Enhancing the Resilience of Edaphic Endemic Plants:


San Diego thornmint

Conceptual Models


Thread-leaved brodiaea


Dehesa nolina


Otay tarplant


Parry's tetracoccus

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Introduction

The Conservation Biology Institute (CBI) is working with project partners to enhance the resilience of five edaphic endemic plant species across their ranges. Our approach is to identify and describe geographic areas that could potentially support these species and their habitat in a design that enhances regional population structure and resilience. Results will help refine our understanding of environmental correlates, species dispersal and distribution, management priorities, and potential locations to restore populations and allow range shifts to adapt to climate change.

As part of this effort, we refined or developed species-specific conceptual models to identify environmental covariates, focus field assessments, highlight management needs, and inform spatially explicit statistical models identifying potentially suitable habitat for the five target species in this study:

- San Diego thornmint (*Acanthomintha ilicifolia*)
- Thread-leaved brodiaea (*Brodiaea filifolia*)
- Otay tarplant (*Deinandra conjugens*)
- Dehesa nolina (*Nolina interrata*)
- Parry's tetracoccus (*Tetracoccus dioicus*)

These species are covered under Natural Community Conservation Plans (NCCPs) and are priority species for management under the San Diego Management and Monitoring Program's Management Strategic Plan for western San Diego County (SDMMP 2013). In addition, these species represent multiple life forms and occur in multiple NCCP Plan areas.

This work builds on previous studies geared towards identifying threats and management strategies for these species, including:

- San Diego Thornmint Adaptive Management Framework (CBI 2014)
- South County Grasslands project (CBI and TNC 2012, additional work in-progress)
- Dehesa Nolina Conservation Vision and Management Strategy (CBI 2015)
- Management Strategic Plan for Western San Diego County (SDMMP 2013)

Table 1 provides the regulatory status, NCCP(s), and MSP management category for each target species.

Table 1

Target Species

Scientific Name[1]	Common Name	Regulatory Status[2]	NCCP[3]	MSP Management Category[4]
Acanthomintha ilicifolia	San Diego thornmint	FT/CE	MSCP NCP	SO
Brodiaea filifolia	Thread-leaved brodiaea	FT/CE	MSCP MHCP MSHCP	SS
Deinandra conjugens	Otay tarplant	FT/CE	MSCP	SS
Nolina interrata	Dehesa nolina	---/CE	MSCP	SO
Tetracoccus dioicus	Parry's tetracoccus	---/---	MSCP MHCP NCP	SS

[1] Plant species nomenclature generally follows Baldwin et al. 2012.

[2] Regulatory Status: FT = Federally threatened; CE = State endangered.

[3] NCCP (Natural Community Conservation Plan): MSCP = City of San Diego Multiple Species Conservation Plan; MHCP = San Diego Multiple Habitat Conservation Plan; MSHCP = Western Riverside County MSHCP; NCP = proposed San Diego North County Plan (SDMMP 2013).

[4] MSP Management Categories: SO = species with significant occurrence(s) at risk of loss from MSP area; SS = species stable but still requires species-specific management to persist in MSP area.

In this document, we present refined conceptual models for San Diego thornmint (CBI 2014), thread-leaved brodiaea (Lewison et al. 2012), Otay tarplant (Strahm 2012), and Dehesa nolina (CBI 2012), and a new conceptual model for Parry's tetracoccus. These models apply to management of the species range-wide, but may require minor modifications for specific sites.

Conceptual Model Development

In adaptive management, conceptual models align management actions with science and plan goals and objectives (Gross 2003). They make implicit ideas explicit and identify areas of critical uncertainty. These models can take many forms, from a simple written statement to a complex diagram showing numerous interconnected elements. Regardless of structure, conceptual models serve to formalize our best understanding of system dynamics and identify relationships between different aspects of the system. For the purposes of adaptive management, conceptual models must be concise and constrained by management goals and scientific consensus. Models should show enough complexity to allow for a selection of achievable management actions, but not so complex as to show all possible relationships, especially those not associated with management goals.

Process

We adopted the format proposed by Hierl et al. (2007) and refined by the Institute for Ecological Monitoring and Management (IEMM) in a conceptual model workshop (Lewison et al. 2012). This format has been used for other rare plant species in San Diego County including San Diego thornmint (CBI 2014) and Otay tarplant (Strahm 2012).

Hierl et al. (2007) described six steps for creating a conceptual model for adaptive management:

1. Identify the conservation management and monitoring goal.
2. Identify anthropogenic threats to the species.
3. Identify natural drivers of the species.
4. Identify variables within the species biology/ecology that evaluate (a) if the goal has been met and (b) the response to management.
5. Describe potential management activities and what processes they will affect (as part of an iterative process).
6. Identify critical uncertainties (as part as an iterative process).

Structure

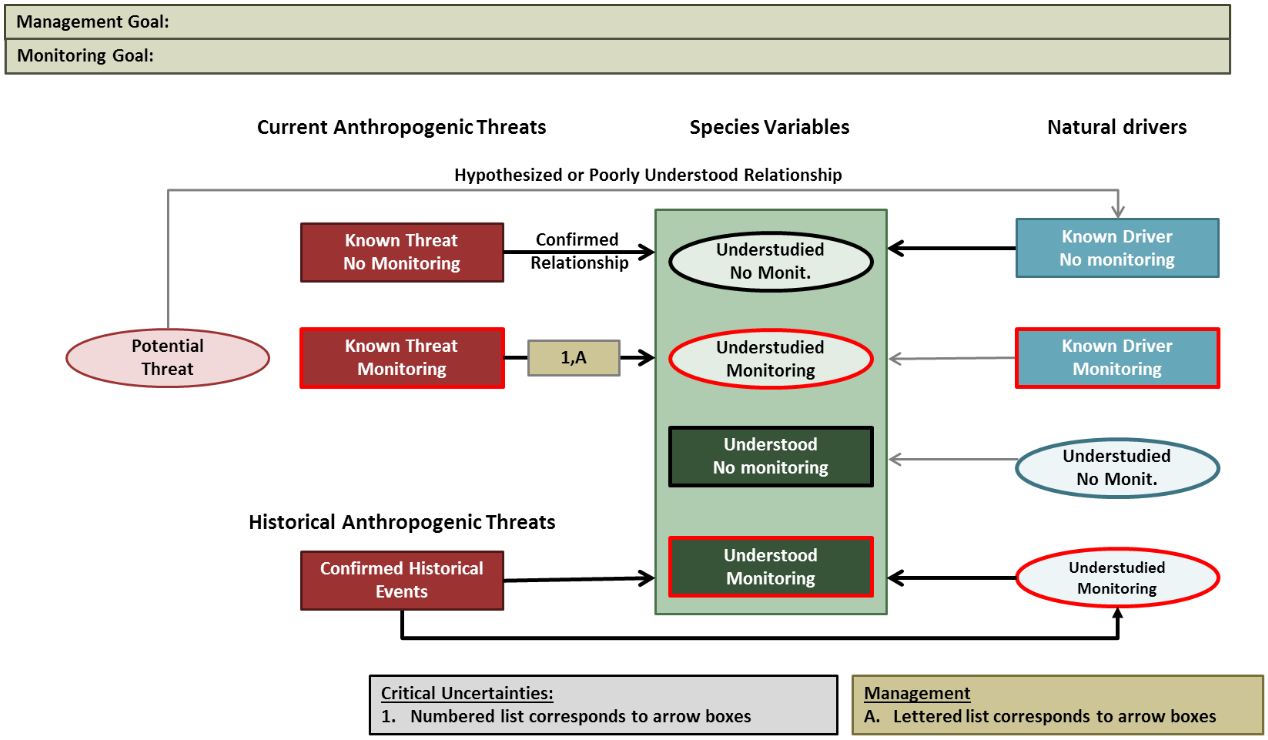
Conceptual models included in this document follow the same general structure, as outlined below and depicted in Figure 1:

- Management and monitoring goals are listed at the top of the model.
- Model elements are separated into three broad categories: anthropogenic threats (red), species variables (green), and natural drivers (blue).
- Arrows indicate the direction of relationships between model elements, with black lines depicting known relationships and grey lines depicting putative or hypothetical relationships that have yet to be confirmed.

In general, conceptual models should avoid including critical uncertainties or hypothetical statements about process. However, we have included some of the most important questions in light-colored circles where very little is known about a species. We also list critical uncertainties and potential management actions at the bottom of the model. Critical uncertainties and management actions related to known processes are included in the model with a corresponding number or letter in a box next to the model element or relationship they are intended to influence. Critical uncertainties and management actions which constitute model elements, or whose potential actions are unknown, are included only at the bottom of the diagram. For these models, arrows for anthropogenic and natural drivers point to the species, in general, but not necessarily to specific variables. Detailed narratives are provided in tables following the models.

