occur within the central coast region of California at multiple scales—by population, by species, and by USGS quarter quadrangle. The resulting risk evaluation and geodatabase allows for a comparison of the risk posed by invasive plants across area, species, and populations.

Our risk analysis categorized a total of 17 of the 50 rare plant species as being at the highest risk of facing impacts from invasive plant species and 13 rare plant species categorized as being at moderate risk. Invasive plant impacts appeared to be higher for coastal populations of rare plants than those for populations that occurred inland, though this geographic pattern may be partly explained by the greater attention that coastal populations receive. The invasive species most frequently listed as co-occurring with rare plants and potentially impacting them were invasive annual grasses (including *Bromus* spp., *Avena* spp., *Festuca* spp., and others), iceplants (*Carpobrotus* spp. and *Mesembryanthemum* spp.), and perennial veldt grass (*Ehrharta calycina*).

To complement the risk assessment for 50 species, Cal-IPC and Santa Barbara Botanic Garden (SBBG) conducted field studies on co-occurrence and potential impacts of invasive plants on three of the listed species suspected to be negatively affected by invasives: Pismo Clarkia (*Clarkia speciosa* ssp. *immaculata*), Gaviota tarplant (*Deinandra increscens* ssp*. villosa*), and Camatta Canyon amole (*Hooveria purpurea* var. *reducta*). We conducted annual field surveys to record plot-level percent cover of all co-occurring plants along with the listed species' plant density, reproductive output, and other site conditions. Three plots were located at each of three locations for each species (n = 9 plots/species) and surveyed over four years. During site visits, SBBG collected seed for conservation seed banking and seed viability and germination tests. Additional voucher specimens and plant tissue were also collected, when possible, to facilitate possible future genetics work.

Each of these three rare plant species were potentially affected by invasive species based on correlations in plant cover, abundance, thatch cover, and reproductive output, though in different ways. Pismo Clarkia density was negatively correlated with annual non-native grasses and the thatch they produced, though thatch alone could have had an ameliorating effect on plants that were able to emerge through it. The combination of thatch, annual non-native grasses, iceplant, and perennial veldt grass was strongly negatively correlated with Gaviota tarplant density. The relationship was less strong with reproductive output, suggesting a complex relationship between site conditions and plant performance. Camatta Canyon amole appeared overall least affected by non-native vegetation, however correlations with invasive plants were still negative. Patterns were more difficult to decipher because of this species' perennial growth habit and the exceptionally dry site conditions that appeared to impact its performance in all but the final year of monitoring.

The information produced 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 invasive plant species are most impactful to rare plant species.

Task 1. Project Management and Administration

Cal-IPC administered Grant Agreement Q1982003 as Grantee, submitting invoices and quarterly reports for Q2 - Q4 of 2020, Q1 - Q4 of 2021 and 2022, and Q1 - Q2 of 2023. Each quarterly report included expenses incurred, in kind contributions, and supporting documentation for work completed. Cal-IPC received a grant extension from its original grant end date of December 31, 2022, to September 30, 2023, in late 2022. The grant extension was requested because a delayed start date (March 2020) and pandemic restrictions did not allow for field monitoring of all sites in Year 1 and Camatta Canyon amole seed collection and germination tests could not be completed until 2023.

The match commitment for grant agreement Q1982003 was $76,125. In total, $112,676 was provided. This match achieved is 52% of the grant contract ($217,375), well above the amount committed (Table 1). Santa Barbara Botanic Garden (SBBG) served as Cal-IPC's project partner and subcontractor for seed and tissue collection and seed viability analysis. They provided additional assistance during field surveys and with reviewing risk scores and character matrices.

Table 1. Grant match commitment and final status.

Source	Match Commitment	2023 Q3	Total Provided
Cal-IPC - TOTAL	**$17,334**	**$1,000**	**$17,650**
Indirect	$12,414	[not included]	$3,759
Travel			$2,560
Benefits			$46
staff time	$4,320		$7,165
Volunteer/specialist time	$600		$3,120
Other (mini-grant to SBBG)		$1000	$1,000
SBBG – TOTAL	**$51,621**	**$42,499**	**$87,487.30**
Indirect	$4,693	$3,864	$7,457
Travel	$2,800		$673
Benefits		$8,452	$16,448
staff time	$28,928	$30,184	$58,744
volunteer time	$15,000		$3,870
equipment/supplies	$200		$306
Cal Bot Garden – TOTAL	**$7,170**		**$6,058**
staff time			$6,000
Mileage			$58
Other Botanist In-Kind			**$1,480**
Grand Total	**$76,125**	**$43,499**	**$112,676**

Subtask 1.1 – Data Management

Cal-IPC is submitting the following as deliverables in compliance with its Data Management Plan:

- An invasive plant risk index for 50 federally listed species in the study region based on an overlay of rare plant distribution data (submitted as Excel files for location records, for species scores, and for plant characteristics);
- A regional spatial risk map for the central coast region (submitted as a shapefile to complement the map provided in the report);
- Updated status information for three populations of each of three federally listed species (submitted in this report);
- Monitoring data for target populations being monitored (submitted as an Excel file);
- All additional location-specific monitoring data used to further inform risk index (included in Excel file described in first bullet).

Quality assurance and quality control (QA/QC) were ensured by the following protocols:

1. Risk assessment scores
    - Experts were consulted for information on specific rare plant populations. We presented experts with maps of the populations labeled by their ObjectID code for reference. Expert data collected for populations was logged and tracked so that input information can be linked to each source.
    - California Plant Rescue (CaPR) records consolidated within California Natural Diversity Database (CNDDB) records were tracked using their unique Element Occurrence Index (EOndx) codes. We also checked the California Consortium of Herbaria (CCH2) for rare plant records that were not already represented by other datasets
    - Source input for geospatial data was tracked (CNDDB, CaPR, CCH2).
    - CNDDB data was updated periodically. When we downloaded updated CNDDB data, we cross-checked our data to ensure it matched and to compare and track updates from the previous data.
    - Large populations that spanned miles were considered “extirpated” in order to prevent inflating quarter quad averages.
    - Multiple sources were used to score parameters when possible. For example, we supplemented using the intersection of buffered roads and populations polygons with manual checks of satellite imagery to confirm there were no roads within 30 meters of the population. We also used both a USGS ultramafic shapefile compiled with CNDDB notes and expert opinion for any reference to serpentine soils (Horton 2017).
    - Final species-level scores and plant character matrices were reviewed internally as well as by collaborators that work on rare plants (Dr. Heather Schneider, SBBG; Dr. Naomi Fraga, CBG; and Dr. Marina LaForgia, UC Davis).
2. Field surveys
    - Field plots were semi-permanently marked with magnails and markers and photo documented to ensure that surveys were being conducted at the same location every year.
    - Field surveys of *D. increscens* ssp. *villosa* began in 2020 with a site visit to a population of *D. increscens* ssp. *increscens* to clarify subspecific differences.

  - Plants were temporarily marked in order to maintain accurate plant counts.
  - Plants, though many were senescent, were identified by distinctive character traits by an experienced botanist (J. Burger) and crosschecked across other botanists when needed (H. Schneider and S. Carson, SBBG; J. Yost, Cal Poly SLO; Steve Junak, SBBG, retired). Some species were keyed on site using the Jepson Manual. A running species list was maintained by plot to verify presence of species across years.
  - Data entry was checked internally.

3. Plant and seed collection
   - All seed and plant material collection was conducted by experienced, permitted professionals from SBBG.
   - Inflorescences of *H. purpurea* var. *reducta* were tagged to facilitate identification when senesced.

Task 2 – Complete an Invasive Plant Risk Index

Subtask 2.1 - 2.2 – Develop a Regional Assessment of Invasive Plant Threat with Site-Specific Data

Site-Specific Data

Cal-IPC compiled available population-level data for the 50 rare species in the California central coast region (including Santa Cruz, Monterey, San Benito, San Luis Obispo, Santa Barbara, and Ventura County, excluding the Channel Islands). California Natural Diversity Database (CNDDB) spatial data for all federally listed species were initially downloaded in 2020 and again in April 2023 (CDFW 2023). 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 subsequently 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). Any overlapping EOndx (element occurrence) codes or other ID fields are referenced in 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 (when longitude or latitude coordinates were missing tenths, hundredths, or thousandths digits we used an error radius of 11,111 meters, 1,111 meters, or 111 meters, respectively). We subsequently consolidated overlapping CaPR records or records with shared EOndx codes. 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 also 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 invasive perceived impact data 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 reached out to 24 local botanists that had expertise with the listed species being studied. (Those botanists that responded to our inquiry but were not able to provide relevant data are not included here.) If there were any discrepancies between experts' information, reports of invasive threat outweighed those of no threat.

Population-level invasive plant co-occurrences were also 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 below.

Species-Specific Data

Species-level threat was assessed independent 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 plant characteristics and ecological affinities of the 50 species studied by creating a detailed matrix of plant characteristics for the 50 species to see if we could associate certain plant traits with vulnerability to invasive plants (see Appendix 1). A total of 17 plant characteristics and five ecological parameters (including level of endemism, fire vulnerability, and habitat specificity) were scored for each species to better understand their role in determining vulnerability to impacts from invasive plants. Collaborator Dr. Marina LaForgia assisted with a multivariate analysis of plant character traits and invasive plant risk. Overall, we were not able to establish significant correlations between plant character traits and current (USFWS and expert knowledge-based) perceived invasive plant risk (data not shown), though the resulting matrix is a valuable comparison of rare plant characteristics and habitat associations and has proven useful in subsequent work. We did include two plant character traits, seed dormancy and perennial underground root storage, in our IPRS schema as modifiers (See Subtask 2.5). Both showed slight negative correlation with high vulnerability to perceived invasive plant risk.

Extinction by hybridization poses a unique potential risk for rare plants by invasive (or other) plants. Collaborator Dr. Naomi Fraga from CBG provided input regarding the importance of hybridization as a significant risk to some species and populations. In our study region, only one species, *Nasturtium gambelii*, is known to be impacted by hybridization with a putative non-native (*Nasturtium officinale*). It was scored accordingly as being impacted.

Geospatial Associations

Additional geospatial data layers were utilized to calculate an IPRS for each 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 scored regardless of their "presence" status (i.e., including records noted as "extirpated", "likely extirpated", or "presumed extant"). 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.

Subtask 2.3 – Develop Priority Invasive Species List for Rare Plants

The most frequently listed invasive plants reported for the subset of 457 rare plant populations with co-occurring species information were: annual grasses (multiple species lumped, including *Bromus* spp., *Avena* spp., *Festuca/Vulpia* spp., *Hordeum* spp., *Briza* spp., and *Gastridium* spp. and references to "annual grasses"), iceplant (including *Carpobrotus* spp. and *Mesembryanthemum* spp.), and *Ehrharta calycina* (Table 2). Annual non-native grasses, *Ehrharta calycina,* and *Carpobrotus edulis* also occurred in survey plots for the three focal rare species being monitored as part of this study (see Task 3).

Invasive annual grasses in dry climates – and *Bromus* spp. in particular – leave behind persistent thatch that can suppress seed germination (Molinari and D'Antonio 2020). These species are also aggressive competitors for water, nutrients, and light. *Carpobrotus* spp. and other invasive members of the Crassulaceae can change soil pH and crowd out germinating plants by covering soil surfaces (see Conser and Conner, 2009). *Ehrharta calycina* has been shown to both leave behind persistent thatch and compete strongly with established vegetation in deeper soil horizons (Phillips et al., 2019).

Table 2. The ten most frequently listed non-native plant taxa / categories in rare plant records for populations that were considered threatened by invasive species.

Non-native Genus / Category	**# Co-occurrences at a rare plant population threatened by invasives**
Bromus	71
Iceplants	66
Non-native annual grasses (unspecified)	61
Ehrharta	44

Non-native species (unspecified)	44
Erodium	29
Avena	25
Centaurea	22
Brassica	17
Ammophila	14

"*Erodium*" (including, most commonly *Erodium botrys*) was not included as one of the top species that posed a direct threat in our analysis because it does not leave behind persistent thatch and is highly correlated (confounded) with non-native annual grass cover. Several other species known to be problematic but not scored as primary threats were listed among the top 10 species. *Centaurea* (both *C. solstitialis* and *C. melitensis*) are problematic late spring and summer annuals that have known impacts on establishment of surrounding vegetation. *Brassica* species (primarily *Brassica nigra* and *Brassica geniculata,* aka *Hirschfeldia incana*) overtop other vegetation, compete with native plant seedlings, and do not support diverse mycorrhizal communities. European beach grass (*Ammophila arenaria*) is a perennial grass that is infamous for stabilizing sand dune habitats into which it was introduced, to the detriment of native plants.

Our data collection efforts focused on collating information on current threats from co-occurring invasive plants; therefore, effects of climate change or future invasions were not incorporated into this analysis. There are, however, new invasive plant species extending into the central coast region of California that should be recorded and managed when observed. Future invaders that have already entered the region and threaten to expand include: *Dittrichia graveolens* (stinkwort)*, Brassica tournefortii* (Saharan mustard)*, and Oncosiphon pilulifer* (stinknet). *Urospermum picroides* (prickly goldenfleece) is also a potential threat and has already begun to expand into rare plant habitat from roadsides along which it has spread from initial first records in Santa Barbara County. However, it is unclear how significant its impact could be. Over the course of this project, two other non-native species that inhabit sensitive coastal dune habitat were evaluated by Cal-IPC for their risk of invasiveness: *Senecio elegans* (red-purple ragwort) and *Pancratium maritimum* (sea daffodil). *Senecio elegans* was given a high-risk rating. Special attention should be paid to these species because of their occurrence in sensitive dune habitats.

Subtask 2.4 – Overlay Federally Listed Plants and State Wildlife Action Plan (SWAP) Habitat Types

The California State Wildlife Action Plan (SWAP) examines the health of wildlife and prescribes actions to conserve wildlife and vital habitat. Areas of Conservation Emphasis (ACE) is a CDFW effort to gather spatial data on wildlife, vegetation, and habitats from across the state as part of the SWAP.

The ACE terrestrial significant habitats data summarize the number of significant habitat categories within a 2.5-mile hexagon grid (CDFW 2017a). The significant habitat categories included rare or sensitive vegetation types, such as oak woodland habitat, riparian habitat, saline wetlands habitat, and several types of freshwater wetlands habitats. The SWAP layer was overlaid with the central coast rare plant populations coded by their Invasive Plant Risk Score (see Subtask 2.5, Figure 1). The number of significant habitat categories within each hexagonal grid cell is represented by SWAP

Terrestrial Habitat rank, with the darker blue hexagons representing those habitats of higher habitat value and higher conservation need.

Subtask 2.5 – Develop Risk Scores for Rare Plant Locations

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 in Subtasks 2.1-2.4. The scoring system 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.

See Appendix 2 for a detailed scoring guide. Each population in our database was given an IPRS, calculated by adding up points across the eight components and two modifiers listed here. The geodatabase submitted as part of this project includes population-level scores for each factor as well as the population-level IPRS.

We used equal intervals of average IPRS to set the ranges for risk categories: “high” risk for scores above 7.5, “medium” 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. “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).

A number of 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). Individual population risk scores were therefore lower for these populations . We developed a confidence score to better identify where data were lacking (see below).

Population-level scores were averaged by USGS 7.5' quarter quad to compare invasive plant risk spatially across the central coast region. Results were plotted as a heat map for the region using the same ranges described above. They are presented in maps both in context of the number of populations in each quarter quad and of the confidence score within that quarter quad.

