Adaptive Management Framework for the Endangered San Diego Thornmint, *Acanthomintha ilicifolia*, San Diego County, California

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Prepared by

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Executive Summary

Under a Local Assistance Grant from the California Department of Fish and Wildlife, the Conservation Biology Institute worked with the San Diego Management and Monitoring Program (SDMMP) and land managers in the San Diego region to conduct a comprehensive review of existing information, past and current research, and current management and monitoring efforts for San Diego thornmint, *Acanthomintha ilicifolia*. SDMMP assimilated a spatially explicit database of all populations and conducted habitat suitability modeling for this species.

This report addresses the management challenge that we face with many annual, edaphic species that undergo large population fluctuations, occur across a fragmented landscape, are vulnerable to many threats and stressors, and may have low genetic diversity due to reduced population sizes, geographic isolation, and loss of pollinators. Therefore, our approach may serve as a model for other plant species covered by the Natural Community Conservation Planning programs in San Diego County. This approach included:

- Obtaining all existing data and interviewing land managers and thornmint experts.
- Developing a conceptual model that articulates our assumptions about natural drivers, stressors, and threats and identifies critical uncertainties.
- Modeling habitat suitability for San Diego thornmint, as well as the nonnative invasive grass species *Brachypodium distachyon*, and identifying vegetation and soil correlates and landscape context.
- Modeling climate influences and evaluating potential impacts of climate change.
- Hypothesizing a regional population structure and identifying potential habitat connectivity.
- Prioritizing opportunities for enhancement or connectivity.
- Prioritizing management actions, Best Management Practices.

Appendix A of this document provides the necessary information for inclusion in the Management Strategic Plan prepared by the SDMMP. Appendix B provides a comprehensive matrix of populations with data contributed by land managers. Appendix C includes a conceptual model and threats assessment and provides the results of SDMMP habitat suitability modeling. Appendices D and E provide Best Management Practices and monitoring metrics, respectively.

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Appendices

1 Introduction

San Diego thornmint (*Acanthomintha ilicifolia*) is a federally and state endangered annual plant species that is restricted to San Diego County and Baja California, Mexico (CNDDB 2013, Beauchamp 1986). Within San Diego County, this species is found largely within the Management Strategic Planning Area (MSPA) (SDMMP 2013) (Figure 1), where it occurs on clay soils or clay lenses in chaparral, scrub, and grassland habitats (Oberbauer and Vanderwier 1991, SANDAG 2012). San Diego thornmint occurs in a relatively large number of populations for a rare species, but many of these face multiple challenges that threaten population and, possibly, species' persistence across the region.

Under a Local Assistance Grant (LAG) from the California Department of Fish and Wildlife (CDFW), the Conservation Biology Institute (CBI), in partnership with the San Diego Management and Monitoring Program (SDMMP), conducted a comprehensive review of existing information, past research, and current management and monitoring for San Diego thornmint and developed an Adaptive Management Framework for future research and monitoring. Components of this framework include:

- Developing or reviewing models
- Identifying potential environmental correlates
- Assessing threats and stressors
- Developing management goals and objectives
- Identifying potential opportunity areas
- Compiling/developing Best Management Practices and monitoring metrics

1.1 Integration with Regional Plans

<u>Management Strategic Plan</u>. The Adaptive Management Framework has been structured to integrate with the SDMMP's Management Strategic Plan (MSP) (SDMMP 2013). The framework follows the MSP format, to the degree feasible, with respect to identification of threats and stressors, management focus group designation, and development of management goals and objectives. Refer to the MSP (SDMMP 2013) for a characterization of the MSPA and Management Units (MU).

<u>Invasives Strategic Plan</u>. The Invasive Plant Strategic Plan (IPSP) (CBI et al. 2012) identifies regional management and monitoring priorities for selected invasive species in San Diego County that threaten narrow endemic species. The IPSP presents detailed information on the biology and current condition or status of these invasives, as well as management practices and recommendations for control. The Adaptive Management Framework incorporates information

from the IPSP on threats and management of these species. However, the IPSP is not comprehensive, as the plan does not address all invasive species suspected of potentially impacting thornmint.