Figure 1

Diagram of General Model Structure[1]



[1] Management and monitoring goals are listed at the top. Anthropogenic threats are in red or pink (for critical uncertainties). Species variables are in green (light green for critical uncertainties). Natural species drivers are in blue (light blue for critical uncertainties). Elements for which we have scientific information are shown in boxes, while understudied or poorly understood elements are in ovals. Black arrows indicate certain relationships; grey arrows indicate potential or poorly understood relationships; arrows point at species box and not necessarily specific variables. Elements outlined in red are monitoring targets.

Conceptual Models and Model Narratives

San Diego thornmint (*Acanthomintha ilicifolia*)

San Diego thornmint is an annual species that is restricted to San Diego County and Baja California, Mexico (CNDDB 2013, Beauchamp 1986, SANDAG 2012). Within San Diego County, thornmint occurs on clay soils or clay lenses in chaparral, scrub, and grassland habitats (Oberbauer and Vanderwier 1991, SANDAG 2012). At the regional-level, this species is threatened by invasive plants, small population size (and possible inbreeding depression), altered fire regimes, habitat fragmentation, nitrogen deposition, and climate change (Bauder and Sakrison 1997, 1999, Lawhead 2006, USFWS 2009a, Conlisk et al. 2012, and others). Preserve-level impacts include invasive plants, trampling, and competitive native plants, among others (Bauder and Sakrison 1997, 1999, Lawhead 2006, USFWS 2009a, CBI 2014).

San Diego thornmint occurs in a relatively large number of populations for a rare species; however, many of these populations face multiple challenges that threaten population and, possibly, species' persistence across the region. CBI and SDMMP (2014) prepared a framework management plan for San Diego thornmint that identified a number of management strategies to enhance species persistence in both the short- and long-term. Potential strategies (among others) include establishing thornmint in suitable but unoccupied habitat within the current species' range to fill gaps in connectivity and promote genetic flow, or translocating San Diego thornmint into suitable habitat beyond the current species' range to facilitate dispersal in response to climate change. The framework plan further identified the need for soil testing for this species to examine potential soil correlates for use in future establishment or translocation efforts.

Refer to Figure 2 for the San Diego thornmint conceptual model diagram and Table 2 for the accompanying model narrative.

Thread-leaved Brodiaea *(Brodiaea filifolia)*

Thread-leaved brodiaea is a perennial herb (geophyte) endemic to southern California. It occurs in San Diego, Los Angeles, Orange, Riverside and San Bernardino counties. In addition to historic habitat loss from development, the species is threatened by invasive plant species, particularly nonnative grasses such as *Brachypodium distachyon*.

Aside from basic information about distribution, life-history, and breeding system, there are no published studies on the biology of thread-leaved brodiaea. However, there have been many restoration efforts for this species, and results of these efforts are described and summarized in USFWS recovery documents (USFWS 1998, 2009, 2011). Thread-leaved brodiaea reproduces both by seed and by clonal propagation of the underground corms (bulb-like storage organs) from which above ground leaves are produced each winter (Niehouse 1971). Research on *Brodiaea* species in general indicates that they are genetically self-incompatible and thus require pollinators for gene flow, sexual reproduction, and seed production (Niehouse 1971). Observations of thread-leaved brodiaea populations suggest that clonal reproduction from corms is more common than recruitment from seed (USWS 1998, 2009, 2011). Reports from restoration efforts suggest that herbivores such as rabbits and gophers may influence brodiaea population dynamics by consuming corms and thus, reducing population size (USFWS 2009b, 2011). Thread-leaved brodiaea is strongly associated with clay soils (although it occasionally occurs on non-clay alkaline soils), which restrict its potential distribution and suitable areas for restoration or transplantation (USFWS 1999, 2009, 2011). Targeted soil studies on Camp Pendleton (AMEC 2009) identified soil parameters that may drive the distribution of this species; the current study intends to expand that effort to other areas of San Diego County where this species occurs.

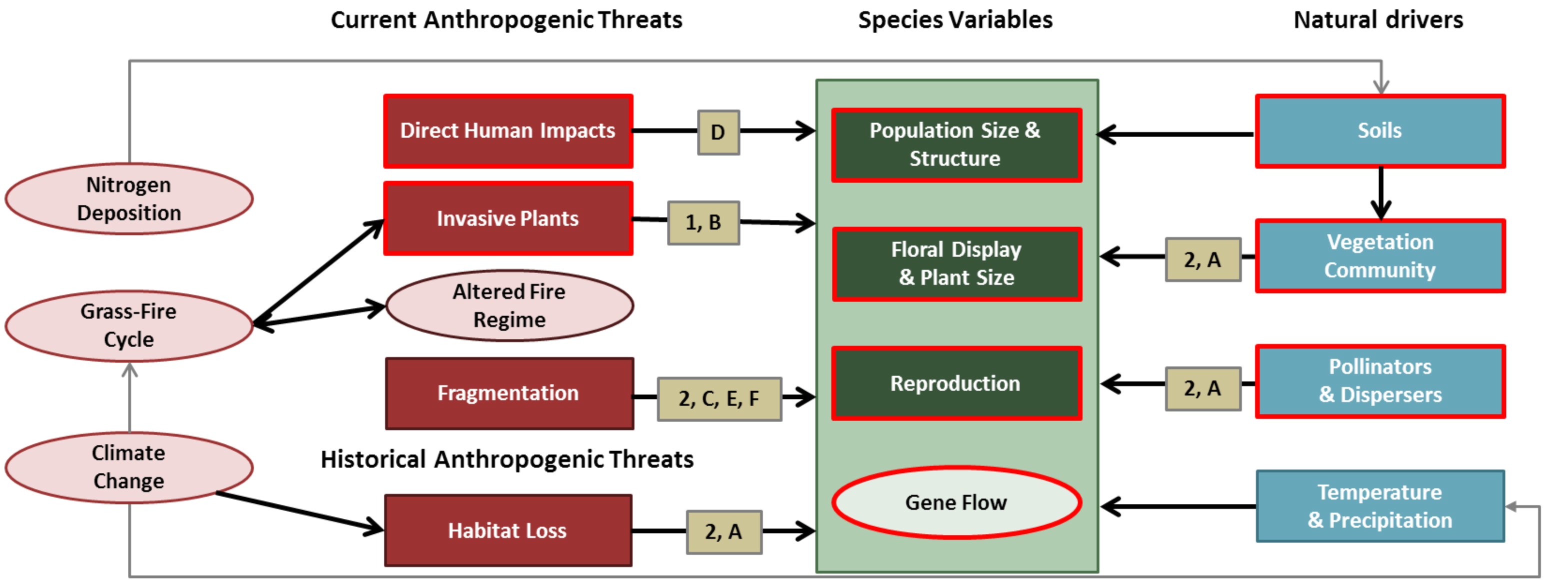
Refer to Figure 3 for the thread-leaved brodiaea conceptual model diagram and Table 3 for the accompanying model narrative.

Figure 2

Conceptual Model Diagram: San Diego Thornmint (*Acanthomintha ilicifolia*)

Management Goal: Maintain large populations, enhance small populations, and establish new populations or pollinator habitat to buffer against environmental stochasticity, maintain genetic diversity, and promote connectivity, thereby enhancing resilience within and among MUs over the long-term (>100 years) in native habitats.

Monitoring Goal: Monitor extant, conserved populations annually to assess population status , identify threats, and determine management needs.



<u>Critical Uncertainties:</u>

1. Best management practices (BMPs) for habitat restoration/enhancement.
2. BMPs for controlling invasive plants.
3. Pollinator attractants.
4. Seed storage, germination rates, and propagation methods.

Others: Visualized Processes

<u>Management</u>

A. Restore/enhance habitat, including pollinator habitat.
B. Control weeds.
C. Enhance connectivity via ‘steppingstone’ populations.
D. Control access.
E. Collect and bank seeds.
F. Move seeds to facilitate gene flow.

Table 2

Conceptual Model Narrative: San Diego Thornmint (*Acanthomintha ilicifolia*)

Goals		
Management	Maintain large populations, enhance small populations, and establish new populations or pollinator habitat to buffer against environmental stochasticity, maintain genetic diversity, and promote connectivity, thereby enhancing resilience within and among MUs over the long-term (>100 years) in native habitats.	
Monitoring	Monitor extant, conserved populations annually using a regional monitoring protocol to assess population status (abundance, spatial extent), identify threats, and determine management needs.	
Anthropogenic Threats		
Direct Human Impacts	Human-related activities can result in plant mortality, reduced reproduction, and limited seed bank inputs through trampling, soil surface disturbance, erosion, and/or dispersal of nonnative propagules. Potential sources of disturbance include recreational activities (motorized ORVs, hiking, biking), irrigation runoff from adjacent development, and grazing (not currently an issue in San Diego County).	USFWS 2009a
Invasive Plants	Invasive species (primarily grasses and forbs) are the primary threat to San Diego thornmint persistence. Invasive plants out-compete thornmint for resources (nutrients, light, water, space), thus affecting thornmint size and reproductive output; suppress germination (thatch); potentially alter soil chemistry; and potentially contribute to a grass-fire cycle which may result in habitat alteration. Invasive species that produce dense thatch may impact potential pollinators (e.g., ground-dwelling bees).	Bauder and Sakrison 1997, 1999, Lawhead 2006, USFWS 2009a, Klein 2009
Fragmentation	Fragmentation due to development or other disturbance may result in population isolation and reduced gene flow. Conserved populations in proximity to development are subject to increased invasive species, herbivory, erosion, trampling. If San Diego thornmint is self-incompatible, fragmentation could represent a severe threat to the species.	USFWS 2009a
Habitat Loss	Habitat loss has been reduced since listing and is no longer the primary threat.	USFWS 2009a