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.

In order to identify where risk scores should be treated with caution because data were lacking, we constructed 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 so that confidence could be averaged for a species or USGS quarter quad. See Appendix 3 for the confidence scoring guide.

Table 3. Population-level confidence score description.

Confidence	Value	Description
Low	1	No CNDDB or supplemental expert data describing invasives.
Moderate	2	One source of data describing invasive threats (CNDDB or expert).
High	3	Both CNDDB and expert data or more than one expert source.

Invasive Plant Risk Score (IPRS) Results by Population

A total of 752 rare plant populations were scored for invasive plant risk in the compiled dataset. Of these, 718 were considered extant (not extirpated) and used in this analysis. A total of 457 populations had some information on co-occurring invasives and 229 had invasive plants specifically identified as a threat to the population.

A total of 100 populations (97 extant) were classified as at "high" risk, 166 (160 extant) populations were "moderate", 290 (277 extant) were "moderate-low" and 196 (184 extant) were "low" (Figure 1). Populations that appeared to be at especially high risk were those occurring along the coast in coastal dune habitat, coastal bluff habitat, and associated coastal scrub habitat. A few populations further inland, such as in the vicinity of Fort Hunter Liggett, were an exception, also scoring higher for being at risk from invasive plants. Rare plant populations were also loosely associated with SWAP sensitive habitat (Figure 2), although invasive plant risk in relation specifically to habitat was not researched further as part of this study and SWAP habitat was not included in our IPRS schema.

Population-level risk scores tended to be lower if data were lacking, but score confidence also dropped with lack of data. Conversely, confidence ratings were higher for species under active management for invasive plants (e.g., *Lupinus nipomensis*). Note also that population-level scores of rare species varied by location and suggested that populations within species differ substantially in their current vulnerability to invasive plant impacts (see maps for focal species below and geodatabase submitted to CDFW for population-level scores). Furthermore, land managers and agencies can refer to the submitted geodatabase to identify specific populations with low confidence levels that should be studied further.

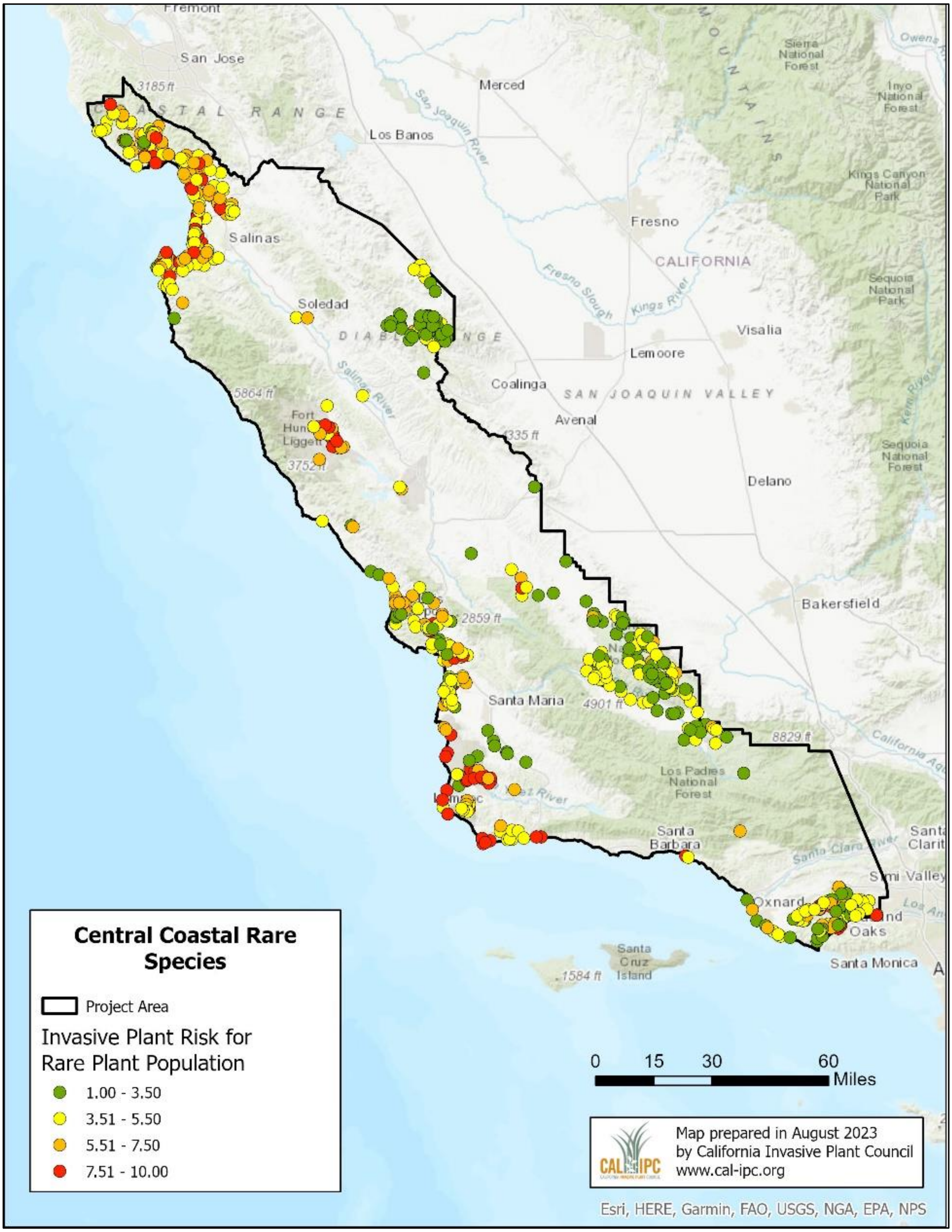

Figure 1. Central coast rare plant populations color-coded by their Invasive Plant Risk Score. A higher Invasive Plant Risk Score represents a higher risk from invasive plant impacts.

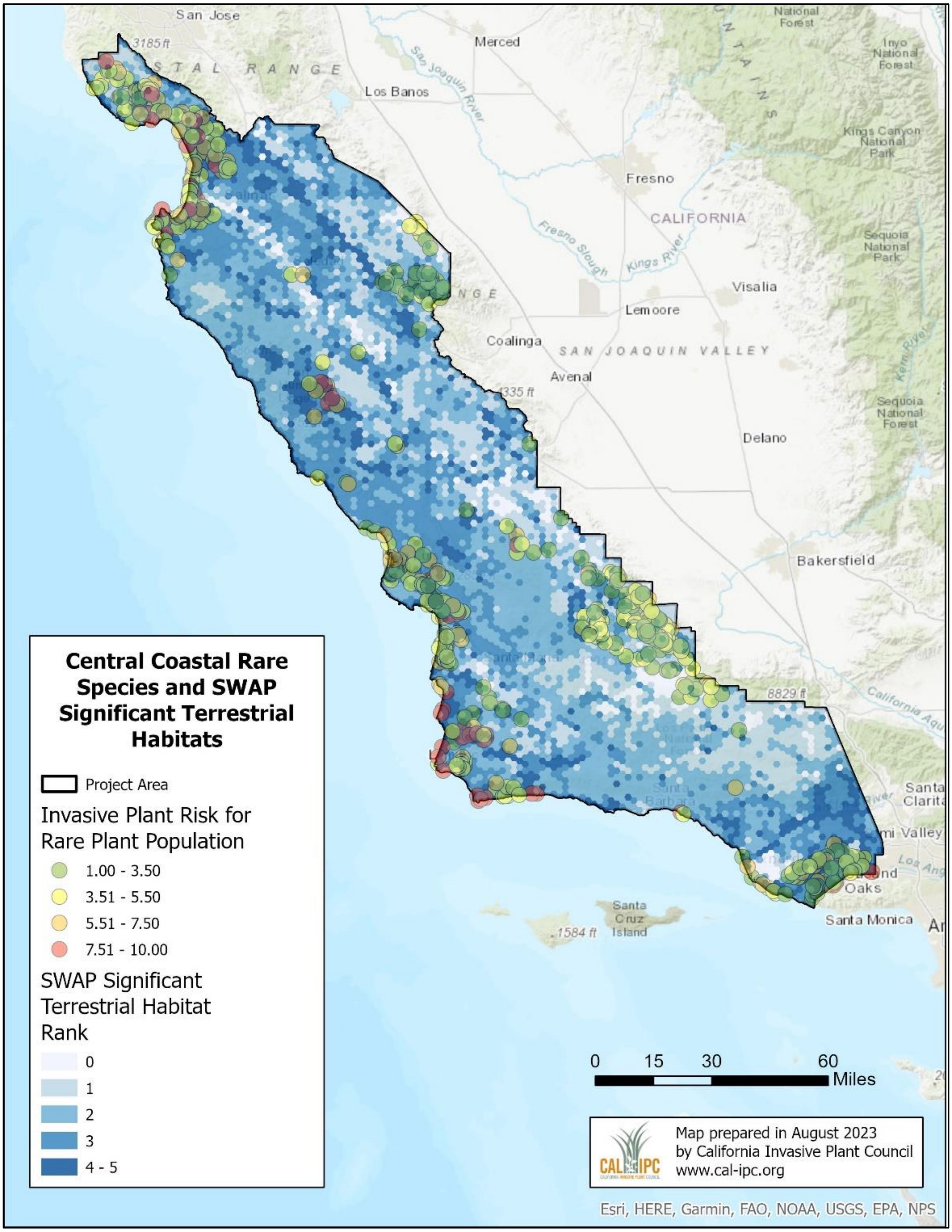

Figure 2. Central coast rare plant populations overlaid on the State Wildlife Action Plan (SWAP) Terrestrial Significant Habitats layer, which represents the number of significant habitats within each 2.5-mile hexagonal grid cell (CDFW 2017a).

Invasive Plant Risk Score (IPRS) Results by Quarter Quad

IPRS averaged by quarter quad also showed a distinct pattern of higher risk occurring closer to the coast (Figure 3). This pattern is likely the result of higher human population density, roads, and, consequently, invasive plant cover in these regions. It may, however, also be exaggerated by sampling bias and more active management occurring along the coast as compared to inland areas. Average quarter quad scores based on a small number of populations also tended to score lower than those represented by a higher number of populations, which could either be the result of a lower level of botanist attention or a more resilient species or habitat (Figure 4).

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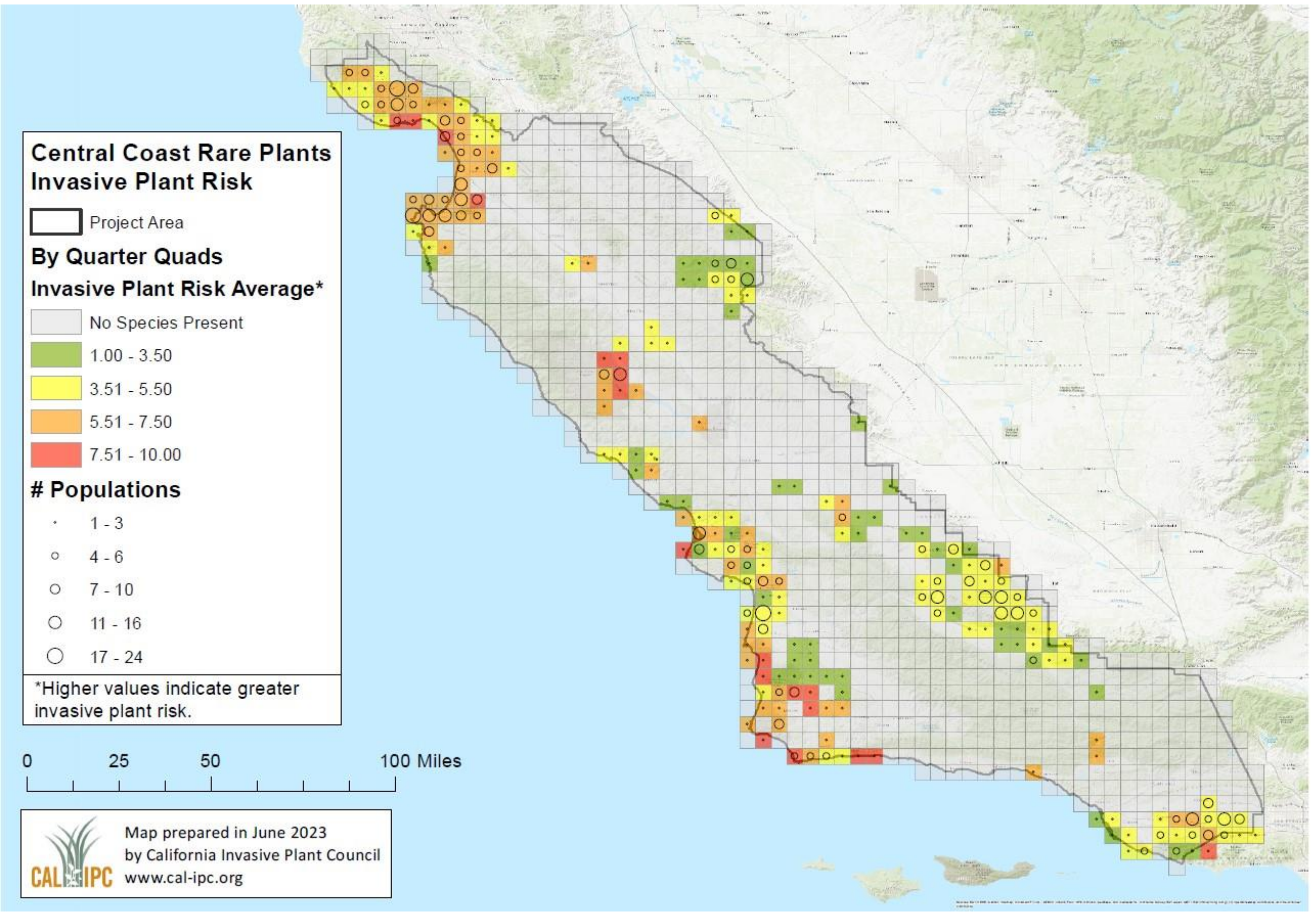


Figure 4. Invasive Plant Risk Score averaged for all rare plant populations within each quarter quad, with overlay of the number of rare plant populations present in each quarter quad.

Confidence scores averaged across populations by quarter quad helped to identify areas where more on-the-ground information about invasive plant co-occurrence and impacts is needed (Figure 5). Inland populations, especially those occurring in the Southern Coast and Transverse Ranges, appear to be poorly studied with regard to invasive plant impacts to rare plants. Land managers and agencies should refer to population-specific confidence scores to identify those populations that are most in need of additional invasive plant risk research or survey effort.