Table 2

Conceptual Model Narrative: San Diego Thornmint (*Acanthomintha ilicifolia*)

Natural Drivers		
Soils	Small clay lenses within a larger matrix of non-clay soil; the species appears restricted to clay soils, including clays derived from gabbro rock. The presence of appropriate soil determines the distribution of potential habitat. The narrow extent of suitable soils exacerbates the role of habitat loss and fragmentation as a threat.	Oberbauer and Vanderwier 1991, USFWS 2008
Vegetation Community	Grasslands, coastal sage scrub, and chaparral; suitable associations must support thornmint pollinators.	USFWS 2008, SANDAG 2012
Temperature & Precipitation	Rainfall and temperature both affect germination rate and successful reproduction.	Bauder and Sakrison 1997, USFWS 2009a
Pollinators & Dispersers	Dominant visitors/effective pollinators appear to be bees in the Apidae and Halictidae families. Seeds appear to be primarily gravity-dispersed; other dispersal events are probably localized.	Bauder and Sakrison 1997, Klein 2009
Herbivory	Herbivory has been reported (e.g., rabbits, possibly snails), but is not considered a widespread threat or primary driver at this time, so is not included in the conceptual model.	City of San Diego 2005, USFWS 2009a
Species Variables (Measurable Aspects of Species Response)		
Population Size & Structure	Includes population size, shape, geographic distribution, and fluctuations associated with environmental and demographic stochasticity.	Bauder and Sakrison 1999, USFWS 2009a
Floral Display & Plant Size	Includes plant biomass and flower visibility, plant height, branching, and flower production. Biomass is related to seed production; visibility is important in attracting pollinators.	Bauder et al. 1994, Bauder and Sakrison 1997, 1999, Klein 2009
Reproduction	Includes plant fecundity (seed production), seed viability and germination rates, and inputs to seed bank.	Bauder and Sakrison 1997, Bauder and Sakrison 1999
Critical Species Variables Uncertainties		
Gene Flow	The breeding system is unknown. Insect visitation to flowers has been observed, so outcrossing may be the primary breeding mechanism. Other species of *Acanthomintha* exhibit some level of self-compatibility; however, the presence of sterile upper stamens suggests that	Steek 1995, Bauder and Sakrison 1997, Scalfani 2005, USFWS 2009a, Klein 2009

Table 2

Conceptual Model Narrative: San Diego Thornmint (*Acanthomintha ilicifolia*)

	self-pollination may be limited in San Diego thornmint. Small populations may be susceptible to inbreeding and genetic drift.	
Critical Process Uncertainties		
Climate Change	Predicted warming temperatures may result in drier and hotter conditions in southern California in the future. Potential impacts to thornmint include (1) reduced germination and smaller population sizes; (2) inhibited germination; (3) increase in nonnative species due to a shift in timing of annual rainfall; (4) reduced pollinator effectiveness if timing of pollinator life-cycles and thornmint flowering become offset; and (5) increased fire frequency and subsequent erosion and nonnative/native plant invasion.	Bergengren et al. 2001, Araujo and New 2007, Westerling and Bryant 2008, Conlisk et al. 2013
Altered Fire Regime	Altered fire regimes may affect population abundance by increasing seed mortality or promoting invasive species.	Bauder and Sakrison 1999, USFWS 2009a, Conlisk et al. 2013
Grass-Fire Cycle	Nonnative grasses increase the fine fuel load and fire risk, and the reduced fire return interval then promotes nonnative grasses, leading to habitat type conversion. This cycle may affect soil and water budgets, increase erosion, promote invasive plant species, and impact pollinators. Habitat components that may be affected include bare ground and openings in shrub habitat, species composition, and cryptogamic crusts.	D'Antonio and Vitousek 1992, Brooks et al. 2004, Reiner 2007, and others
Nitrogen Deposition	Excess nitrogen may alter soil properties (including soil microbial community) and, subsequently, plant species composition and structure. Fire may alter/reduce effects of nitrogen deposition on productivity in the short-term. Most areas within the range of this species are likely affected by nitrogen deposition.	Allen et al. 1998, Zavaleta et al. 2003, Henry et al. 2006, Tonnesen et al. 2007, Talluto and Suding 2008, Vourlitis and Pasquini 2009, Bobbink et al. 2010, Fenn et al. 2010, Ochoa-Hueso and Manrique 2010, Ochoa-Hueso et al.

Table 2

Conceptual Model Narrative: San Diego Thornmint (*Acanthomintha ilicifolia*)

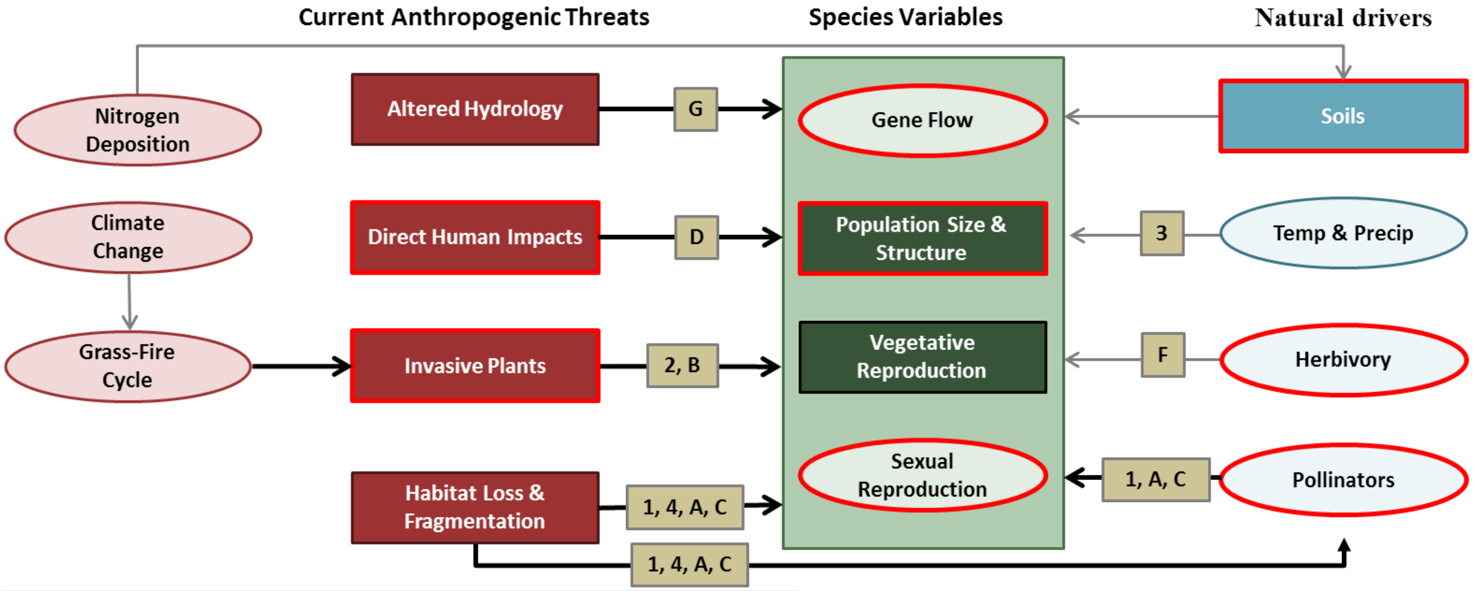
		2011
Potential Management Actions		
A	Restore or enhance suitable habitat, including habitat for pollinators.	
B	Control weeds to reduce competition and fire risk.	
C	Enhance connectivity via creation of “steppingstone” populations at sites with appropriate soils using a suite of techniques (e.g., seeding, pollinator release).	
D	Control access by closing and/or rerouting trails and roads inside populations where possible.	
E	Collect and bank seeds for propagation and conservation collections and genetic studies.	
F	Propagate, out-plant, and/or translocate seeds (of known genotypes) to improve connectivity and gene flow.	
Critical Management Uncertainties		
1	Develop/refine Best Management Practices (BMPs) for habitat restoration/enhancement (note: BMP development is in progress by CBI, City of San Diego, AECOM and others).	
2	Develop/refine BMPs for invasive plant control, including possible impacts of herbicide on pollinators (note: BMP development for invasive plants is in-progress as part of the *Brachypodium* control project).	
3	Investigate the effects of species abundance and plant size on floral display and pollinator attraction.	
4	Develop BMPs for seed storage, germination, and propagation (note: refer to SDMMP 2013 and San Diego thornmint Adaptive Management Framework for seed collection and storage BMPs; San Diego thornmint has been successfully propagated and out-planted by AECOM).	

Figure 3

Conceptual Model Diagram: Thread-leaved Brodiaea (*Brodiaea filifolia*)

Management Goal: Maintain very large and large populations and enhance and expand small populations to increase resilience to environmental stochasticity, maintain genetic diversity and ensure persistence over the long term (>100 years) in native plant communities.

Monitoring Goal: Monitor extant, conserved populations annually to assess population status , identify threats, and determine management needs.



Critical Uncertainties:
1. Best Management Practices (BMPs) for habitat restoration/enhancement.
2. BMPs for controlling invasive plants.
3. Apparent vs. actual population size
4. Propagation and transplantation methods.
5. Effective pollinators.
6. Hybridization with other species.
7. Influence of localized seed dispersal.

Others: Visualized Processes

Management

A. Restore/enhance habitat while promoting pollinators.
B. Control weeds.
C. Enhance connectivity by creating 'steppingstone' populations.
D. Control access.
E. Propagate, transplant, or translocate corms to restore populations, improve connectivity and gene flow.
F. Protect populations from herbivores.
G. Install erosion control devices.

Table 3

Conceptual Model Narrative: Thread-leaved Brodiaea (*Brodiaea filifolia*)

Goals		
Management	Maintain very large and large populations and enhance and expand small populations to increase resilience to environmental stochasticity, maintain genetic diversity and ensure persistence over the long term (>100 years) in native plant communities.	
Monitoring	Monitor extant, conserved populations using a regional monitoring protocol to assess population status (abundance, spatial extent), identify threats, and determine management needs.	
Anthropogenic Threats		
Altered Hydrology	Increased urban run-off and diversion of natural water flow modifies habitat suitability and causes corm mortality.	USFWS 1998, 2009b, 2011, Vinje pers. obs.
Direct Human Impacts	Authorized and unauthorized activities (e.g., fuel modification, biological monitoring, trespass) impact plants through trampling, habitat degradation, and invasive plant introductions.	USFWS 1998, 2009b, 2011, CNDDB 2012
Invasive Plant Species	Invasive plant species compete directly with thread-leaved brodiaea and alter habitat in ways that result in the loss of suitable habitat.	USFWS 1998, 2009b, 2011, CNDDB 2012
Habitat Loss/Fragmentation	Current and historic habitat loss and fragmentation may reduce genetic diversity and long-term resilience by impeding gene flow within and between populations.	USFWS 1998, 2009b, 2011
Natural Drivers		
Soils	Occurs primarily on soils with high clay content and occasionally on non-clay alkaline soils. The narrow extent of suitable soils exacerbates the role of habitat loss and fragmentation as a threat. Additional uncharacterized soil factors may also contribute to habitat suitability.	USFWS 1998, 2009b, 2011, AMEC 2009
Critical Natural Driver Uncertainties		
Temperature & Precipitation	Annual climatic conditions influence vegetative growth and flowering, although temperature and rainfall parameters (e.g., amount and timing of rainfall) that affect species response are uncertain.	USFWS 1998, 2009b, 2011, CNLM unpublished data
Herbivory	Corm damage/destruction (often by pocket gophers) has been shown to reduce population density in some *Brodiaea* species; herbivory has been noted for thread-leaved brodiaea, but the	Hobbs and Mooney 1995, Fiedler and Lavin 1996

Table 3

Conceptual Model Narrative: Thread-leaved Brodiaea (*Brodiaea filifolia*)

	level of damage is uncertain.	
Pollinators	Pollinators are required for sexual reproduction due to partial or complete self-incompatibility in this species. However, the importance of pollinators remains uncertain because the extent of self-incompatibility is unknown.	Keator 1968, Niehouse 1971, Doalson 1999
Species Variables (Measurable Aspects of Species Response)		
Population Size & Structure	Population size and structure reflect the abundance of corms in an occupied patch, and the proportion of vegetative versus flowering individuals in a given year.	USFWS 1998, 2009b, 2011, CNLM 2010
Vegetative Reproduction	Vegetative reproduction occurs through production of cormlets from underground corms, and appears to be more common than recruitment from seed. The resultant spatial clustering of genetically identical individuals may influence the frequency of sexual reproduction, which can probably only occur between distinct genotypes.	Taylor 1991, USFWS 1998, 2009b, 2011
Critical Species Variables Uncertainties		
Sexual Reproduction	The species is largely self-incompatible and thus, requires outcrossing to produce seed. While partial self-compatibility and modest seed set/viability may be possible via pollination of closely related individuals, the extent to which this occurs is unknown. The importance of sexual versus vegetative reproduction in terms of population size is also uncertain.	Niehouse 1971, Taylor 1991, USFWS 1998, 2009b, 2011
Gene Flow	*Brodiaea* species are generally self-incompatible and require pollinators to transfer pollen from unrelated individuals in order to produce viable seed. As a result, gene flow via pollinators is necessary for sexual reproduction. Some genetic systems may allow for partial self-compatibility whereby a limited number of viable seeds can be produced by self-pollination, but it is uncertain whether thread-leaved brodiaea has this capacity.	Niehouse 1971, Taylor 1991, USFWS 1998, 2009b, 2011
Critical Process Uncertainties		
Climate Change	Predicted warming temperatures may result in drier and hotter conditions in southern California	Bergengren et al. 2001, Araujo and

Table 3

Conceptual Model Narrative: Thread-leaved Brodiaea (*Brodiaea filifolia*)

	in the future. Potential impacts from climate change include (1) reduced germination and smaller population sizes, (2) reduced vegetative growth or flowering, (3) increase in nonnative species due to a shift in timing of annual rainfall, (4) shifts in flowering times that may result in lowered pollination success and/or loss of compatible pollinators, (5) altered photosynthetic rates and nutrient uptake that may result in increased growth and competition of nonnative species or an increase in herbivores, and (6) increased fire frequency and subsequent loss of habitat and invasion by nonnative plants.	New 2007, Westerling and Bryant 2008
Grass-Fire Cycle	Nonnative grasses increase the fine fuel load and fire risk, and the reduced fire return interval then promotes nonnative grasses, leading to habitat type conversion. This cycle may affect soil and water budgets, increase erosion, promote invasive plant species, and impact pollinators (e.g., ground-nesting bees). Vegetative and flowering production may increase temporarily following fire due to removal of thatch.	Stone 1951, Keator 1968, D'Antonio and Vitousek. 1992, Conlisk et al. 2013
Nitrogen Deposition	Excess nitrogen may alter soil properties (including soil microbial community) and subsequently, plant species composition and structure. Invasive plant species may benefit from increased nitrogen. Fire may alter/reduce effects of nitrogen deposition on productivity in the short-term. Most areas within the species range are likely affected by nitrogen deposition.	Bobbink et al. 2010, Fenn et al., 2010

Potential Management Actions	
A	Restore or enhance suitable habitat, including habitat for pollinators.
B	Control weeds.
C	Enhance connectivity via creation of “steppingstone” populations at sites with appropriate soils using a suite of techniques including seeding, corm transplantation/out-plantings, pollinator release, etc.
D	Control access by closing and/or rerouting trails and roads inside populations where possible.
E	Propagate, transplant, or translocate corms to restore populations and

Table 3

Conceptual Model Narrative: Thread-leaved Brodiaea (*Brodiaea filifolia*)

	improve connectivity and gene flow.
F	Protect populations from above-ground herbivores (note: there may be the potential to protect populations from below-ground herbivores during transplantation/out-planting of corms).
Critical Management Uncertainties	
1	Develop/refine Best Management Practices (BMPs) for habitat restoration/enhancement.
2	Develop/refine BMPs for invasive plant control, including possible impacts of herbicide on pollinators.
3	Determine detected versus actual population size. The number of corms in a population may be 1,000 to 10,000 times greater than number of flowering individuals which are the typical monitoring unit of measurement. Flowers are far easier to detect, which streamlines and standardizes counts, but these data provide a population size that is orders of magnitude smaller than the actual population size.
4	Develop/refine effective propagation and transplantation methods to offset local extirpations, supplement gene flow, and bolster dwindling populations. The ability to successfully propagate corms must be addressed if assisted migration is undertaken as a response to fragmentation and/or climate change.
5	Identify effective pollinators to guide management actions (e.g., expand bare ground for ground-nesting bees, control invasive plants, augment native plants) and locate potential connectivity areas based on pollinator dispersal capabilities.
6	Identify hybrids that may pose a threat to species persistence. Thread-leaved brodiaea may hybridize with congeners (*B. orcuttii*), although hybridization has not been confirmed with genetic testing and could represent undescribed species (Niehaus 1971, Chester et. al 2007, USFWS 1998, 2009, 2011).
7	Verify seed dispersal mechanisms. Seed dispersal is thought to be highly localized (e.g., gravity-dispersed), which would influence the distribution of self-incompatible alleles.