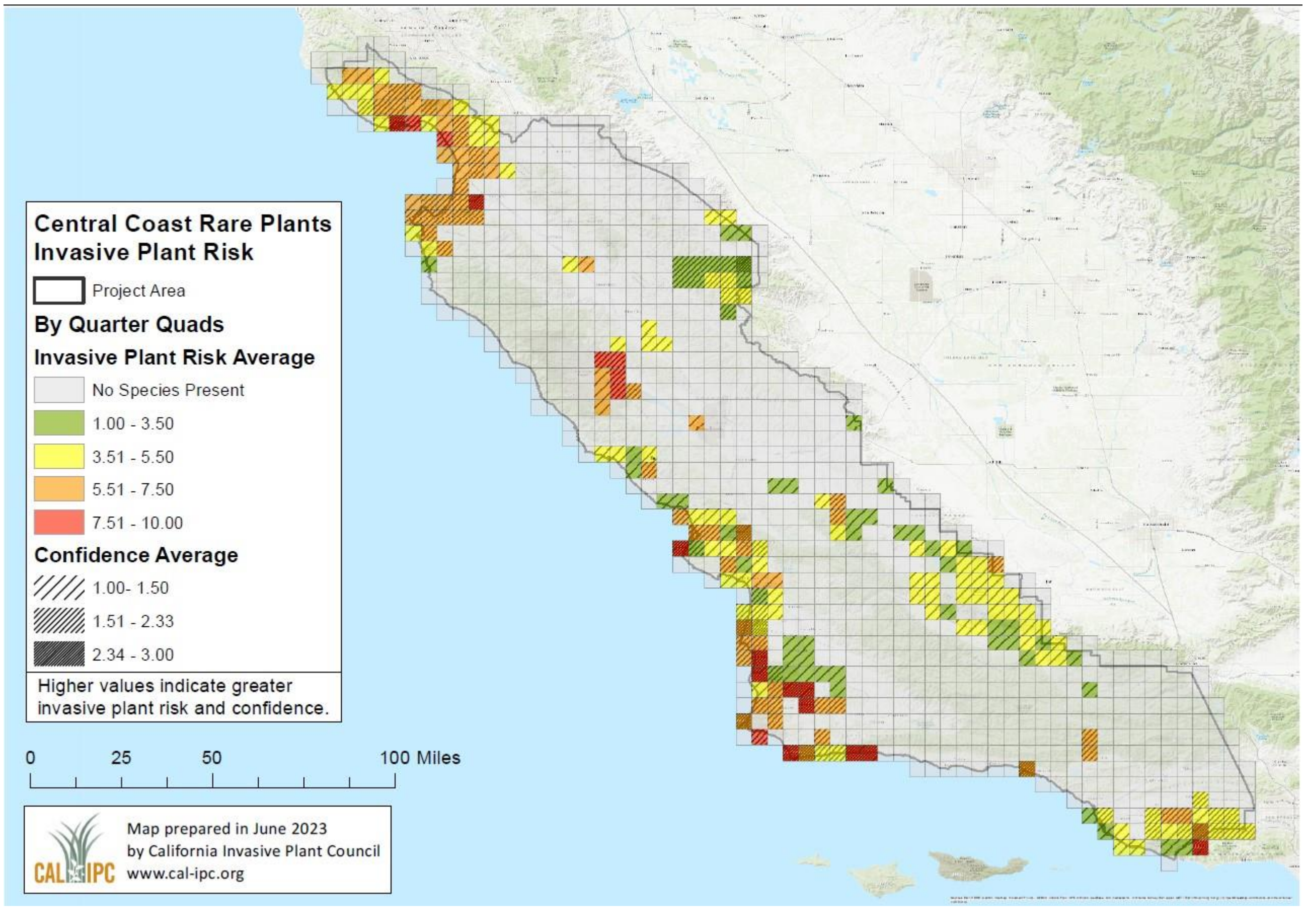


Figure 5. Invasive Plant Risk Score and confidence levels averaged by quarter quad.

Invasive Plant Risk Score (IPRS) Results by Species

We derived species-level Invasive Plant Risk Scores by averaging each score component across all populations of the species and summing them. This resulted in a total of 17 species being considered “high” risk, 23 species “moderate” risk, five species “moderate-low” risk, and five species “low” risk (Table 4). *Chorizanthe robusta* var. *hartwegii*, a diminutive summer annual, scored highest for invasive plant risk, while *Eriastrum hooveri* scored lowest.

Table 4. All listed rare species, sorted by the sum of averaged Invasive Plant Risk Score components across all populations of that species, with corresponding risk category (high, moderate, moderate-low, and low). Confidence scores were averaged across populations. The three species that were targeted with field study through this project are shown in bold text.

Species	Net Invasive Plant Risk[1]	Risk Ranking	Average Confidence	# Populations (Extant)[2]
Chorizanthe robusta var. *hartwegii*	8.92	HIGH	2.50	4
Erysimum menziesii	8.89	HIGH	1.67	9
Chorizanthe robusta var. *robusta*	8.87	HIGH	1.60	15
Potentilla hickmanii	8.75	HIGH	3.00	2
Diplacus vandenbergensis	8.74	HIGH	2.94	17
Gilia tenuiflora ssp. *arenaria*	8.70	HIGH	1.44	25
Chorizanthe pungens var. *pungens*	8.61	HIGH	1.58	50

Hooveria purpureum var. *purpureum*	8.48	HIGH	1.50	26
Layia carnosa	8.20	HIGH	2.38	8
Clarkia speciosa* ssp. *immaculata	8.15	HIGH	1.27	26
Holocarpha macradenia	8.09	HIGH	1.94	17
Hooveria purpurea* var. *reducta	8.00	HIGH	1.75	4
Chorizanthe parryi var. *fernandina*	8.00	HIGH	3.00	1
Lupinus nipomensis	8.00	HIGH	3.00	2
Chorizanthe pungens var. *hartwegiana*	7.89	HIGH	1.17	18
Polygonum hickmanii	7.67	HIGH	3.00	3
Piperia yadonii	7.54	HIGH	1.65	26
Astragalus tener var. *titi*	7.50	MODERATE	3.00	1
Trifolium trichocalyx	7.50	MODERATE	2.00	2
Suaeda californica	7.42	MODERATE	1.63	8
Pentachaeta lyonii	7.26	MODERATE	2.67	21
Eremalche parryi ssp. *kernensis*	7.19	MODERATE	1.04	100
Lasthenia conjugens	7.17	MODERATE	3.00	3
Cirsium fontinale var. *obispoense*	7.12	MODERATE	1.77	22
Monolopia congdonii	7.00	MODERATE	1.10	29
Chloropyron maritimum ssp. *maritimum*	6.98	MODERATE	2.00	13
Dudleya parva	6.86	MODERATE	1.69	13
Deinandra increscens* ssp. *villosa	6.84	MODERATE	2.24	29
Arctostaphylos morroensis	6.83	MODERATE	2.50	6
Erysimum teretifolium	6.55	MODERATE	1.29	14
Astragalus pycnostachyus var. *lanosissimus*	6.50	MODERATE	2.00	2
Orcuttia californica	6.50	MODERATE	1.33	3
Eriodictyon capitatum	6.25	MODERATE	1.50	8
Lupinus tidestromii	6.17	MODERATE	2.00	6
Hesperocyparis abramsiana var. *abramsiana*	6.17	MODERATE	1.67	9
Arenaria paludicola	6.14	MODERATE	1.43	7
Dudleya cymosa ssp. *marcescens*	6.10	MODERATE	1.20	5
Nasturtium gambelii	5.83	MODERATE	2.17	6
Dudleya verity	5.69	MODERATE	2.00	8
Hesperocyparis goveniana	5.63	MODERATE	2.00	5
Cirsium scariosum var. *loncholepis*	5.17	MOD-LOW	2.14	21
Pentachaeta bellidiflora	5.00	MOD-LOW	1.00	3
Astragalus brauntonii	4.50	MOD-LOW	1.81	27
Caulanthus californicus	4.08	MOD-LOW	1.00	30
Thysanocarpus conchuliferus	3.67	MOD-LOW	1.00	3
Navarretia fossalis	3.50	LOW	1.00	1
Dudleya cymosa ssp. agourensis	2.83	LOW	3.00	3
Camissonia benitensis	2.66	LOW	2.06	50
Eriodictyon altissimum	2.00	LOW	1.00	6
Eriastrum hooveri	1.50	LOW	1.00	1

[1] Species-level IPRS is the sum of the averages of each of the eight invasive plant risk factors scored for every population.

[2] Number of populations presented here represents the number of unique records we used and not the number of extant, distinct populations recognized by CDFW or USFWS.

The three species we targeted for field study, *Clarkia speciosa* ssp. *immaculata*, *Deinandra increscens* ssp. v*illosa,* and *Hooveria purpurea* var. *reducta*, had species-level IPRS that were "High", "Moderate", and "High", respectively (Table 4), independent of our site-specific survey reports (described in Task 3). Population-level IPRS is mapped here for each of these three species serves as an example of the variation found across populations for individual species (Figures 6-8). In some cases, sites are on private land and are therefore lacking data, have lower-scores, and have lower confidence (not shown).

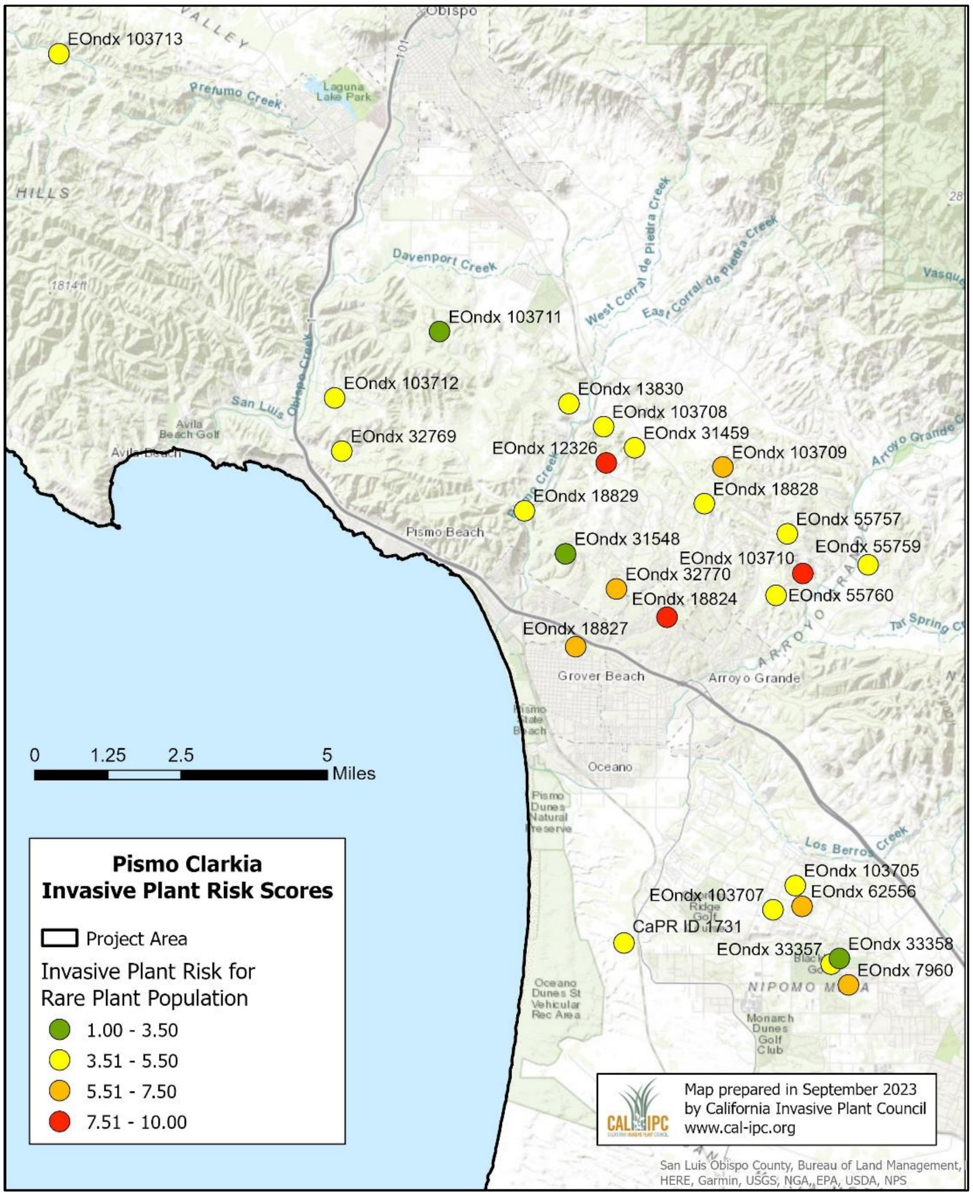


Figure 6. Pismo Clarkia (*Clarkia speciosa* ssp. *immaculata*) populations with Invasive Plant Risk Scores labeled by EOndx or CaPR ID (study plots are in EOndx 12326 and 13830).

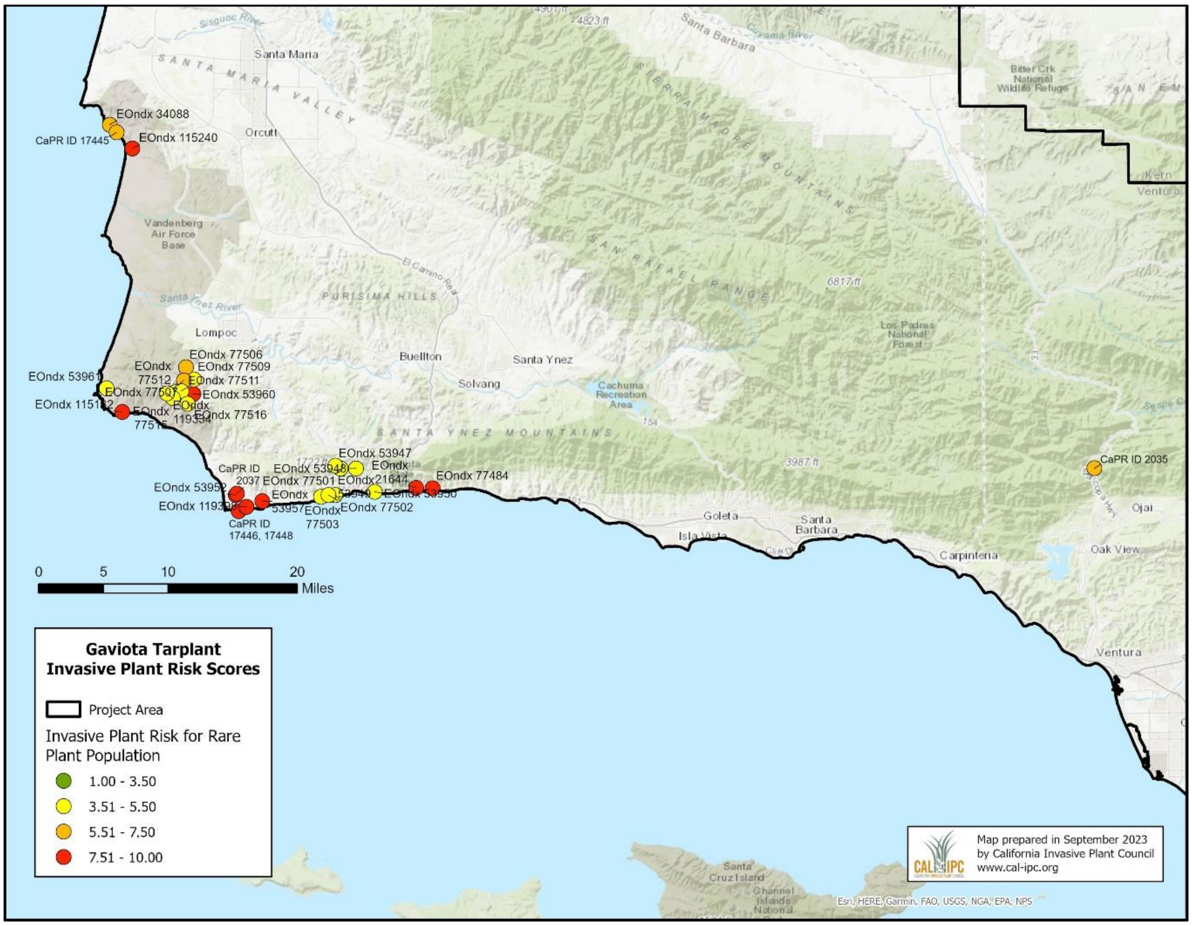


Figure 7. Gaviota tarplant (*Deinandra increscens* ssp. *villosa*) populations with Invasive Plant Risk Scores labeled by EOndx or CaPR ID (study plots are in EOndx 119398, CAPR 17446, 17448, 17445).