Otay Tarplant (*Deinandra conjugens)*

Otay tarplant is a late-spring-blooming annual herb endemic to southern San Diego County, where it occurs on clay soils and sub-soils. The primary threat to Otay tarplant is invasive plants, especially annual grasses and forbs (USFWS 2009c, IEMM 2012). Populations are also impacted by direct disturbance from off-highway vehicle activity, illegal trails, trampling, and maintenance of access roads, utility corridors, trails, and fuel modification zones. Otay tarplant is at risk of loss of genetic connectivity due to habitat fragmentation and a potential loss of pollinators (SDMMP 2013). Habitat fragmentation is of particular concern because Otay tarplant cannot cross-breed with genetically similar individuals.

CBI, The Nature Conservancy (TNC), and South County land managers developed a Management Vision for Otay tarplant, which identified three types of management areas critical to short-and long-term persistence of this species in the South County region: core habitat areas, restoration/expansion areas, and connectivity areas (CBI and TNC 2012). The latter two areas, in particular, may be targets for Otay tarplant out-planting or translocation to bolster species resilience to stochastic events. The South County grasslands project is currently developing BMPs for Otay tarplant propagation and habitat restoration (including invasives control). Refining soils and habitat covariate data for this species will help identify suitable restoration and translocation sites.

Refer to Figure 4 for the Otay tarplant conceptual model and Table 4 for the accompanying model narrative.

Dehesa Nolina (*Nolina interrata)*

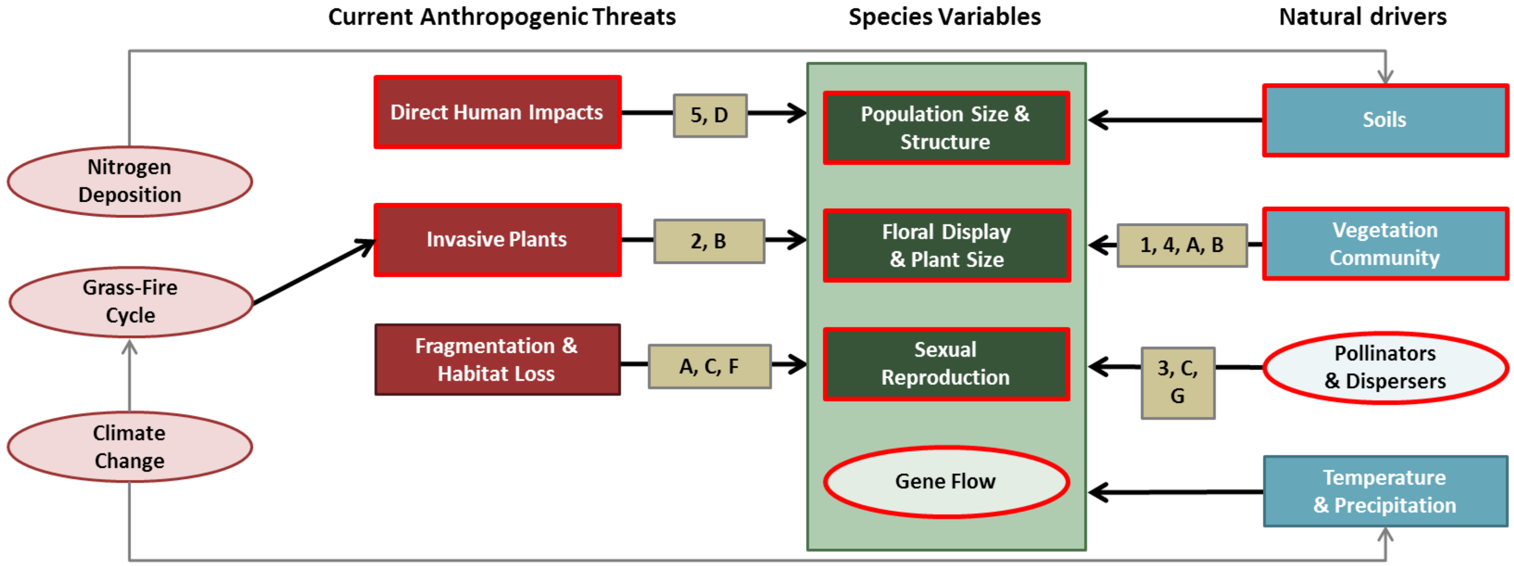
Dehesa nolina is a perennial herb that is endemic to San Diego County and Baja California, Mexico. This species is restricted to gabbroic or metavolcanic soils in chaparral or occasionally, coastal sage scrub or grassland habitats (Oberbauer 1979, 1991, Beauchamp 1986, Rombouts 1996, CNPS 2012, CBI 2012, 2015, McNeal and Dice 2016). Dehesa nolina is a fire-adapted, clonal species that re-sprouts from an underground stem, and also reproduces sexually through a dioecious breeding system (male and female flowers on separate plants) (Dice 1989, Rombouts 1996, CBI 2015). Flowering generally occurs between June and July, and is sporadic except where stimulated by fire or other disturbance (Oberbauer 1979, Dice 1988, USFWS 1995, Rombouts 1996, and others). Flowers are presumably insect-pollinated (Rombouts, 1996), so plants of different sexes must occur within range of one another to effect pollination and viable seed production (Rombouts 1996, CBI 2015). Based on the breeding system, species distribution, and dependence on fire or other disturbance for flowering, recruitment from seed is rare (Oberbauer 1979, Dice 1988).

Figure 4

Conceptual Model Diagram: Otay Tarplant (*Deinandra conjugens*)

Management Goal: Maintain large occurrences, expand small occurrences, and establish new occurrences to enhance connectivity , increase resilience to environmental stochasticity, maintain genetic diversity, and ensure persistence over the long-term (>100 years) in native plant communities.

Monitoring Goal: Monitor populations annually to assess population, identify threats, and determine management needs.



Critical Uncertainties:

1. Best Management Practices (BMPs) for habitat restoration/enhancement.
2. BMPs for controlling invasive plants, herbicide effects on pollinators.
3. Pollinators attractants.
4. Competition with other native species.
5. Disturbance experiments.
6. Spatial distribution of genetic variation and the rate of outcrossing.
7. Minimum patch size or s-allele diversity for adequate genetic mixing.
8. Seed storage, germination rates, and propagation methods.
9. Extent, viability, and longevity of soil seedbank.

Others: Visualized Processes

Management

A. Restore/enhance habitat.
B. Control weeds.
C. Enhance connectivity.
D. Control access.
E. Collect and bank seeds.
F. Move seeds to facilitate gene flow.
G. Promote pollinators.

Table 4

Conceptual Model Narrative: Otay Tarplant (*Deinandra conjugens*)

Goals		
Management	Maintain large occurrences, expand small occurrences, and establish new occurrences to enhance connectivity between occurrences and to increase resilience to environmental stochasticity, maintain genetic diversity, and ensure persistence over the long-term (>100 years) in native plant communities.	
Monitoring	Monitor extant, conserved populations annually using a regional monitoring protocol to assess population status (abundance, spatial extent), identify threats, and determine management needs.	
Anthropogenic Threats		
Direct Human Impacts	Authorized and unauthorized activities (e.g., utility maintenance, access roads, trails, fire breaks, off-highway vehicles, mountain bikes, equestrian use, grazing) resulting in above- or below-ground plant mortality.	USFWS 2004
Invasive Plant Species	Nonnative forbs and grasses that compete directly with Otay tarplant or suppress germination through thatch/litter accumulation.	USFWS 2004
Habitat Loss/Fragmentation	Current and historic habitat loss and fragmentation may reduce genetic diversity and long-term resilience by impeding gene flow within and between populations.	USFWS 2004
Natural Drivers		
Soils	Occurs primarily on clay soils, subsoils, or clay lenses. The narrow extent of suitable soils exacerbates the role of habitat loss and fragmentation as a threat.	USFWS 2004
Vegetation Community	Grassland, open coastal sage scrub, or maritime succulent scrub with appropriate soils. In addition, the vegetation community must support Otay tarplant pollinators year-round.	USFWS 2004
Temperature & Precipitation	Annual climatic conditions influence vegetative growth and flowering. Environmental stochasticity interacts with demographic stochasticity to create large fluctuations in population size each year.	USFWS 2004
Critical Natural Driver Uncertainties		
Pollinators & Dispersers	Insect-pollinated. The role of native versus nonnative pollinators, pollinator effectiveness,	USFWS 2004

Table 4

Conceptual Model Narrative: Otay Tarplant (*Deinandra conjugens*)

	and pollinator foraging ranges are unknown. Seeds are animal- and possibly, wind-dispersed.	
Species Variables (Measurable Aspects of Species Response)		
Population Size & Structure	The number of populations, their size, shape, and geographic distribution. Includes population density and cover, seedbank spatial characteristics and viability, population size fluctuations associated with environmental stochasticity, and genetic diversity within patches.	USFWS 2004
Sexual Reproduction	Includes seed production, adult fecundity, inputs to seedbank, and germination and viability rates.	USFWS 2004
Floral Display & Plant Size	Cover and visibility of plants and flowers, flower production, plant height, plant branching. Visibility is important for attracting pollinators.	USFWS 2004
Critical Species Variables Uncertainties		
Gene Flow	In general, genetic mixing and the prevention of inbreeding and genetic drift are the primary goals. Otay tarplant is self-incompatible, and cannot cross with itself or another individual that shares the same allele at the 's locus.'	USFWS 2004
Critical Process Uncertainties		
Climate Change	Climate change may result in species range shifts, fire regime alterations, habitat suitability changes, and invasive species increases, and compound the effects of demographic stochasticity. Some studies suggest that the most vulnerable species are in small populations, limited in distribution, and associated with certain habitats or edaphic conditions. A climate change vulnerability assessment suggested that other factors may mitigate the effects of climate change for some rare plants, including Otay tarplant, but it did not explicitly factor in the impact from invasive species. Refer to Table 2 for additional impacts to plant species from climate change.	Zavaleta et al. 2003, Henry et al. 2006, Bergengren et al. 2001, Araujo and New 2007, Westerling and Bryant 2008, Anacker et al. 2013, Conlisk et al 2013
Grass-Fire Cycle	Nonnative grasses increase the fine fuel load and fire risk, and the reduced fire return interval then promotes nonnative grasses, leading to habitat type conversion. This cycle may affect soil and	D'Antonio and Vitousek 1992, Henry et al. 2006, Syphard 2006

Table 4

Conceptual Model Narrative: Otay Tarplant (*Deinandra conjugens*)

	water budgets, increase erosion, promote invasive plant species, and impact pollinators.	
Nitrogen Deposition	Excess nitrogen may alter soil properties (including soil microbial community) and subsequently, plant species composition and structure. Invasive plant species may benefit from increased nitrogen. Fire may alter/reduce effects of nitrogen deposition on productivity in the short-term. Most areas within the species range are likely affected by nitrogen deposition.	Talluto and Suding 2008, Vourlitis 2009, Bobbink et al. 2010, Fenn et al. 2010
Potential Management Actions		
A	Control weeds at extant and newly restored populations.	
B	Restore or enhance suitable habitat, including habitat for pollinators.	
C	Enhance connectivity by creating “steppingstone” populations at sites with appropriate soils using a suite of techniques (e.g., seeding, pollinator release).	
D	Control access by closing and/or rerouting trails and roads inside populations where possible.	
E	Collect and bank seeds for propagation and conservation collections and genetic studies.	
F	Propagate, out-plant, and/or translocate seeds (of known genotypes) to improve connectivity and gene flow.	
G	Promote pollinators and dispersers via research, habitat enhancement, and reintroduction.	
Critical Management Uncertainties		
1	Develop/refine Best Management Practices (BMPs) for habitat restoration/enhancement (note: BMP development is in-progress as part of the South County grasslands project).	
2	Develop/refine BMPs for invasive plant control, including possible impacts of herbicide on pollinators (note: BMP development for invasive plants is in-progress as part of the South County grasslands project).	
3	Investigate the effects of species abundance and plant size on floral display and pollinator attraction.	
4	Investigate the potential negative impacts of Otay tarplant on other native species.	
5	Identify small-scale disturbances that negatively affect Otay tarplant or its habitat or pollinators.	
6	Quantify the extent and temporal and spatial distributions of genetic	

Table 4

Conceptual Model Narrative: Otay Tarplant (*Deinandra conjugens*)

	variation, and determine the rate of outcrossing needed to create a robust breeding population (note: genetic studies are in-progress [USGS]).
7	Determine patch size needed to maintain adequate genetic diversity within a population.
8	Develop BMPs for seed storage, germination, and propagation (note: refer to SDMMP 2013, Volume 3.0 for BMPs for seed collection and storage; Otay tarplant has been successfully propagated as part of the South County grasslands project).
9	Measure the extent, viability, and longevity of the natural soil seedbank.

This species is known from seven occurrences in the U.S., and all are in or near the Dehesa Valley (CNPS 2012). Five of the seven occurrences are on conserved lands. In 2015, CBI developed a conservation vision and management strategy for Dehesa nolina in San Diego County (CBI 2015), and recommended population enhancement and translocation as potential management measures (among others) to enhance long-term species persistence. Identifying suitable receiver sites will require refined habitat and edaphic data.

Refer to Figure 5 for the Dehesa nolina conceptual model and Table 5 for the accompanying model narrative.

Parry’s tetracoccus *(Tetracoccus dioicus)*

Parry’s tetracoccus is a deciduous shrub that occurs between 165-1000 m elevation on gabbroic soils in chaparral and coastal sage scrub in Orange, Riverside, and San Diego counties, and Baja California, Mexico (CNPS 2012). In San Diego County, the species occurs sporadically in coastal foothills, but may be locally abundant (Dressler 1954). Parry’s tetracoccus is likely fire-adapted; however, the fire-response mechanism is not known. The species is dioecious, bearing male and female flowers on different shrubs. Flowers are presumably insect-pollinated and governed by rainfall patterns; flowering typically occurs between April and May (CNPS 2012).

Very little information is known about the ecology of Parry’s tetracoccus. The species’ affinity for gabbroic soils may be one factor limiting its distribution, but this has not been fully explored. Other factors that likely play a role in the species distribution include temperature and rainfall (Dressler 1954). Refined information on soil and habitat affinities for this species will allow us to target areas for future surveys and conservation of suitable habitat.

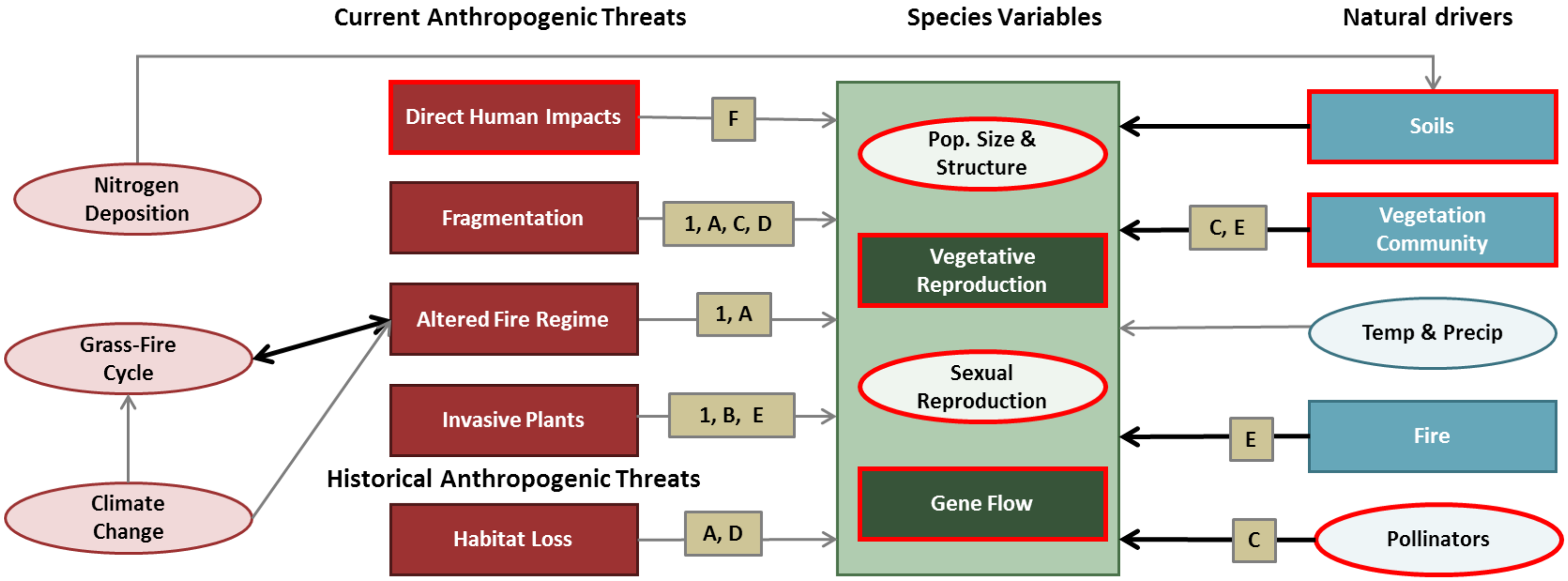
Refer to Figure 6 for the Parry’s tetracoccus conceptual model diagram and Table 6 for the accompanying model narrative.

Figure 5

Conceptual Model Diagram: Dehesa Nolina (*Nolina interrata*)

Management Goal: Maintain populations to increase resilience to environmental stochasticity, maintain genetic diversity and ensure persistence over the long term (>100 years) in native plant communities.

Monitoring Goal: Monitor conserved populations every 3-5 years or at a frequency determined by SDMMP to assess population status, identify threats, and determine management needs. See narrative for additional goals.



Critical Uncertainties:

1. Best Management Practices (BMPs) for habitat restoration/enhancement.
2. BMPs for controlling invasive plants.
3. Determine sex ratios, spatial distribution of alleles, and population structure.
4. Refine monitoring methods and counting unit.
5. Identify effective pollinators and mating system details.

Others: Visualized Processes

Management:

A. Restore/enhance suitable habitat.
B. Control weeds.
C. Enhance populations through out-planting and translocation.
D. Control access.
E. Collect and bank seeds.
F. Conserve unprotected populations.