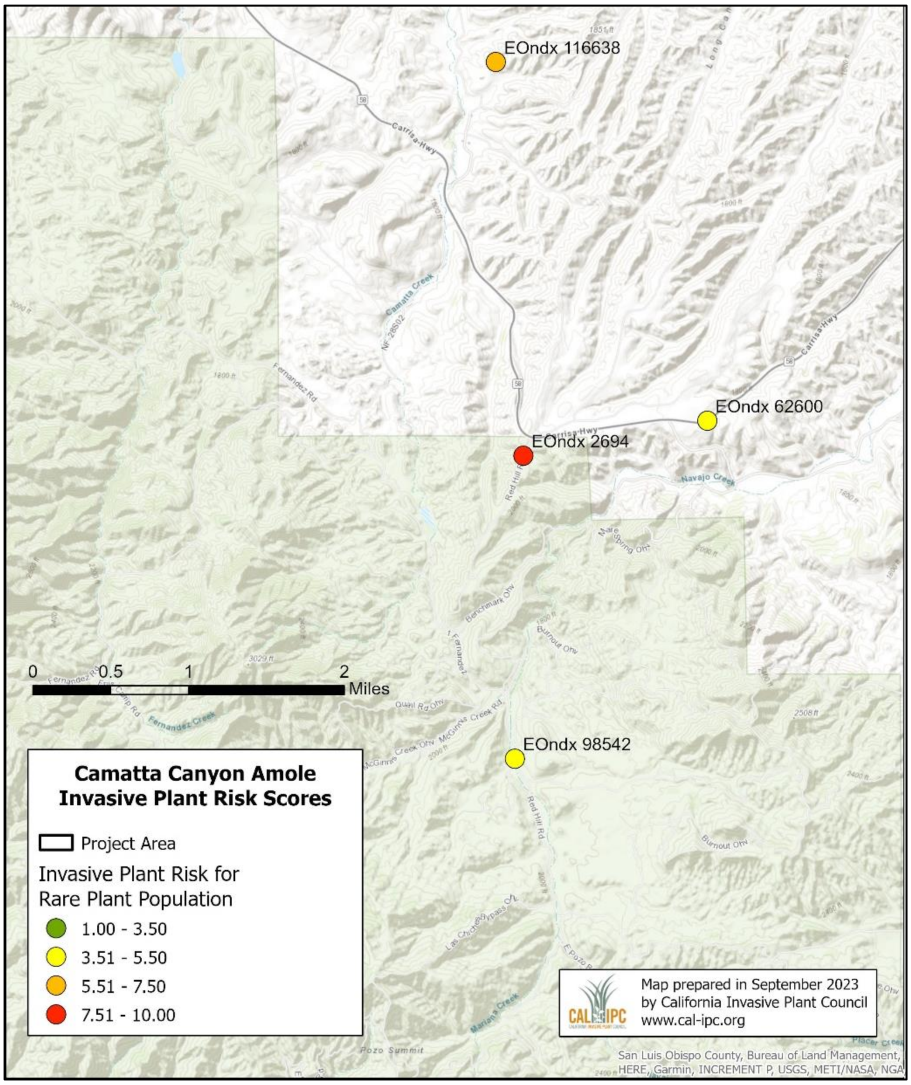


Figure 8. Camatta Canyon amole (*Hooveria purpurea* var. *reducta*) populations with Invasive Plant Risk Scores labeled by EOndx (study plots are in EOndx 2694).

Task 3 – Update Population Status Information for Three Federally Listed Plants: Pismo Clarkia, Camatta Canyon Amole, and Gaviota Tarplant

Subtask 3.1 – Select Sites for Three Federally Listed Focal Species

Three sites were selected for each of three target rare plant species: Pismo Clarkia, Gaviota tarplant, and Camatta Canyon amole. Sites were selected based their known distribution from CNDDB data (CDFW 2017), site accessibility, and willing landowner partners. Within each site, three semi-permanent 3x3-meter plots were established for seasonal monitoring (Figures 9-11). Most plots were established in 2020, except for Camatta Canyon amole plots and Gaviota State Park plots for Gaviota tarplant, which were established late because of access restrictions in 2020 due to COVID.

Pismo Clarkia sites were on San Luis Obispo County property and accessed via entry permit. Gaviota tarplant sites at Vandenberg Space Force Base were accessed by landowner permission renewed annually. Sites at Dangermond Preserve were accessed via research access permit, reviewed and renewed annually. Sites at Gaviota State Park were accessed via State Parks access permission. Camatta Canyon amole sites occurred on US Forest Service land and were accessed with permission and coordination with other researchers.

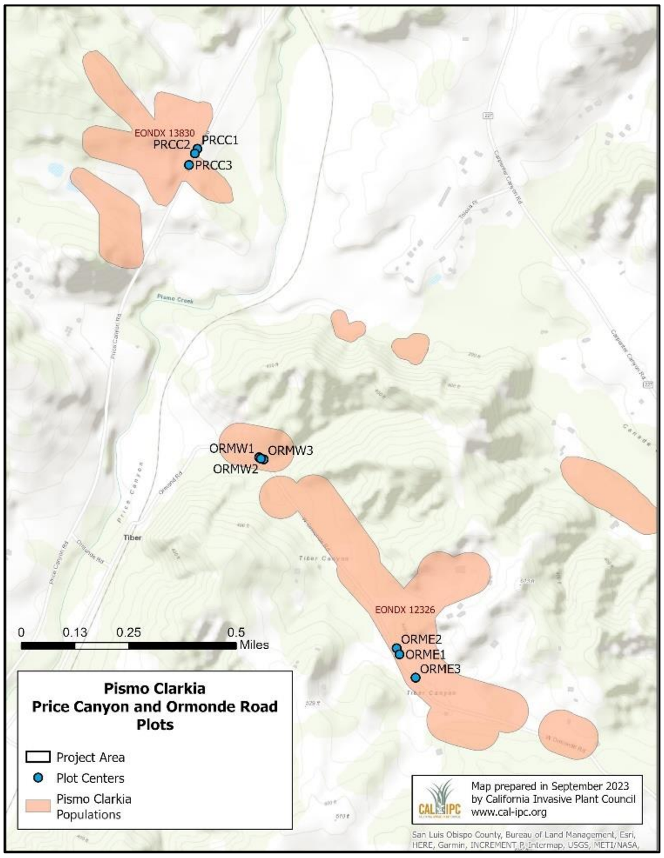


Figure 9. Nine Pismo Clarkia plots across three sites along Price Canyon Road and Ormonde Road.

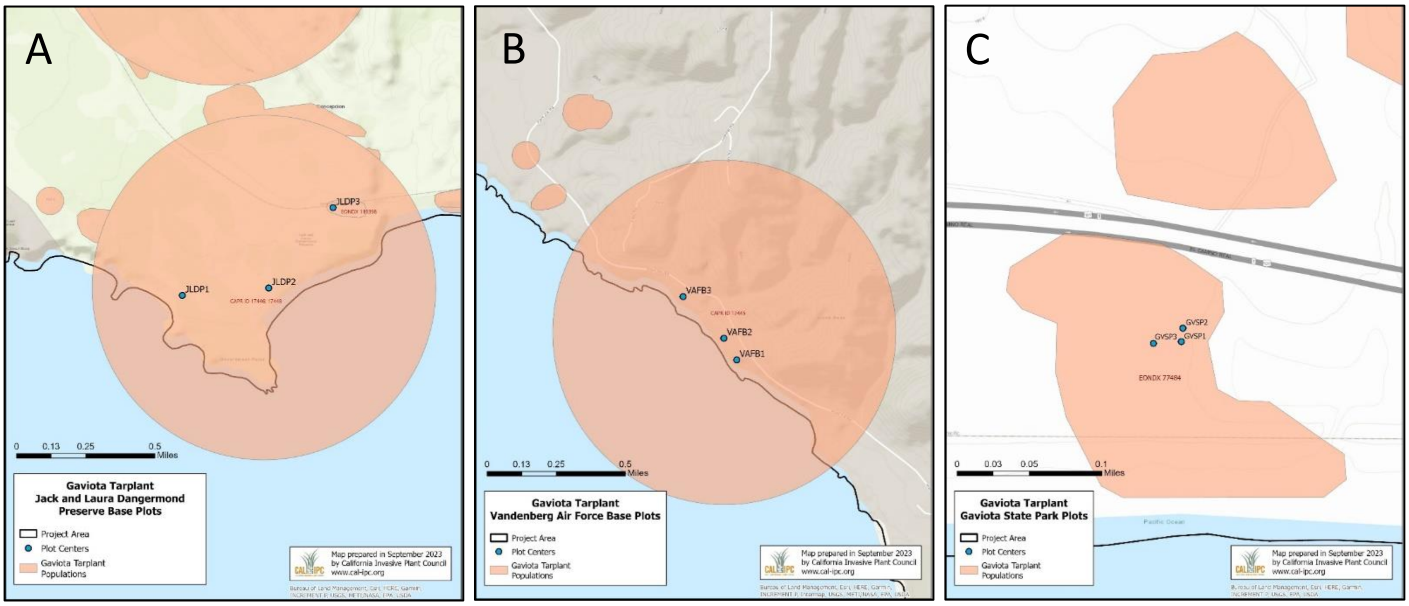


Figure 10. Gaviota tarplant plots at (A) the Jack and Laura Dangermond Preserve, (B) Vandenberg Space Force Base, and (C) Gaviota State Park.

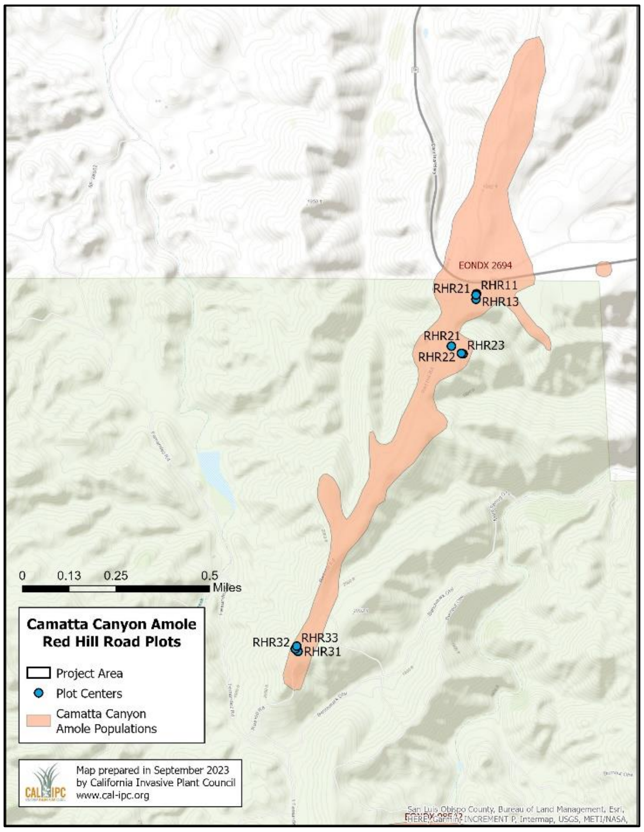


Figure 11. Nine Camatta Canyon amole plots across three sites along Red Hill Road.

Subtask 3.2 – Monitor Field Sites

Sites were surveyed using a modified California Native Plant Society (CNPS) relevé protocol (described in Cal-IPC 2020 annual report to CDFW). For each plot, we attempted to visit the plot around peak flowering stage and recorded: 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. In 2021, we modified our protocol to add estimates of percent thatch cover at all plots. We also added a count of flowers and flower heads for a representative subset of plants (20 or as many as were available in the plot) to estimate potential reproductive output more accurately. We used pin flags to facilitate more accurate plot-level searches and to differentiate between reproductively successful and unsuccessful target plants. In 2023, when there were significantly more target plants, we used colored flags to mark groupings of 10 plants where plants were exceptionally dense. See Appendix 4, 5, and 6 for sequential photos of all plots.

Conditions in 2021 were exceptionally dry and those in 2023 were exceptionally wet (Table 5 and Figure 12). Rainfall in both 2021 and 2022 was very limited during late winter and early spring months when it was needed to support growth and reproduction of plant species. In 2021 and 2022, plant phenology was also earlier than it had been in 2020.

Table 5. Precipitation totals for San Luis Obispo from July 2019 through June 2023 (PRISM 2023, using "San Luis Obispo" as search term) as an example of regional precipitation.

Date	Precipitation (inches)
July 2019 - June 2020	17.89
July 2020 - June 2021	12.62
July 2021 - June 2022	16.84
July 2022 - June 2023	54.17

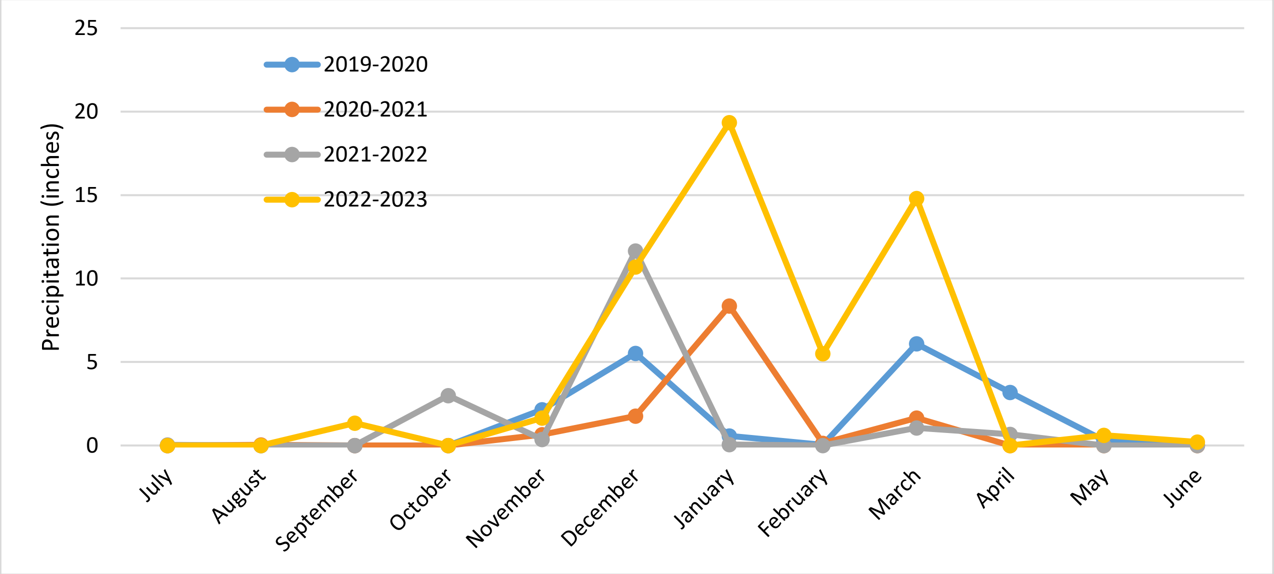


Figure 12. Monthly precipitation in San Luis Obispo during the project's rare plant monitoring period (PRISM 2023).