Table 5

Conceptual Model Narrative: *Nolina interrata*

Goals		
Management	Maintain populations to increase resilience to environmental stochasticity, maintain genetic diversity, and ensure persistence over the long term (>100 years) in native plant communities.	
Monitoring	Monitor extant, conserved populations every 3-5 years or at a frequency determined by SDMMP using a regional monitoring protocol to assess population status (abundance, spatial extent), identify threats, and determine management needs. Monitor burned populations for 3 consecutive years following the fire, regardless of other monitoring intervals or schedules, to assess recovery and threats (particularly, invasive species).	
Anthropogenic Threats		
Direct Human Impacts	Authorized and unauthorized activities (e.g., road maintenance, off-highway vehicles) impact plants directly or degrade habitat. Unauthorized take or removal by humans including collecting for nursery trade is considered a low risk at this time.	Regan et al. 2006, CBI 2012, 2014, 2015
Fragmentation	Ongoing activities that eliminate habitat within or between populations, such as development and roads. When patches of occupied habitat are further than the natural range of pollinators and other dispersal agents, they are considered fragmented. In a dioecious species like Dehesa nolina, effective pollination occurs when male and female flowers are in proximity to one another.	USFWS 1995, 1998, Gordon-Reedy and Vinje pers. obs.
Invasive Plant Species	Plant invasion, particularly nonnative grasses, may increase fire frequency and/or intensity, alter nutrient cycling, and eliminate suitable germination sites. The nonnative grass *Brachypodium distachyon* is of particular concern as it colonizes clay and gabbroic soils readily.	D'Antonio and Vitousek 1992, USFWS 1995, Keeley 1999, Regan et al. 2006, CBI 2012, 2014, 2015
Habitat Loss	Currently, five of seven extant populations occur on conserved lands within the San Diego Multiple Species Conservation Plan (MSCP) area, including the three largest populations: Sycuan Peak Ecological Reserve, McGinty Mountain Ecological Reserve, and South Crest-	CBI 2015

Table 5

Conceptual Model Narrative*: Nolina interrata*

	Dehesa Mountain.	
Altered Fire Regime	Fire suppression may result in increased fuel loads and fire intensity, while increased fire frequency may prevent plants from reaching maturity and contributing to the soil seedbank. Results may include direct mortality, population declines or extirpation, and/or loss of genetic diversity.	Zedler et al. 1983, D'Antonio and Vitousek 1992, USFWS 1995, 1998, Keeley 1999, Regan et al. 2006, CBI 2012, 2014, 2015
Natural Drivers		
Soils	Occurs most commonly on clay soils derived from gabbroic (Las Posas series) or metavolcanic bedrock, but can also be found on soil with gabbro inclusions (Cieneba, Cieneba-Fallbrook, and Fallbrook series) and on clay soils (e.g., Auld series). The presence of appropriate soil determines the distribution of potential habitat. The narrow extent of suitable soils exacerbates the role of habitat loss and fragmentation as a threat.	Oberbauer 1979, 1991, Beauchamp 1986, USFWS 1998, CNPS 2012, CBI 2015
Vegetation Community	Occurs primarily in chaparral, but is also found in coastal sage scrub and grasslands. Over half of the conserved populations are associated with *Adenostoma*-dominated alliances and associations.	USFWS 1995, USFWS 1998, CBI 2015
Fire	Fire stimulates mass flowering necessary for sexual reproduction. Altered fire regimes threaten long-term species persistence through direct mortality, habitat type conversion, increase in invasive plants, and loss of genetic diversity. Conversely, fire suppression may result in increased fuel loads and fire intensity, senescent populations, and reduced flowering.	Rombouts 1996, Keeley 1999, USFWS 1995
Critical Natural Driver Uncertainties		
Temperature & Precipitation	Sporadic flowering in the absence of fire may be stimulated by climactic conditions and mechanical disturbance.	USFWS 2004, Gordon-Reedy and Vinje pers. obs.
Pollinators & Dispersers	Pollination is presumably achieved by insects including bees and possibly, bee flies and	Rombouts 1996, Gordon-Reedy and

Table 5

Conceptual Model Narrative: *Nolina interrata*

	beetles.	Vinje pers. obs.
Species Variables (Measurable Aspects of Species Response)		
Vegetative Reproduction	Reproduces asexually by cloning a new plant from the underground caudex to create clusters of genetically identical ramets.	Dice 1989
Gene Flow	The genetic diversity of Dehesa nolina is extremely low; however, this may be normal for the species and genus. It is hypothesized that the dioecious mating system, which would typically maintain a high level of genetic diversity, evolved after low levels of genetic diversity were already established. There exists some genetic divergence between populations in the US and Mexico, but no divergence within these populations. In general, populations with greater genetic diversity tend to be more resilient to stochastic events, environmental changes, and direct disturbance. Clonal growth may buffer populations from environmental stochasticity that might otherwise cause local extinction.	Rombouts 1996, Heaney pers. comm.
Critical Species Variables Uncertainties		
Population Size & Structure	The population size and demographic structure is difficult to determine visually due to the clonal nature of the plant. Genetic study has revealed that some populations may be entirely composed of the same genet and/or a single sex. Other studies have found that clusters (separated by no less than 2 m and no more than 20 m) often represented different genets.	Dice 1989, Rombouts 1996, CBI 2015
Sexual Reproduction	Reproduces sexually through a dioecious breeding system which may help maintain genetic diversity within or between populations; however, Dehesa nolina appears to have little genetic diversity as a species overall. Mass flowering is stimulated by fire. Although plants bloom sporadically in the absence of fire, successful sexual reproduction is limited by the proximity of male and female flowers.	Dice 1989, Rombouts 1996, CBI 2012, Gordon-Reedy and Vinje pers. obs.

Table 5

Conceptual Model Narrative: *Nolina interrata*

Critical Process Uncertainties		
Climate Change	Predicted warming temperatures may result in drier and hotter conditions in southern California in the future. Climate change poses a particular threat to plants due to their relative lack of mobility. While plant species' ranges shift naturally, the rate of shift may be outpaced by anthropogenic climate change, thus affecting the ability of some species to persist. The most vulnerable species to climate change occur in small populations, are limited in distribution, or are closely associated with certain habitats or edaphic conditions. Modeling for other rare and invasive species that occur in similar habitat and often with Dehesa nolina indicates that both invasive plants and fire frequency might pose threats under changing climatic conditions. Refer to Table 2 for additional impacts from climate change.	Bergengren et al. 2001, Walther et al. 2002, Parmesan and Yohe 2003, Araujo and New 2007, Westerling and Bryant 2008, Loarie et al. 2008, Cal-IPC 2012, Conlisk et al. 2013, Anacker et al. 2013
Grass-Fire Cycle	Nonnative grasses increase the fine fuel load and fire risk, and the reduced fire return interval then promotes nonnative grasses, leading to habitat type conversion. This cycle may affect soil and water budgets, increase erosion, promote invasive plant species, and impact pollinators. Fire regime alterations could have further implications for nolina as mass flowering is stimulated by fire.	D'Antonio and Vitousek 1992, Conlisk et al. 2013
Nitrogen Deposition	Primary threats from nitrogen deposition may be via nonnative grass invasion and alteration of the natural fire regime. The extent to which nitrogen deposition may directly affect Dehesa nolina is unknown; however, it's restriction to nutrient poor soil suggests there may be direct impacts. Refer to Table 2 for additional impacts from nitrogen deposition. Most areas within the range of this species are likely affected by nitrogen deposition.	Bobbink et al. 2010, Fenn et al. 2010, CBI 2015
Potential Management Actions		
A	Restore or enhance suitable habitat, including habitat for pollinators.	

Table 5

Conceptual Model Narrative: *Nolina interrata*

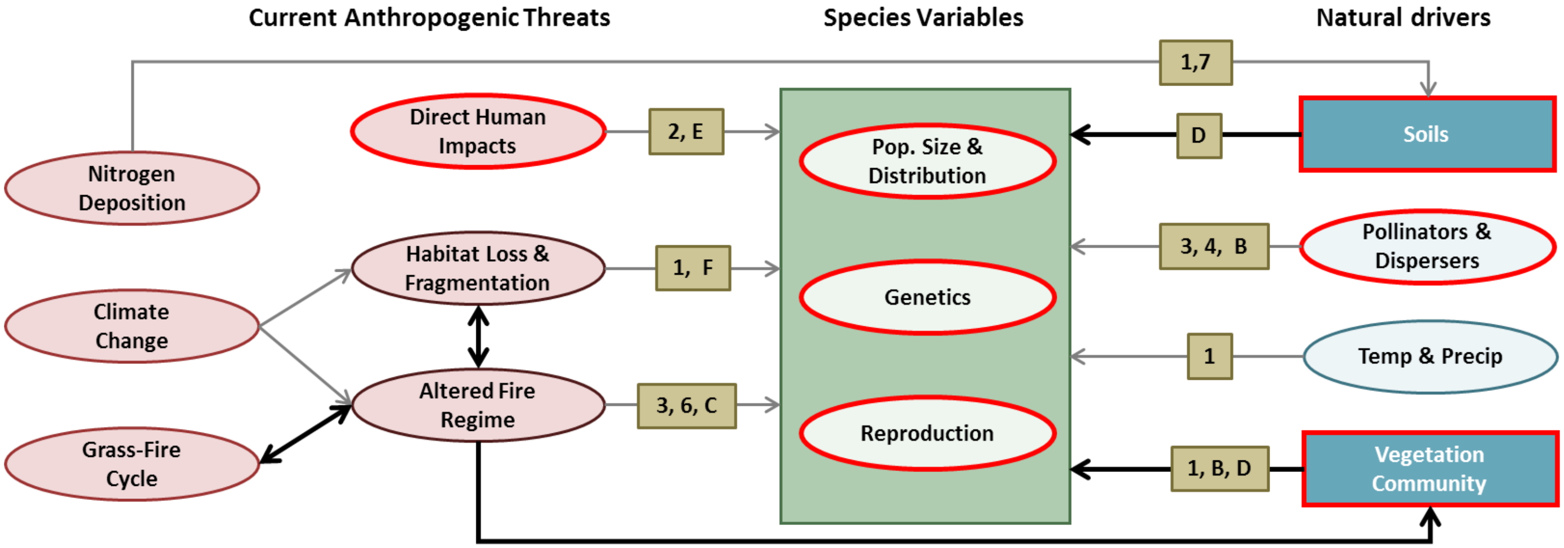
B	Control weeds.
C	Out-plant and/or translocate propagated stock.
D	Control access by closing and/or rerouting trails and roads inside populations where possible.
E	Collect and bank seeds for propagation and conservation collections and genetic studies.
F	Conserve unprotected populations, especially "steppingstone" populations which provide connectivity between large, conserved populations.
Critical Management Uncertainties	
1	Develop/refine Best Management Practices (BMPs) for habitat restoration/enhancement (note: BMP development is in-progress as part of the *Dudleya-Nolina* and *Brachypodium* Phase II projects).
2	Develop/refine BMPs for invasive plant control, including possible impacts of herbicide on pollinators (note: BMP development for invasive plant control is in-progress as part of the *Brachypodium* Phase II project).
3	Determine sex ratios, spatial distribution of alleles, and structure of populations.
4	Refine monitoring methods and counting unit.
5	Identify effective pollinators and floral morphology that produce viable seed.

Figure 6

Conceptual Model Diagram: Parry's Tetracoccus (*Tetracoccus dioicus*)

Management Goal: Maintain conserved occurrences to increase resilience to environmental and demographic stochasticity, maintain genetic diversity, and improve chances of persistence over the long-term (>100 years) on Las Posas soils in chaparral vegetation communities.

Monitoring Goal: Monitor extant, conserved populations every 3-5 years or at a frequency determined by SDMMP to assess critical uncertainties, including population status, threats, and management needs.



Critical Uncertainties:
1. Species extent, distribution, suitable habitat.
2. Threats to species/population persistence.
3. Effective pollinators.
4. Genetic diversity within and among populations.
5. Reproductive capacity and breeding system.
6. Impacts of climate change on species/populations.
7. Impacts of nitrogen deposition on suitable habitat.

Management

A. Address critical uncertainties.
B. Restore/enhance suitable habitat.
C. Control weeds.
D. Propagate, transplant, or translocate plants to restore populations, improve connectivity and gene flow (if determined necessary).
E. Control access.
F. Conserve unprotected populations/habitat.

Table 6

Conceptual Model Narrative: Parry's Tetracoccus (*Tetracoccus dioicus*)

Goals		
Management	Maintain conserved occurrences to increase resilience to environmental and demographic stochasticity, maintain genetic diversity, and improve chances of persistence over the long-term (>100 years) on Las Posas soils in chaparral vegetation communities.	
Monitoring	Monitor extant, conserved populations every 3-5 years or at a frequency determined by SDMMP using a regional monitoring protocol to assess critical uncertainties, including population status (abundance, spatial extent), threats, and determine management needs.	
Anthropogenic Threats		
Critical Anthropogenic Threats Uncertainties		
Direct Human Impacts	Authorized and unauthorized activities (e.g., fuel modification, illegal brush clearing, off-road vehicle activity) may potentially reduce populations through mortality and habitat degradation.	CBI 2012
Habitat Loss & Fragmentation	Current and historic habitat loss and fragmentation may reduce genetic diversity and long-term resilience by impeding gene flow within and between populations. In addition, populations in proximity to development are subject to edge effects (e.g., invasive species, illegal clearing, altered fire regimes).	Regan et al. 2006, CBI 2012, CNDDB 2016, NatureServe 2016
Altered Fire Regime	Altered fire regimes may affect populations by increasing plant mortality, depleting the soil seedbank, or promoting invasive species.	Regan et al. 2006, Conlisk et al. 2013
Natural Drivers		
Soils	Occurs on soils derived from gabbro parent material. The affinity for gabbroic soils may be one factor limiting the species distribution. The narrow extent of suitable soils exacerbates the role of habitat loss and fragmentation as a threat.	Dressler 1954, Oberbauer and Vanderwier 1991
Vegetation Community	Chaparral and occasionally coastal sage scrub on gabbro-derived soils	CNDDB 2016, NatureServe 2016
Critical Natural Drivers Uncertainties		
Temperature & Precipitation	Climatic factors likely play a role in the distribution of this species on the landscape; however, specific climatic parameters governing	Dressler 1954

Table 6

Conceptual Model Narrative: Parry's Tetracoccus (*Tetracoccus dioicus*)

	this species' distribution are unknown. Flowering may also be dependent on rainfall patterns.	
Pollinators & Dispersers	Most dioecious species are insect-pollinated and have unspecialized pollinators. Dispersal agents are unknown but seeds are presumed to be gravity- and/or animal-dispersed.	Dressler,1954, Proctor et al. 1996
Species Variables (Measurable Aspects of Species Response)		
Critical Species Variables Uncertainties		
Population Size & Distribution	Total population size and distribution of Parry's tetracoccus is unknown at the landscape level. Individuals tend to be distributed across the landscape in a discontinuous fashion, but may be locally abundant.	Dressler 1954, CBI 2012, SDMMP 2013
Genetics	There is little information on the genetics of Parry's tetracoccus.	---
Reproduction	Parry's tetracoccus is dioecious (male and female flowers on separate plants). As a dioecious species, the ratio and distribution of male and female plants relative to one another may be important. However, we have observed high fruit production in many populations over several years and under varying climatic conditions.	Dressler 1954, Proctor et al. 1996, Gordon-Reedy and Vinje pers. obs.
Critical Process Uncertainties		
Climate Change	Predicted warming temperatures may result in drier and hotter conditions in southern California in the future. Climate change may threaten Parry's tetracoccus if areas of appropriate climatic conditions are offset from areas with appropriate soils. The magnitude of this potential threat is unknown because specific information on the species' climatological requirements is not yet available. Refer to Table 2 for additional, potential impacts from climate change.	Bergengren et al. 2001, Araujo and New, 2007, Westerling and Bryant 2008
Grass-Fire Cycle	Nonnative grasses increase the fine fuel load and fire risk, and the reduced fire return interval then promotes nonnative grasses, leading to habitat type conversion. This cycle may affect soil and water budgets, increase erosion, promote invasive plant species, and impact pollinators. An altered	D'Antonio and Vitousek 1992, CBI 2012, Conlisk et al. 2013

Table 6

Conceptual Model Narrative: Parry's Tetracoccus (*Tetracoccus dioicus*)

	fire regime could further threaten this species through increased plant mortality and soil seedbank depletion.	
Nitrogen Deposition	Excess nitrogen may alter soil properties (including soil microbial community) and, subsequently, plant species composition and structure. Fire may alter/reduce effects of nitrogen deposition on productivity in the short-term. Most areas within the range of this species are likely affected by nitrogen deposition.	Bobbink et al., 2010, Fenn et al. 2010
Potential Management Actions		
A	Address critical uncertainties through monitoring or research.	
B	Restore or enhance suitable habitat, including habitat for pollinators.	
C	Control weeds to reduce competition and fire risk.	
D	Out-plant or translocate seeds or propagated stock to restore populations and enhance connectivity and gene flow (if determined necessary).	
E	Control access and reduce direct and indirect impacts by closing and/or rerouting trails and roads within populations, where possible.	
F	Conserve additional populations and habitat to bolster species resilience and accommodate range shifts due to climate change.	
Critical Management Uncertainties		
1	Determine or refine species extent, distribution, and habitat parameters to guide management and conservation efforts.	
2	Identify threats to guide management actions.	
3	Identify effective pollinators to guide management actions and restoration efforts.	
4	Assess genetic diversity at the species and population-levels to guide out-planting and translocation efforts, if determined to be important for this species.	
5	Identify breeding system and reproductive capacity (e.g., seed production) to determine if either poses a threat to species persistence.	

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