Pismo Clarkia

Pismo Clarkia plots were monitored on June 29, 2020, June 16, 2021, June 29, 2022, and June 28, 2023. Target plant phenology at the time of monitoring ranged from full flower to early seed set and surrounding annual vegetation was mostly senesced. Survey results for Pismo Clarkia are summarized in Table 6. Pismo Clarkia density averaged 6.6 plants/m^2 overall but ranged from 0.3 plants/m^2 in 2022 to 27.8 plants/m^2 in 2020. Although the number of plants per plot generally decreased at more exposed plots (Ormonde E and W) from 2020-2023, plant size (measured by number of flowers or fruits per plant) per plant also increased between 2021 and 2023; plants in 2023 were fewer, but slightly larger, at those sites. At Price Canyon, plant density remained more stable but plant size also increased dramatically in 2023. Plant size was not measured in 2020, but surveyors noted that plants were generally larger than they were in 2021 and 2022.

Drought conditions such as those during mid-spring in 2022 were not favorable for Pismo Clarkia and resulted in very small plant size and significant abortion of target plants before successful reproduction at highly exposed sites (Table 6, Figure 15). Total vascular vegetation cover varied from 12% to 89%. Sites were relatively species-rich, with the total number of species observed per plot ranging from 17-28. *Erodium botrys*, *Bromus diandrus*, *Hypochaeris glaber*, *Ehrharta calycina*, and *Bromus madritensis* were, in order of decreasing abundance, the five most common non-native species that we observed co-occurring with Pismo Clarkia. The four most common native plants in plots were *Croton californicum*, *Quercus agrifolia* (at one site*), Acmispon americanum*, and Pismo Clarkia. All plots had some level of bioturbation and several showed signs of fruit stalk herbivory at least in one year (2021). One site (ORM-E-3) repeatedly showed evidence of early-season annual mowing: vegetation was clipped, Pismo Clarkia was highly branched and thatch cover was low, ranging from 1-4%. *Ehrharta calycina* on the mowed site averaged 6% and was able to successfully flower despite mowing (see plot photos, Appendix 4 and supplemental survey data submitted).

Overall, Pismo Clarkia populations exhibited a troubling downward trend over the four years they were surveyed (Figure 13). Price Canyon sites, which were more native-dominated and had lower bare ground cover, supported fewer– but often substantially larger – plants. Overall, our data corroborate the existing population-level assessments of Pismo Clarkia at these sites: Ormonde E and W plots were highly degraded and also appeared highly impacted, while Price Canyon plots appeared less immediately affected by invasive plants.

Annual grasses, *Ehrharta* cover, thatch (predominantly from past years' annual grass growth), and the combined cover of all non-natives were negatively associated with Pismo Clarkia density (Figure 14). Annual grass cover was also weakly negatively associated with relative per area reproductive output (number of flowers/m^2). However, thatch was *positively* associated with per area reproductive output; while thatch may have been reducing plant abundance by obscuring light penetration and inhibiting germination, it may also have been reducing moisture loss for those plants that were able to establish (Figure 15). At the three sites we monitored, *Ehrharta calycina* appeared to be a contributor to—but not a prime driver of—Pismo Clarkia abundance.

Table 6. Average plant density and number of flowers per plant from fixed plot Pismo Clarkia surveys spanning 2020-2023.

	Plant Density (plants/m^2)[1]				No. Flowers/Plant (ave.)[2]			
Plot	**2020**	**2021**	**2022**	**2023**	**2020[3]**	**2021**	**2022**	**2023**
ORM-E-1	13.9	1.3	0.3	1.9	.	2	1.4	13
ORM-E-2	27.8	23.8	16.3	13.8	.	2	3.0	7.5
ORM-E-3	23.1	18.7	9.8	6.8	.	3	4.9	6
ORM-W-1	4.4	4.2	4.3	0.6	.	1	1.9	2
ORM-W-2	6.7	5.8	1.1	0.3	.	1	1.6	2
ORM-W-3	7.8	2.4	0.6	0.3	.	1	1.8	6
PRICE-1	6.9	0.7	1.1	4.2	.	2	3.0	99
PRICE-2	6.1	3.9	0.4	2.4	.	4	12.3	38.5
PRICE-3	8.3	1.0	1.0	5.3	.	6	10.4	45.5
Average	**11.7**	**6.9**	**3.9**	**4.0**	**.**	**2.4**	**4.5**	**24.4**

[1] Directly calculated by dividing the number of plants observed in 3x3m plots by nine.

[2] The average of flower counts from 10 plants (or as many as occurred if there were fewer) in the plot.

[3] Number of flowers per plant was not recorded in 2020.

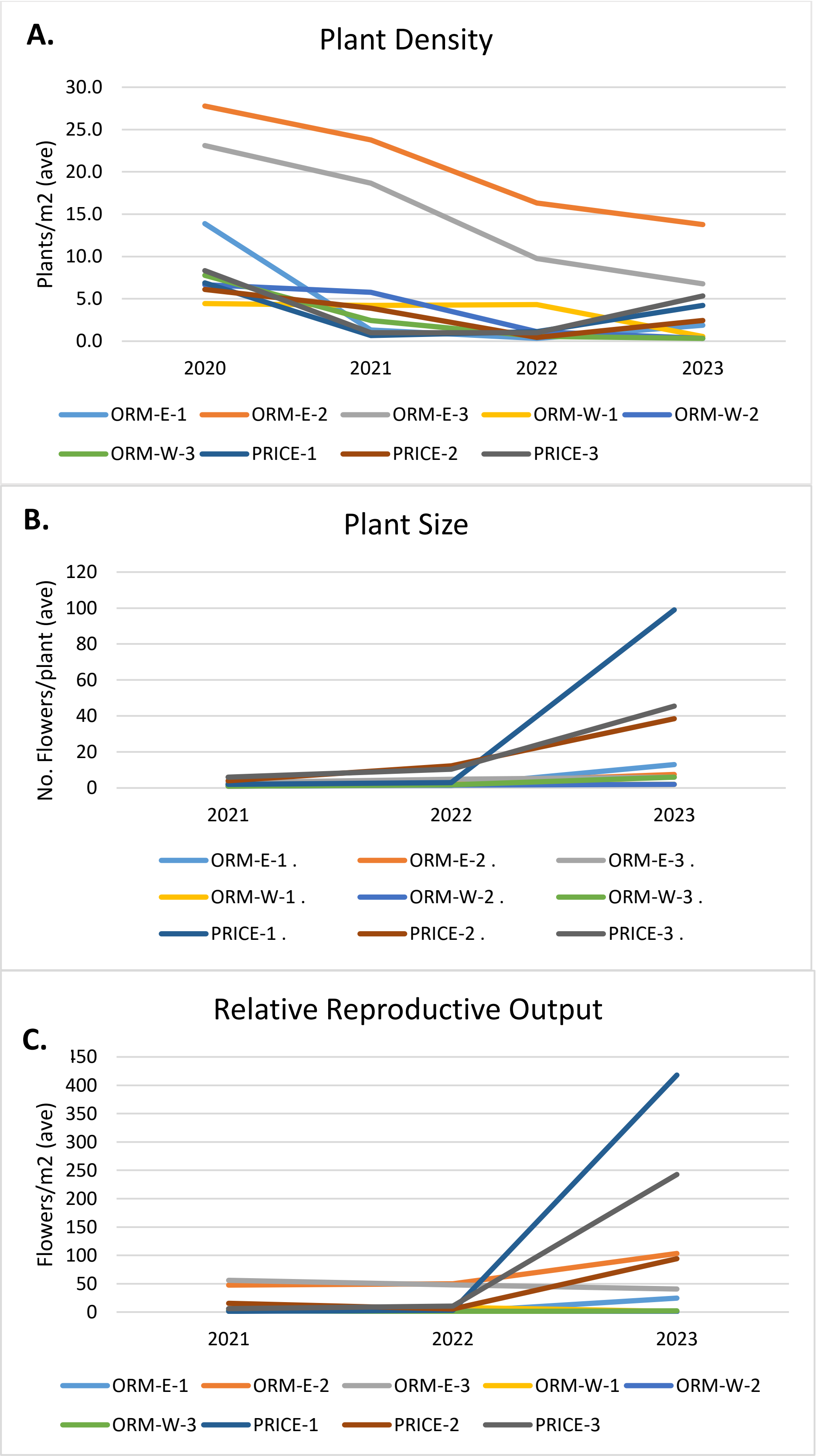


Figure 13. Plant demographic trends of Pismo Clarkia at Ormonde-East, Ormonde-West, and Price Canyon plots in San Luis Obispo County. (A) Plant Density; (B) Flower Production (per plant); and (C) Reproductive Output (calculated as average plant density x average flower production per plant).

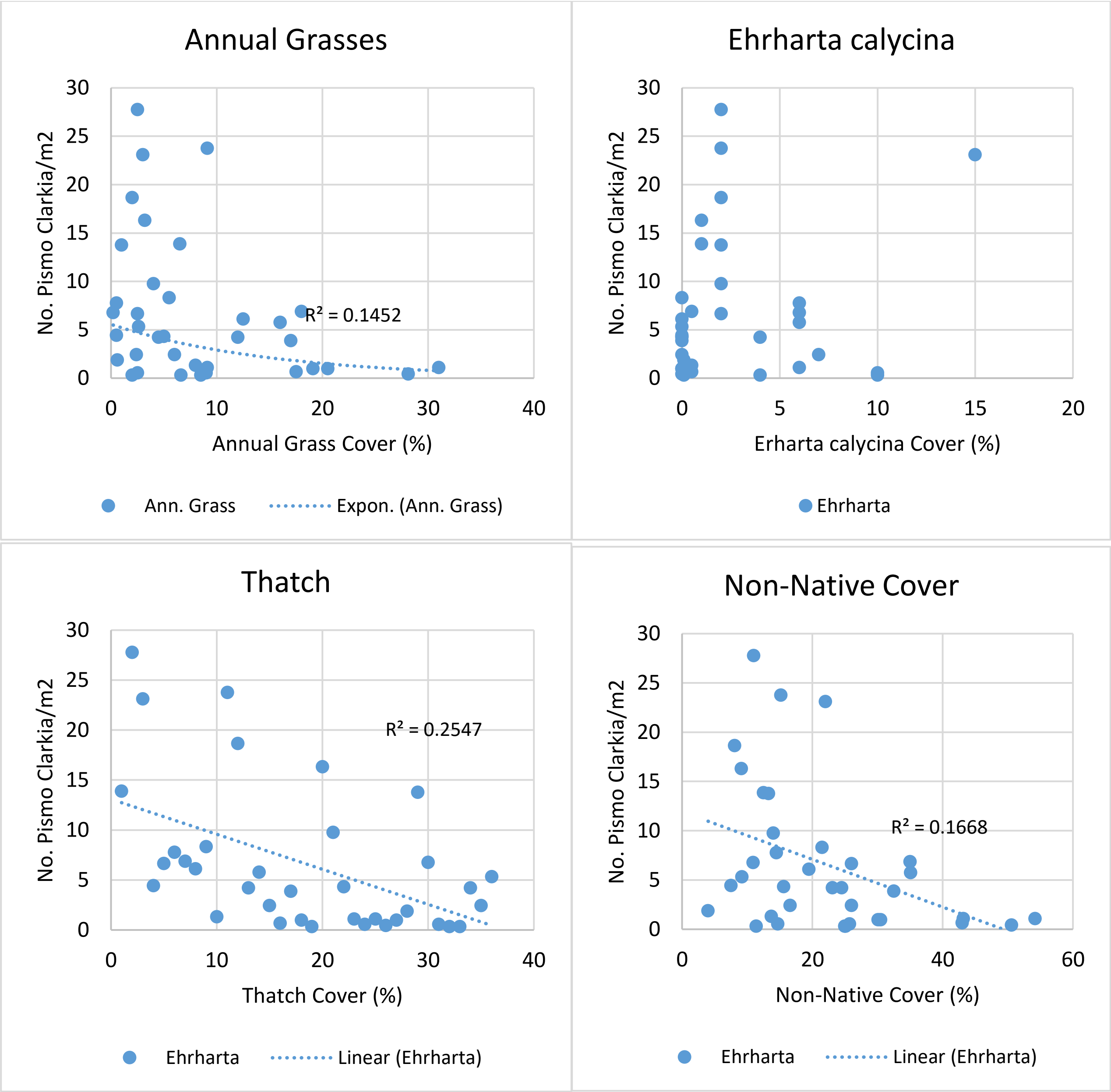


Figure 14. Association between non-native vegetation and Pismo Clarkia density and reproductive output.

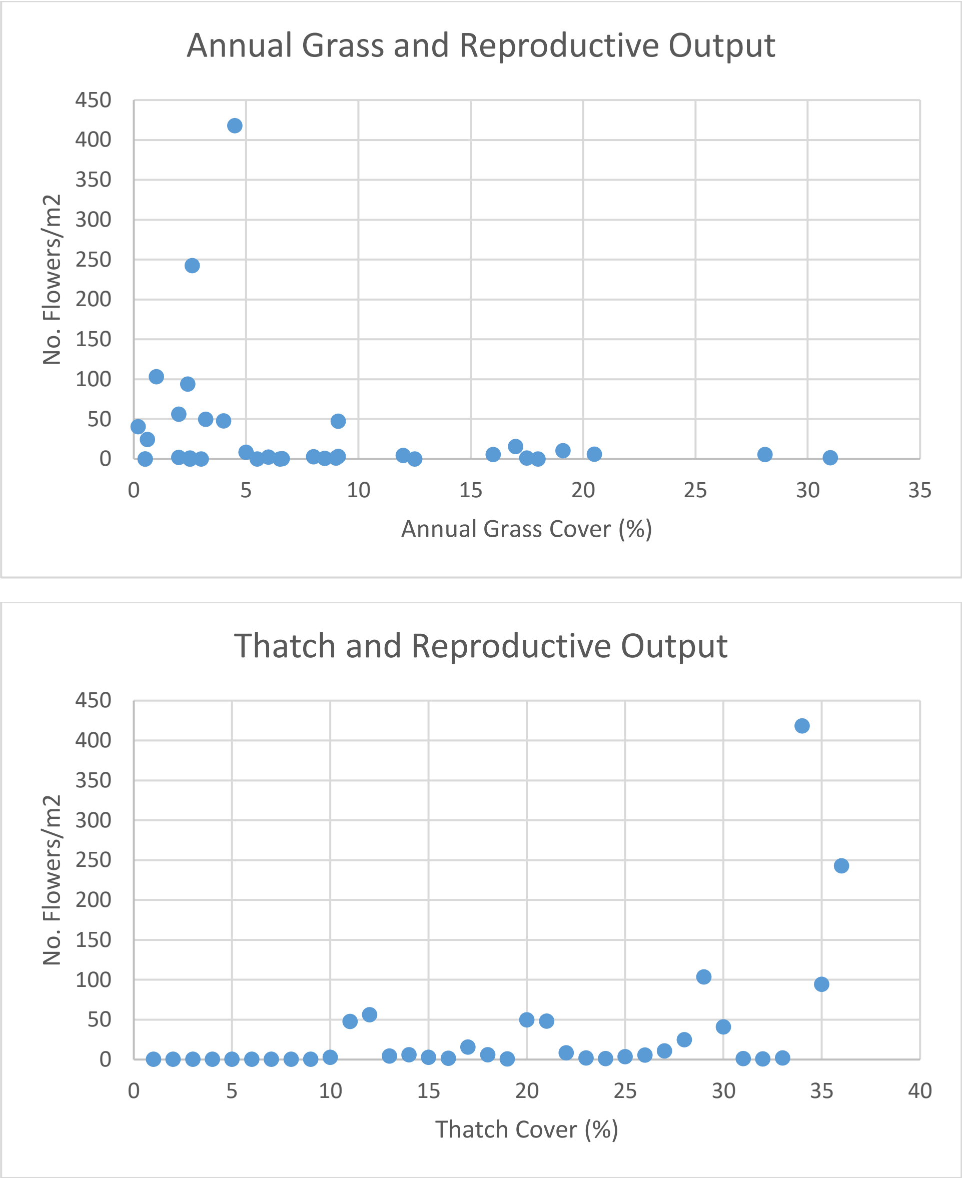


Figure 15. Association between (A) annual grass cover and (B) thatch and relative reproductive output per area.

Figure 16. Counting Pismo Clarkia at Ormonde-W-2 plot.

Gaviota Tarplant

Gaviota tarplant sites were monitored on July 27 and 28, 2020, June 20 and 21, 2021, June 15 and 17, 2022, and June 28 and 29, 2023. Study plots were located at Vandenberg Space Force Base (VSFB), the Jack and Laura Dangermond Preserve (JLDP), and Gaviota State Park (GVSP). Gaviota tarplant density was, on average, 26.7 plants/m^2, and ranged from 0.7 - 148.2 plants/m^2 (Table 7). Average reproductive output was 13.3 flower heads/plant but varied greatly over the three years surveyed – from an average of 4.7 heads/plant in 2021 to 26.0 in 2023 (see Figure 17 for trends). When compared to other sites, plants at Gaviota State Park were notably smaller and more phenologically advanced every year they were surveyed. Gopher and/or ground squirrel disturbance was common. Average total vegetation cover was 52%, with the lowest cover occurring at the VAFB-2 plot in 2021 (28%) and the highest at VAFB-3 in 2023 (91%). Overall, population trends generally were positive over the four-year study period, in part because Gaviota tarplant responded so favorably to high rainfall in 2023.

Erodium botrys, Bromus hordeaceus, *Carpobrotus edulis,* and *Bromus diandrus* were, in order of decreasing abundance, the four most common co-occurring non-native species overall. The three most common native species in our plots included *Stipa pulchra, Isocoma menziesii*, and Gaviota tarplant. Species richness was high and relatively similar across plots, ranging from 22-34 species. Overall, non-native cover averaged 40%, ranging from a low of 17% at Gaviota State Park in 2022 to a high of 89% at JLDP plot 1 in 2023, where invasive annual grasses had, disturbingly, taken hold.

Annual grasses, *Ehrharta*, and *Carpobrotus* cover each independently had a very weak negative relationship with Gaviota tarplant density, but thatch had a strong negative relationship. When these four factors were combined, the negative relationship was especially strong and appeared to be non-linear (Figures 18,19). There was, however, no clear relationship between relative reproductive output per area (number of flower heads/m^2, data not shown) and these factors. Therefore Gaviota tarplant may be able to partially compensate for low abundance under high impact conditions with larger plant size, but more research is needed to understand this relationship.

Table 7. Average plant density and number of flowers per plant from fixed plot Gaviota tarplant surveys spanning 2020-2023.

	Plant Density (per m^2)[1]				**Flower Heads/Plant (Ave)[2]**			
Plot	**2020**	**2021**	**2022**	**2023**	**2020[3]**	**2021**	**2022**	**2023**
GVSP-1	.	4.1	106.7	148.2	.	1.0	4.0	3.6
GVSP-2	.	20.3	62.2	77.6	.	1.0	2.5	3.0
GVSP-3	.	4.1	20.2	20.4	.	1.0	2.0	6.3
JLDP-1	7.7	50.7	43.2	26.9	.	3.0	4.0	13.5
JLDP-2	15.9	15.6	53.6	40.1	.	2.0	16.0	14.5
JLDP-3	20.1	0.7	3.1	22.4	.	1.0	1.0	7.1
VAFB-1	8.9	8.8	29.2	44.1	.	6.0	13.0	15.0
VAFB-2	3.1	14.7	1.9	5.0	.	20.0	29.0	122.0
VAFB-3	13.6	12.8	5.3	3.9	.	7.0	10.0	49.0
Ann. Average	**11.5**	**17.2**	**22.7**	**23.7**	**.**	**4.7**	**9.1**	**26.0**

[1] Directly calculated by dividing the number of plants observed in 3x3m plots by nine.

[2] The average of flower counts from 10 plants (or as many as occurred if there were fewer) in the plot.

[3] Number of flowers per plant was not recorded in 2020.

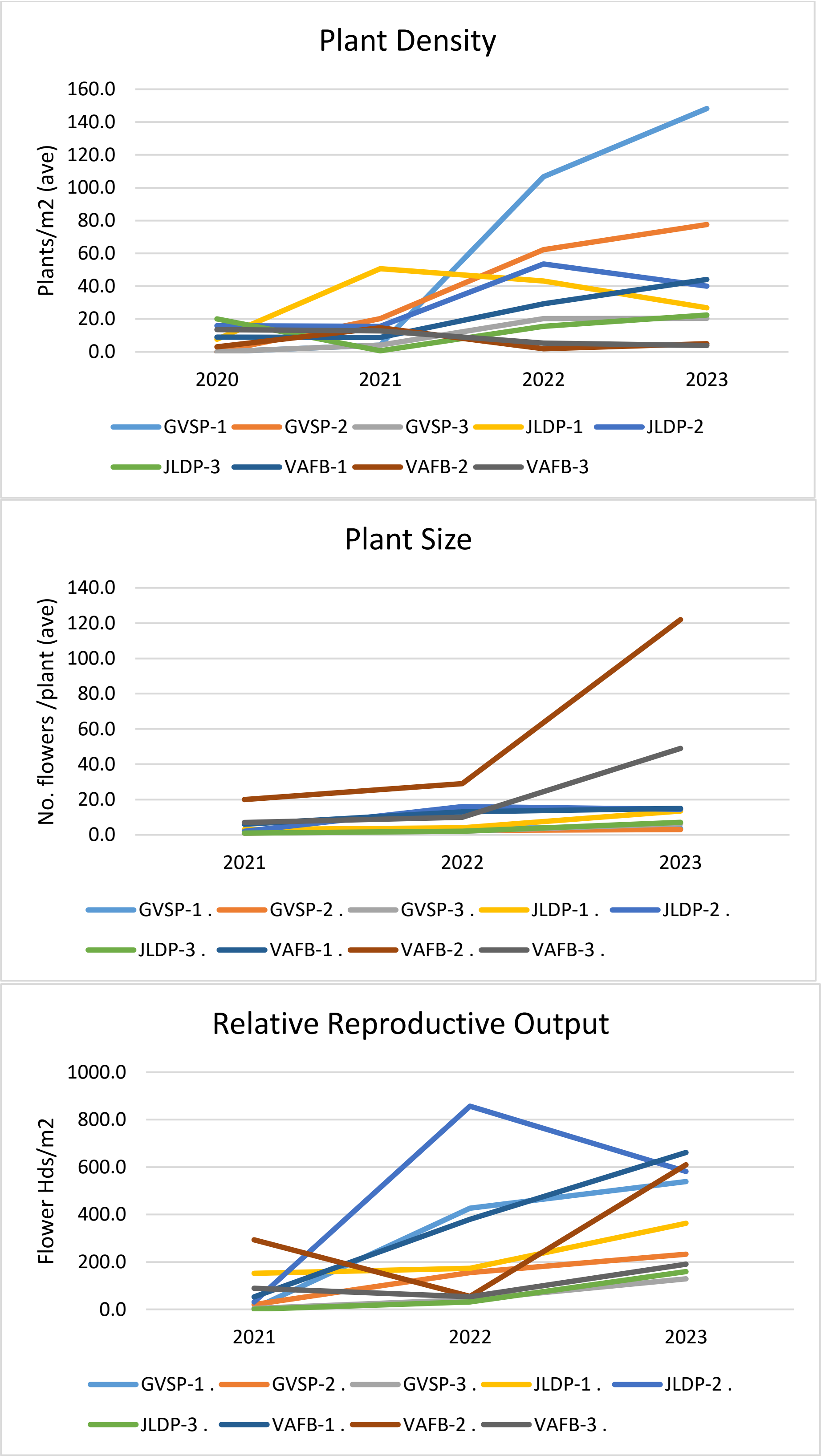
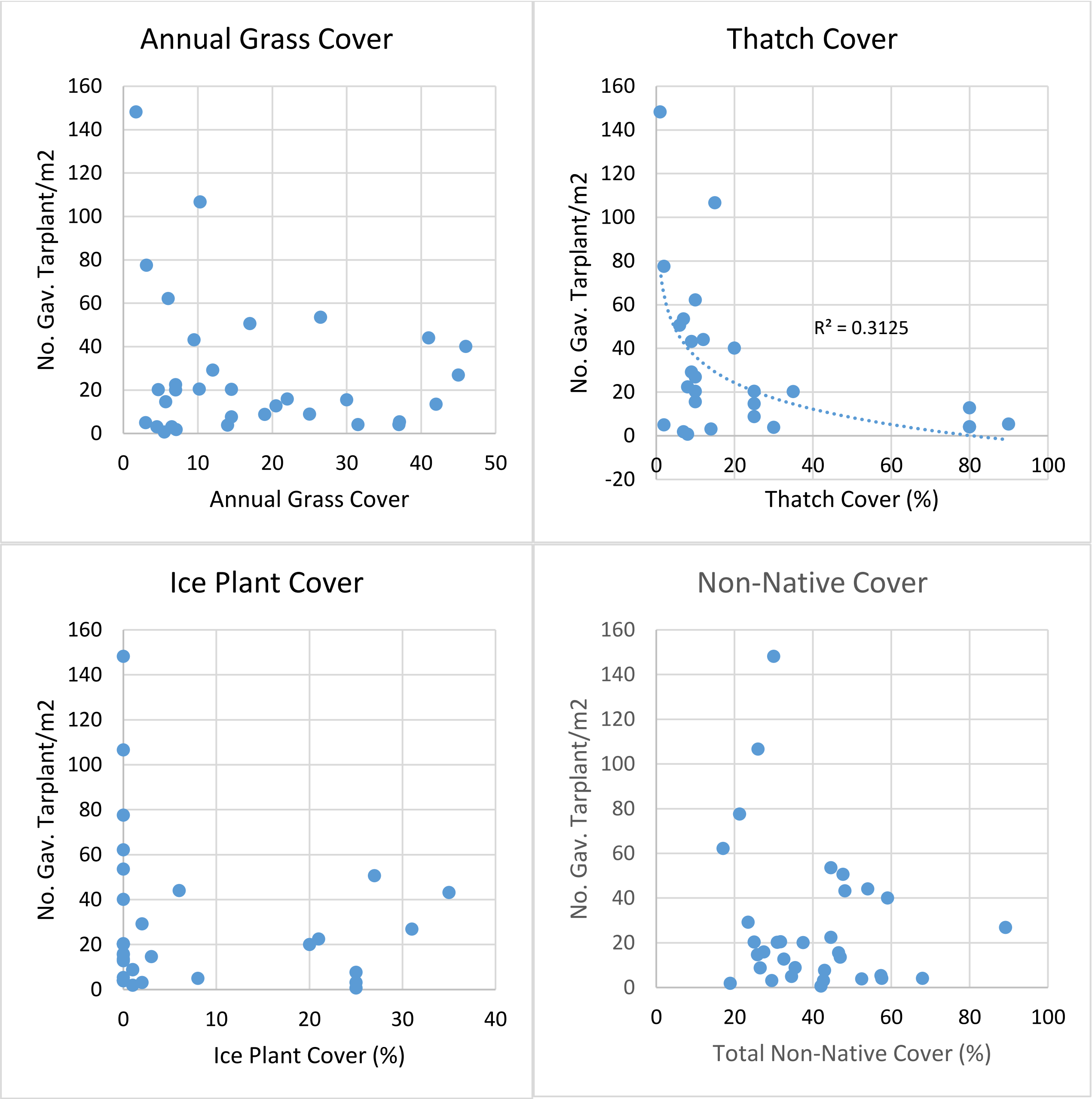


Figure 17. Demographic trends of Gaviota tarplant at Gaviota State Park (GVSP), Dangermond Preserve (JLDP), and Vandenberg Space Force Base (VAFB) in Santa Barbara County.


Annual Grass Cover

Thatch Cover

Ice Plant Cover

Non-Native Cover

Figure 18. Correlations between non-native vegetation and Gaviota tarplant density.

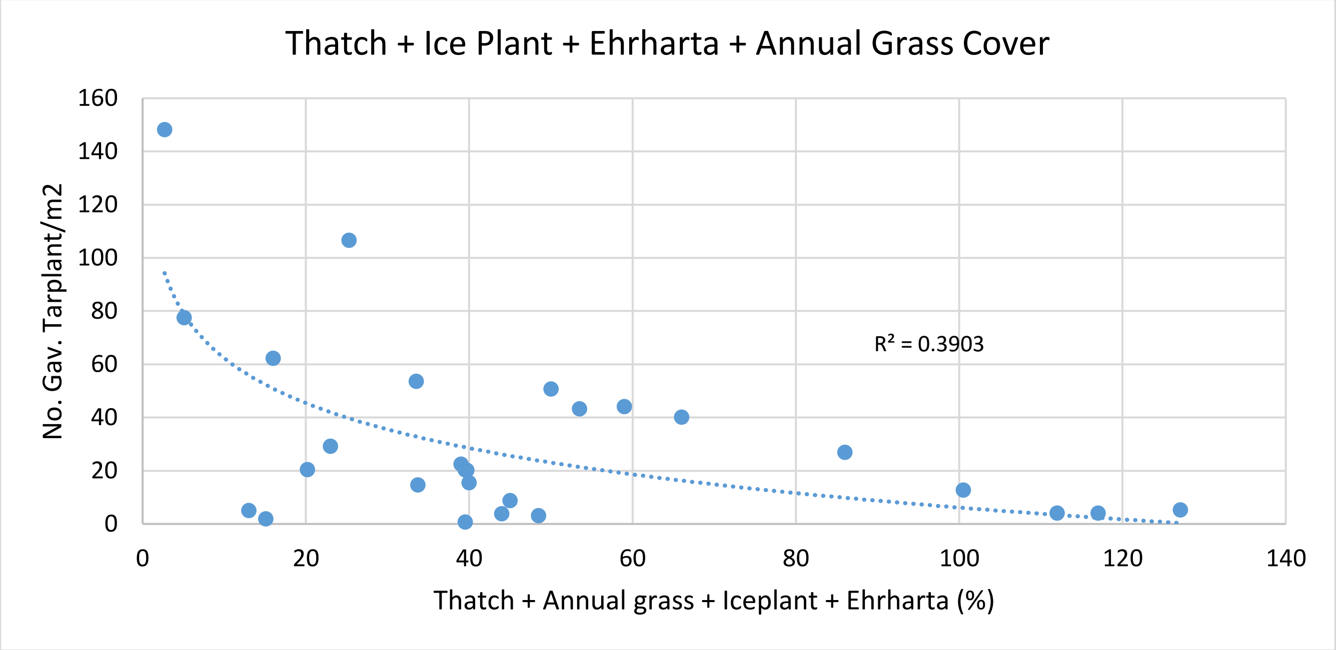


Figure 19. Gaviota tarplant density in relation to the combined cover of thatch plus major non-native species suspected of affecting rare species (iceplant, Ehrharta and non-native annual grasses).

Figure 20. Extensive annual and perennial grass cover at Gaviota tarplant survey plot JLDP-2.

Camatta Canyon Amole

Camatta Canyon amole surveys occurred on May 20 2021, May 9 2022, and May 9, 2023. Given its limited range of distribution and lack of access to a large population on private land, all plots were located on USFS land in the Los Padres National Forest, Las Posas Ranger District, San Luis Obispo County, along Red Hill Road. This area is represented by a single element occurrence (EOndx #2694). We clustered three plots in each of three distinct areas within the larger population.

Based on surveys, Camatta Canyon amole appears to grow on sites that have low vegetation cover and limited thatch. The average density of Camatta Canyon amole in plots was 5.3 plants/m^2 (ranging from 0.9/m^2 in 2022 to 24.7/m^2 in 2023; Table 8). The maximum number of plants observed per plot can be considered the best estimate of this species density at each plot since this species is a perennial lily that does not emerge and flower every year. Total vegetative cover ranged from 4%-42%. Cryptogamic crust was also extensive on plots 2.1-2.3, which had especially low vegetative cover.

Camatta Canyon amole density and plant size increased substantially in 2023, indicating that many plants remained dormant below-ground during the two previous drought years and that they can respond to wet conditions within a single season (Figure 21). Correlations between annual grass cover, thatch, and both combined with plant density were negative but not strongly so, while those with total non-native cover were unclear (Figure 22). Similarly, relative reproductive output was negatively associated with thatch and annual grass cover (Fig 23).

In parallel to this study, Cal Poly San Luis Obispo graduate student Kieran Althaus (advisor Dr. J. Yost) has completed a thesis on local demographics and effects of thatch removal on this species (Althaus 2022). We met and coordinated with researchers in the field.

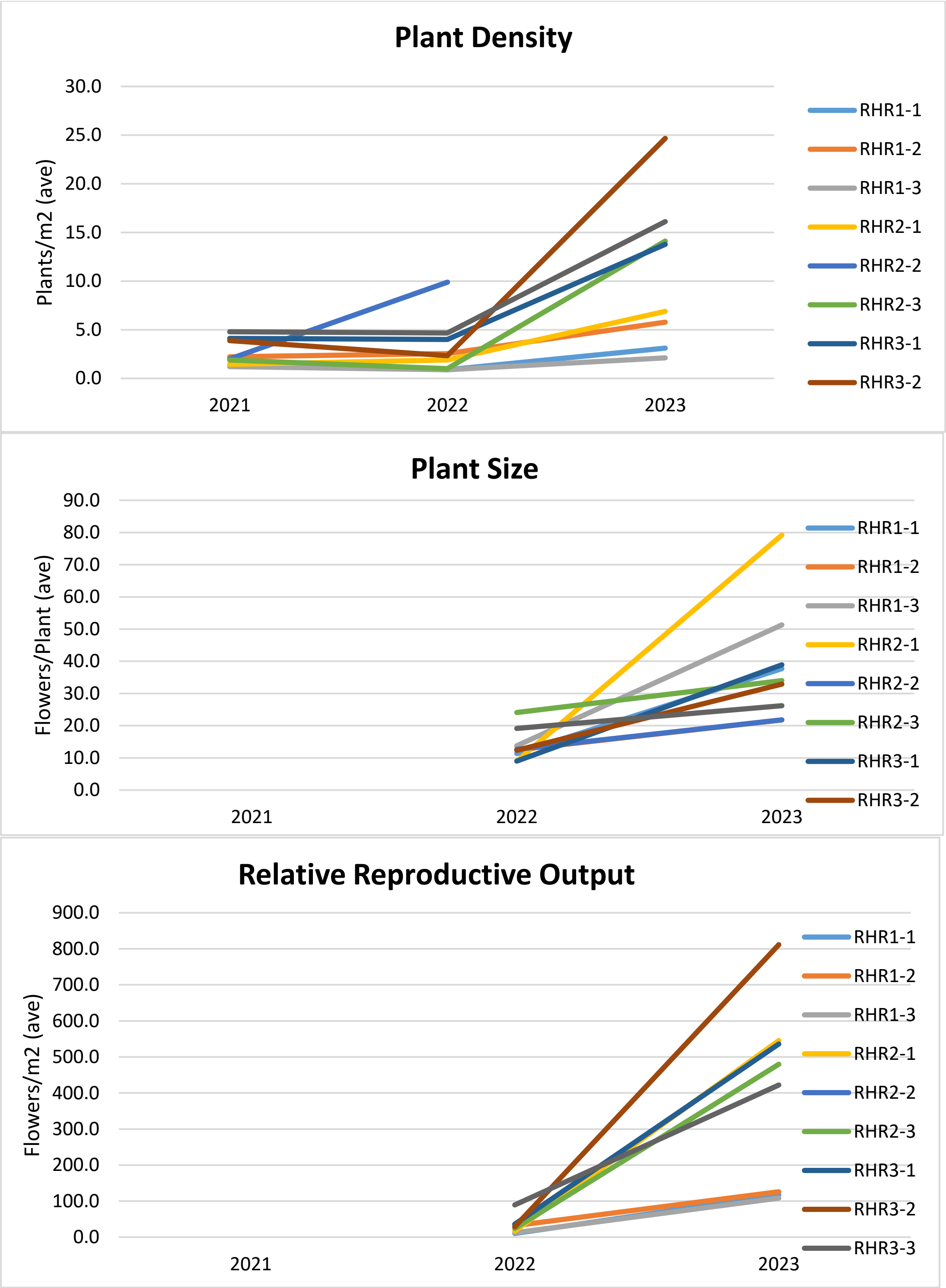
Table 8. Average plant density and number flowers per plant from fixed plot Camatta Canyon amole surveys spanning 2021-2023 (data for RHR2-2, 2023 are missing).

	Plant Density (per m^2)[1]			Flowers/Plant (ave)[2]		
Plot	**2021**	**2022**	**2023**	**2021[3]**	**2022**	**2023**
RHR1-1	1.9	0.9	3.1	.	11.4	37.7
RHR1-2	2.2	2.6	5.8	.	12.5	21.8
RHR1-3	1.2	0.9	2.1	.	13.8	51.3
RHR2-1	1.4	1.9	6.9	.	9.0	79.2
RHR2-2	2.0	9.9	.	.	12.7	21.8
RHR2-3	1.9	1.0	14.1	.	24.1	34.0
RHR3-1	4.1	4.0	13.8	.	9.0	38.9
RHR3-2	3.9	2.3	24.7	.	12.4	32.9
RHR3-3	4.8	4.7	16.1	.	19.1	26.2

[1] Directly calculated by dividing the number of plants observed in 3x3m plots by nine.

[2] The average of flower counts from 10 plants (or as many as occurred if there were fewer) in the plot.

[3] Number of flowers per plant was not recorded in 2021.



Plant Density

Plant Size

Relative Reproductive Output

Figure 21. Plant demographic trends of Camatta Canyon amole at Red Hill Road (RHR).

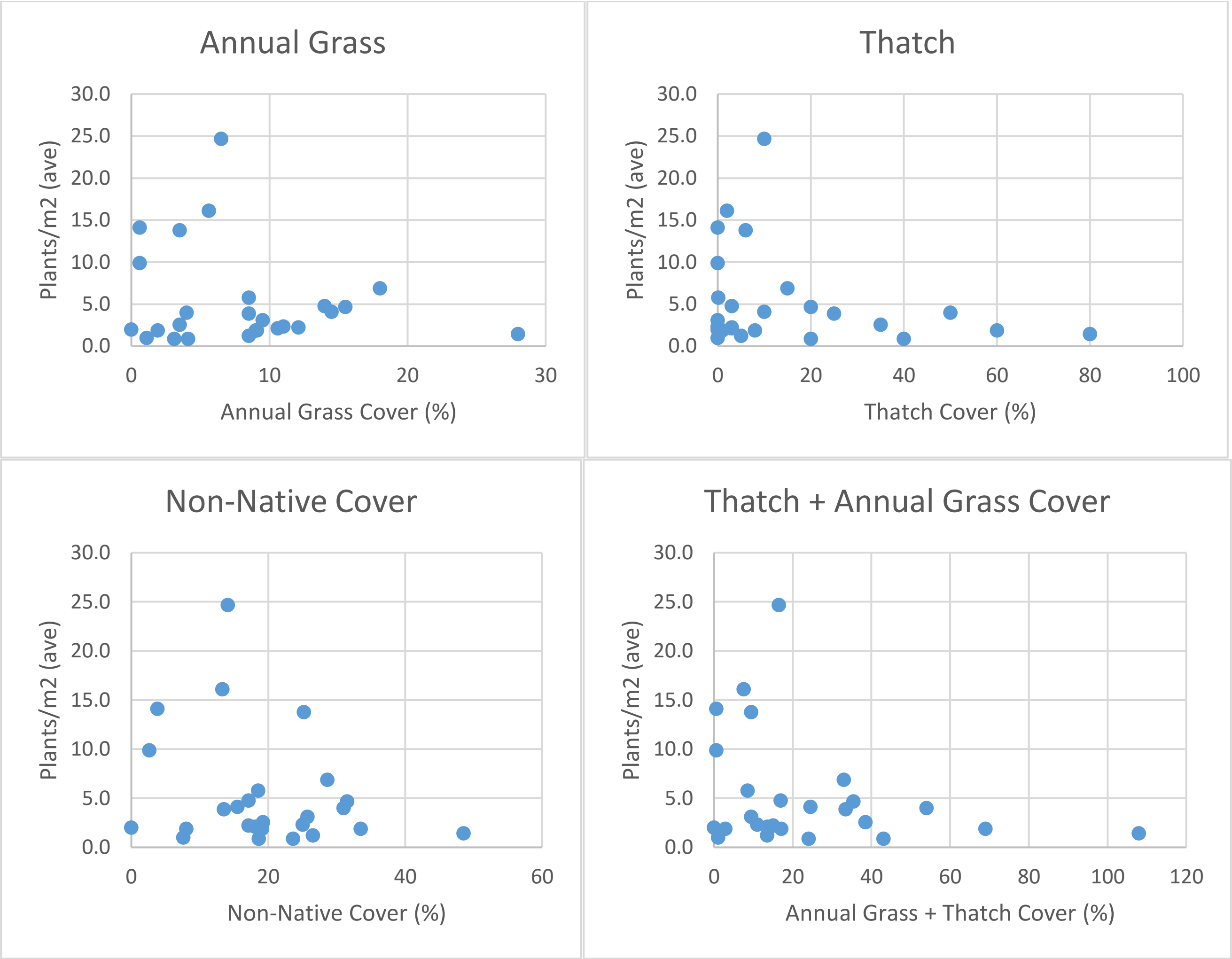


Figure 22. Correlations between non-native vegetation and Camatta Canyon amole density.

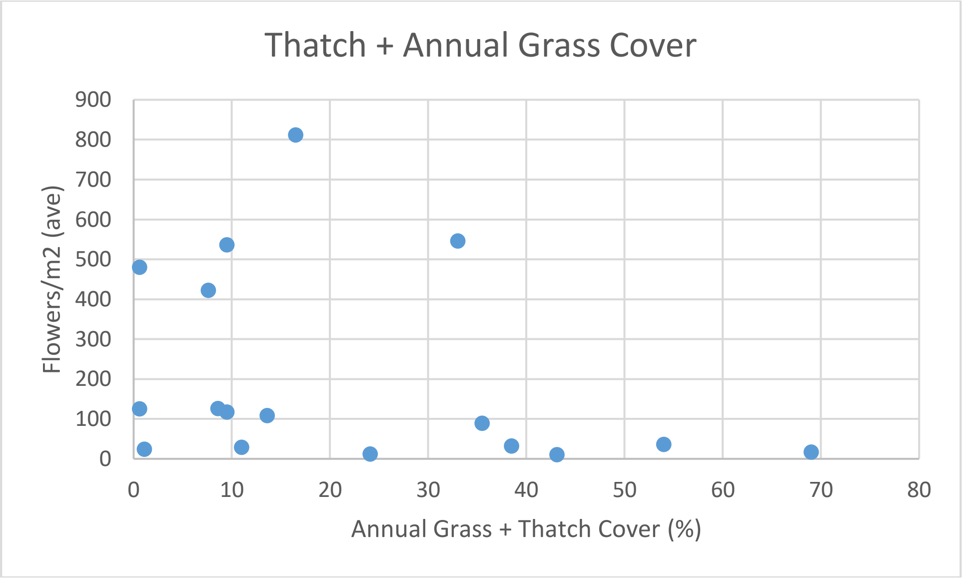


Figure 23. Association between combined thatch and annual grass cover and relative reproductive output per acre.

Figure 24. Camatta Canyon amole (*Heather Schneider, SBBG*).

Figure 25. Low plant cover and thin soils characterized Camatta Canyon amole plots at Red Hill Road.

Subtask 3.3 – Collect Voucher Specimens

SBBG collected voucher specimens for Camatta Canyon amole, Pismo Clarkia and Gaviota tarplant. All vouchers are stored at SBBG’s Clifton Smith Herbarium and once curated, label data will be available online via CCH2 (https://cch2.org/portal/).

Table 9. Voucher specimens collected as part of the study.

Taxon	Collector #	Date	Site name	Latitude	Longitude
Clarkia speciosa ssp. *immaculata*	HES808	5/14/2020	Ormonde Rd. West	35.17385	-120.60735
Deinandra increscens ssp. *villosa*	CMG6109	6/20/2020	Vandenberg Space Force Base, Lion's Head	34.85283	-120.60245
Deinandra increscens ssp. *villosa*	CMG6033	5/29/2020	Gaviota State Park	34.47298	-120.1988
Deinandra increscens ssp. *villosa*	KHL3010, 3111	6/27/2020	Jack and Laura Dangermond Preserve	34.44521	-120.45761
Deinandra increscens ssp. *villosa*	KHL3115	6/27/2020	Jack and Laura Dangermond Preserve	34.44707	-120.45277
Hooveria purpurea var. *reducta*	HES966	5/9/2023	Los Padres National Forest, Red Hill	35.401226	-120.280303

Subtask 3.4 – Submit Population Assessment and Collection Data

SBBG curated data in ArcGIS and submitted status updates to CNDDB in January of each year: 2021, 2022 and 2023. Another update that includes 2023 data will be submitted in January of 2024.

Task 4 – Make Conservation Seed and Tissue Collections

SBBG made conservation seed collections for each of the three focal taxa and all plot locations included in this project's field studies. Seed collection for Camatta Canyon amole was limited because seed production was poor.

Subtask 4.1 – Collect, Process, and Store Seeds

Seeds of all three species were collected by SBBG, but collection was hampered for Camatta Canyon amole because of pandemic-related access restrictions in Year 1 and drought conditions in Year 3. A total of eight accessions of Pismo Clarkia were collected at study sites during 2020, 2021, and 2022, representing 258 maternal lines (Table 9). Seed mass averaged 0.015g/100 seeds.

Twelve accessions were collected for Gaviota tarplant from 2020-2023, primarily from the Dangermond Preserve (JLDP), representing 638 maternal lines (Table 10). Seed mass averaged 0.066g/100 seeds.

Only four accessions of Camatta Canyon amole could be collected over the course of two years (in 2021 and 2023), representing 157 maternal lines. Seed mass averaged 0.278 g/100 seeds.

All seed collections were made by hand in accordance with permit guidelines and Center for Plant Conservation best practices. Less than 5% of viable seed was collected from a population and seeds were collected by maternal line to preserve the genetic structure of wild populations. When collections were sufficiently large (e.g., >30 seeds per maternal line, 50 maternal lines), a portion of each collection was divided and sent to the USDA's National Laboratory for Genetic Resources Preservation (NLGRP) in Fort Collins, CO for backup storage. Small collections are housed entirely in the Santa Barbara Botanic Garden Conservation Seed Bank.

Table 10. *Clarkia purpurea* ssp. *immaculata* seed collections.[1,2]

SBBG Access. Number	Date of Collection	Propagules Collected (No.)	# of Matern. Lines	Source	Site Name	Latitude	Longitude
2020_01700	6/29/2020	2632	50	Wild	Ormonde West	35.180782	-120.613146
2020_03500	7/16/2020	4763	56	Wild	Ormonde East	35.173850	-120.607350
2020_03600	7/16/2020	2734	47	Wild	Price Canyon Rd	35.191047	-120.615944
2021_09600	8/6/2021	1688	39	Wild	Price Canyon Rd	35.191140	-120.615932
2021_09700	8/6/2021	2143	50	wild	Ormonde East (Plot 3)	35.173359	-120.606660
2022-090	6/16/2022	TBD	16	wild	Ormonde Rd East	35.1734239	-120.6067427
2022-176	2022	1060	Bulk	nursery	Greenhouse grown 2022.[2]	n/a	n/a
2022-177	2022	7584	Bulk	nursery	Greenhouse grown. 2022[2]	n/a	n/a

[1] Seeds collected by and stored in the Santa Barbara Botanic Garden Conservation Seed Bank.

[2] Plants derived from germination testing were used for seed bulking in the Santa Barbara Botanic Garden nursery. Seeds were collected in bulk; these ex situ-produced collections were not sent to NLGRP for backup storage.

Table 11. *Deinandra increscens* spp. *increscens* seed collections.[1]

SBBG Access. Number	Date of Collection	Propagules Collected (No.)	# of Matern. Lines	Source	Site Name	Latitude	Longitude
2020_03700	7/27/2020	7170	104	wild	Lions Head VAFB	34.871179	-120.622327
2020_03800	7/28/2020	1065	51	wild	JLDP Plot 1	34.447356	-120.458504
2020_03900	7/28/2020	1288	50	wild	JLDP Plot 2	34.447308	-120.452696
2020_04000	7/28/2020	432	38	wild	JLDP Plot 3	34.451395	-120.449609
2021_00100	8/13/2020	2117	47	wild	JLDP Plot 1	34.447356	-120.458504
2021_00200	8/13/2020	1394	50	wild	JLDP Plot 2	34.447308	-120.452696
2021_00300	8/13/2020	1148	50	wild	JLDP Plot 3	34.451395	-120.449609
2021_00400	8/13/2020	1629	50	wild	JLDP Plot 4	34.452227	-120.440726
2021_10500	8/9/2021	1466	50	wild	JLDP Plot 1	34.448109	-120.459126
2021_10600	8/9/2021	2344	50	wild	JLDP Plot 2	34.447762	-120.453025
2021_10700	8/9/2021	1336	48	wild	JLDP Plot 3	34.450805	-120.448900
2022-094	6/15/2022	423	50	wild	Gaviota State Park	34.4722031	-120.1988769

[1] Seeds collected by and stored in the Santa Barbara Botanic Garden Conservation Seed Bank.

Table 12. *Hooveria purpurea* var. *reducta* seed collections.[1]

SBBG Access. Number	Date of Collection	Propagules Collected (No.)	# of Matern. Lines	Source	Site Name	Latitude	Longitude
2021_05700	6/4/2021	130	25	wild	Red Hill Rd. (site 1 and 2)	35.400950	-120.279619
2021_07000	6/4/2021	156	23	wild	Red Hill Rd. (site 3)	35.389369	-120.287330
2023-106	6/20/2023	480	59	Wild	Red Hill Rd.	35.389467	-120.287316
2023-107	6/20/2023	435	50	Wild	Red Hill Rd.	35.389467	-120.287316

[1] Seeds collected by and stored in the Santa Barbara Botanic Garden Conservation Seed Bank.

Table 13. Accessions backed up at National Laboratory for Genetic Resources Preservation (NLGRP). Not all collections were backed up at NLGRP. Only collections with a sufficient number of wild-collected seeds were divided for backup storage at NLGRP. Small collections are housed entirely in the Santa Barbara Botanic Garden Conservation Seed Bank.

Scientific name	SBBG Accession Number	NLGRP	NLGRP Active Bulk	# of Maternal Lines
Clarkia speciosa ssp. *immaculata*	2020_01700	923	121	50
Clarkia speciosa ssp. *immaculata*	2020_03500	1824	462	56
Clarkia speciosa ssp. *immaculata*	2020_03600	1018	151	47
Clarkia speciosa ssp. *immaculata*	2021_09600	627	155	39
Clarkia speciosa ssp. *immaculata*	2021_09700	621	135	50
Hooveria purpurea var. *reducta*	2021_05700	0	0	25
Hooveria purpurea var. *reducta*	2021_07000	0	0	23
Deinandra increscens ssp. *villosa*	2020_03700	2716	669	104
Deinandra increscens ssp. *villosa*	2020_03800	145	35	51
Deinandra increscens ssp. *villosa*	2020_03900	226	130	50
Deinandra increscens ssp. *villosa*	2020_04000	0	0	38
Deinandra increscens ssp. *villosa*	2021_00100	488	379	47
Deinandra increscens ssp. *villosa*	2021_00200	374	87	50
Deinandra increscens ssp. *villosa*	2021_00300	191	47	50
Deinandra increscens ssp. *villosa*	2021_00400	312	169	50
Deinandra increscens ssp. *villosa*	2021_10500	298	273	50
Deinandra increscens ssp. *villosa*	2021_10600	461	530	50
Deinandra increscens ssp. *villosa*	2021_10700	311	379	48

Subtask 4.2 – Test Seed Viability and Germination

In 2021, SBBG initiated viability tests of Gaviota tarplant and Pismo Clarkia seeds. Seeds were plated onto agar gel in petri dishes and placed into a seed germination chamber set at a diurnal schedule mimicking winter conditions (12-hour days at 20°C, 12-hour nights at 7°C). Seed germination was monitored at least three times per week and seedlings were transplanted into SBBG's nursery. Germination trials for Camatta Canyon amole were delayed until 2023 because of lack of sufficient seed.

Based on germination tests conducted by SBBG, Pismo Clarkia has high seed viability (89%) and no dormancy under the conditions tested. Cut tests conducted separately estimated viability of 76% (19 of 25 seeds cut were filled).

Table 14. Seed viability and germination of Pismo Clarkia.

Accession #	Treatment	Seeds Tested (#)	Total Germ.	Filled (#)	Empty (#)	Moldy (#)	Infest. (#)	Tot. Germ. (%)	Germ. / Filled (%)
2020-036	None	9	7	0	2	0	0	78%	100%
2020-035	None	10	9	0	1	0	0	90%	100%
2020-017	None	10	10	0	0	0	0	100%	100%

Based on germination tests conducted by SBBG, Gaviota tarplant has high seed viability (90% for accessions tested), but variable germination. Gaviota tarplant produces two different achene morphologies, depending on the parental floral morphology. Preliminary data suggest that seeds produced by disk flowers exhibit nearly 100% germination without treatment, but those produced by ray flowers germinate much less readily. To address this dichotomous germination, SBBG implemented several treatments to try to increase the germination rates of ray achenes. Interestingly, plants in the SBBG nursery were found to produce nearly five times the number of viable ray seeds compared to disk seeds, which aligns with anecdotal evidence from seed cleaning wild plant collections. This differential germination likely represents a bet-hedging strategy, whereby disk seeds germinate readily at the onset of winter rains, while ray seeds are designed to build a persistent soil seed bank. Cut tests conducted separately estimated viability of 78% (43 of 55 achenes cut were filled, without differentiating between ray and disk morphs).

Table 15. Seed viability and germination of Gaviota tarplant.

Source	Acc #	Treat.	Seeds Tested (#)	Total Germ.	Filled (#)	Empty (#)	Moldy (#)	Infest. (#)	Tot. Germ. (%)	Germ. / Filled (%)
Ray flower	2021-023	None	10	1	9	0	0	0	10%	10%
Ray flower	2020-060	None	10	4	4	2	0	0	40%	50%
Disk flower	2021-022	None	10	10	0	0	0	0	100%	100%
Disk flower	2021-020	None	10	9	0	1	0	0	90%	100%
Ray flower	2021-020	None	10	0	6	3	1	0	0%	0%
Ray flower	2021-022	nick, 2hr soak	9	0	8	1	0	0	0%	0%
Ray flower	2021-021	None	10	0	9	1	0	0	0%	0%
Disk flower	2021-023	None	10	10	0	0	0	0	100%	100%
Disk flower	2020-060	None	9	8	0	1	0	0	89%	100%
Disk flower	2021-021	None	10	10	0	0	0	0	100%	100%

Seeds from 2023's collection effort of Camatta Canyon amole were plated onto agar gel and placed in a germination chamber for germination testing. Ten seeds from each accession were plated on agar and placed into a germination chamber set to a diurnal program that mimics winter germination conditions on the central coast. As of the writing of this report, no seeds have germinated. Per usual germination protocols, the seeds were not subjected to any treatment prior to germination. After four weeks in the germination chamber, no germination was observed and seeds were moved into the refrigerator at approximately 4°C. Due to the inherent dormancy found in many California native plant seeds, it is relatively common to wait months before observing germination or implementing a treatment that works for any given species. A cut test of 5 seeds from each accession revealed that 100% of the seeds were filled (i.e., potentially viable). SBBG also noted that the seeds appear to be rich in phytomelanin, which serves to discourage granivores and prevent desiccation. Phytomelanin-rich seeds are common in the family Asteraceae and the order Asparagales, to which Camatta Canyon amole belongs. This thick, hard seed coat likely contributes to dormancy mechanisms and suggests that seed treatment may be needed to elicit germination.

Subtask 4.3 – Collect Plant Tissue

Leaf tissue samples were collected in conjunction with project vouchers for Pismo Clarkia and Gaviota tarplant. Due to the small amount of leaf material available, a tissue sample was not collected from Camatta Canyon amole. However, future researchers could potentially sample tissue from the voucher specimen or grow seeds from the conservation seed bank to produce fresh tissue. To obtain a tissue sample, fresh green leaf tissue was sampled from individual plants and placed into paper coin envelopes stored in plastic zip top bags filled with silica desiccant. Those samples will be stored at the Santa Barbara Botanic Garden Tissue Bank for future research use. Some of the Gaviota tarplant tissues are being included in a distribution-wide genetics study being conducted by SBBG staff that is separately funded and not yet complete.

Table 16. Plant tissue sample collections.

Taxon	Collector #	Date	Site name	Latitude	Longitude
Clarkia speciosa ssp. *Immaculata*	HES808	5/14/2020	Ormonde Rd. West	35.17385	-120.60735
Deinandra increscens ssp. *villosa*	CMG6109	6/20/2020	Vandenberg Space Force Base, Lion's Head	34.85283	-120.60245
Deinandra increscens ssp. *villosa*	CMG6033	5/29/2020	Gaviota State Park	34.47298	-120.1988
Deinandra increscens ssp. *villosa*	KHL3010, 3111	6/27/2020	Jack and Laura Dangermond Preserve	34.44521	-120.45761
Deinandra increscens ssp. *villosa*	KHL3115	6/27/2020	Jack and Laura Dangermond Preserve	34.44707	-120.45277

Conclusions

The regional invasive plant risk index we developed for listed plants in the central coast region of California provides a straightforward visual overview of the relative risk of invasive plants to across rare plant species, rare plant populations, and geographic locations. Results suggest that coastal populations of listed species are generally at higher risk and that a handful of low-growing annual species are especially vulnerable (see Table 4). High and moderate risk species and populations are those where management should be prioritized. Specifically, sites with iceplant, heavy annual grass cover and associated thatch, and perennial veldt grass should be considered for careful management. We believe that similar regional risk assessments conducted for the remainder of the state would be beneficial, and we currently have a Section 6 grant proposal in review to continue risk scoring for the south coast region of California.

More site-specific survey data and analysis are needed for many rare plant populations in the central coast region, especially those that are further inland. Our confidence scores for populations and species provide guidance for which of each need more field-based evaluation of potential risk. Our collective knowledge of the impacts from invasive plants could be improved by implementing more consistent documentation of invasive plant risk data. Observations of co-occurrence and potential impacts can be relatively easily collected during seed collection (CaPR) activities, as is currently being done by SBBG and CBG. Key attributes to collect include presence of known impactful invasive plants (including annual grasses and associated thatch) and their approximate cover at a site. Both SBBG and CBG are supportive of these standardization measures and may be able to help lead the way in standardizing data entry for others involved in CaPR.

We characterized site-level conditions, associations with invasive plant cover, and plant density ranges at each of nine plots across three sites for our three focal species: Pismo Clarkia, Gaviota tarplant, and Camatta Canyon amole. We found that invasive plant associations differ for each of the three species, as describe below. Lastly, we – through subcontract with SBBG –collected viability and germination data for all three species. Pismo Clarkia has high viability and low dormancy. Gaviota tarplant has dimorphic seeds with apparent high viability, including both highly dormant and non-dormant seed. Initial seed germination trials for Camatta Canyon amole suggest that it has high dormancy and relatively high viability.

Pismo Clarkia appears to be strongly affected by within-season competition by annual grasses and other non-native vegetation. Furthermore, its germination appears to be strongly affected by thatch. Drought had an especially dramatic impact on this species, likely because of its low seed dormancy. However, plants are phenotypically plastic and plants can produce a multitude of fruits (and seed) even under low germination conditions if growing conditions are favorable.

Gaviota tarplant appears to have a negative relationship with the combined effects of different invasive plant species and thatch. It too can compensate for reduced germination by producing large plants with many flower heads. Its relationship with surrounding ground cover is complex and warrants more research. Our Section 6 grant proposal in review includes experimental management trials on invasive grass and iceplant cover at sites that we have surveyed as part of this study at the Dangermond Preserve, which would help to answer questions about the relationship between invasive plant cover and tarplant reproductive output and density trends.

Camatta Canyon amole, the only perennial studied in detail, appears to have a negative relationship with annual grass and thatch cover and only a limited ability to compensate with reproductive output when conditions are not favorable beyond remaining dormant. Longer-term studies are needed to better understand the specific role that invasive plants and thatch cover play on both reproduction and episodic germination of this species.

New conservation seed collections for all three species have helped to further ensure the long-term conservation of the populations of these species that were studied. Furthermore, sufficient seed of both Gaviota tarplant and Pismo Clarkia were collected to enable SBBG to do seed bulking, a critical step for preserving and restoring populations.

The approach taken in this project demonstrates the utility of cross-cutting study at several levels for informing management aimed at protecting rare plant populations. The approach can be refined as it is applied for use in other regions in the future.

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Appendix 1. Plant Character Matrix
Appendix 2. Invasive Plant Risk Scoring Guide
Appendix 3. Confidence Scoring
Appendix 4. Plot Photos for Pismo Clarkia
Appendix 5. Plot Photos for Gaviota Tarplant
Appendix 6. Plot Photos for Camatta Canyon Amole