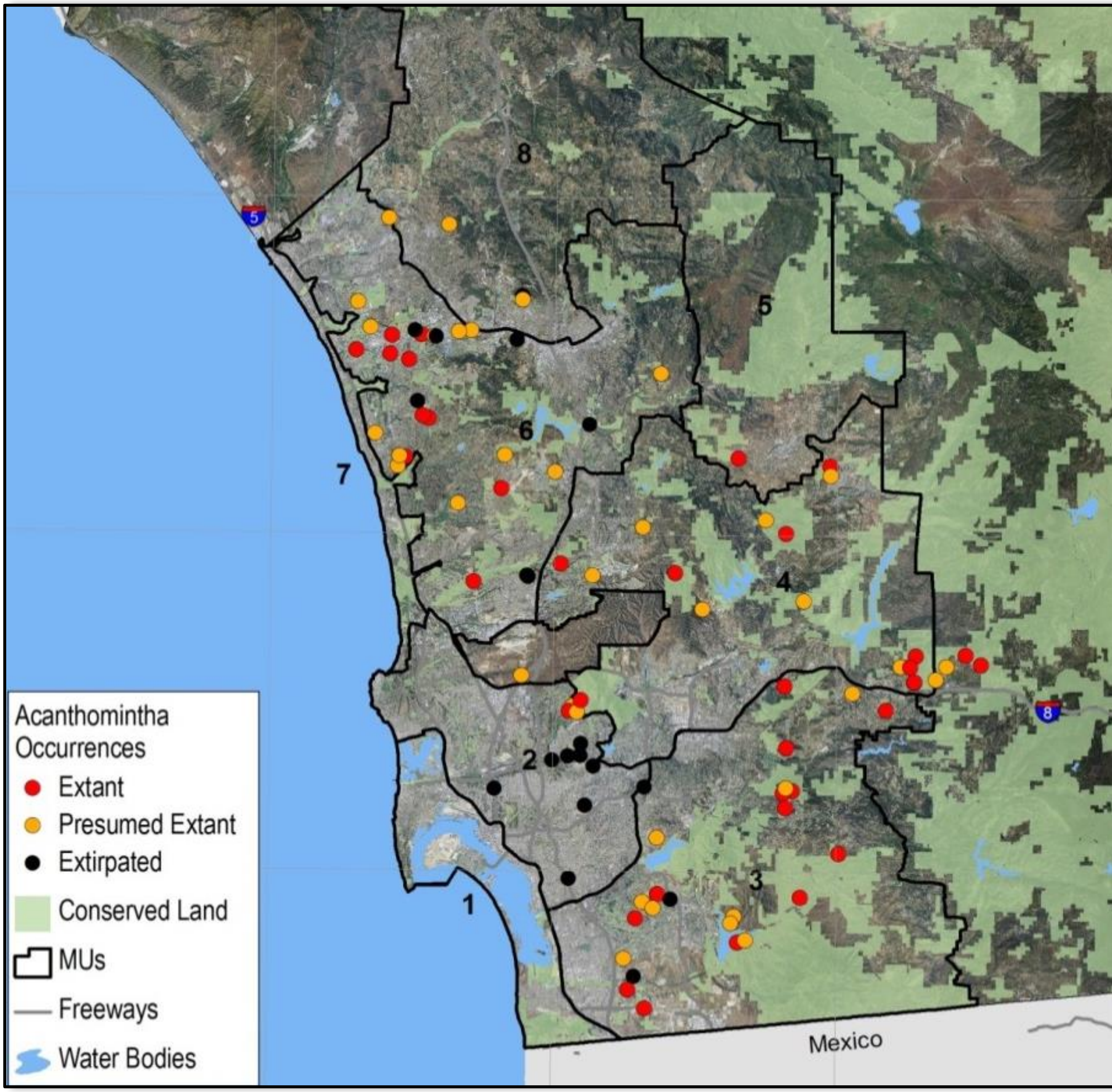

Figure 1. Distribution of San Diego Thornmint in San Diego County

1.2 Approach

San Diego thornmint was selected as a pilot species for developing an Adaptive Management Framework due, in part, to the relative quantity of information available, including research (Klein 2009, Lawhead 2006, Bauder and Sakrison 1997, 1999, Bauder et al. 1994), modeling (Conlisk et al. 2013), survey data and records (CNDDB 2013, USFWS no date), a 5-year status review (USFWS 2009), and long-term monitoring data for several conserved populations (e.g., City of San Diego, Center for Natural Lands Management). Additional thornmint data sources include the USFWS listing package (USFWS 1998), more recent data assembled by the San Diego Management and Monitoring Program (SDMMP), and numerous reports.

The approach to plan development included the following steps:

- Review existing data.
- Develop a conceptual model.
- Identify potential vegetation and soils correlates.
- Identify threats and stressors.
- Develop models to guide monitoring and management.
- Hypothesize regional population structure.
- Identify data gaps and areas that need to be surveyed.
- Prioritize populations for enhancement or connectivity.
- Identify priority research questions.

Despite the amount of information available for San Diego thornmint relative to other covered species in the region, there are significant data gaps with respect to species' biology, environmental correlates, population status, and spatial location. Information on biology will likely require targeted research, while other data gaps may be filled through targeted surveys. The most common limitations to accurately assessing population status are: (1) lack of recent census data, (2) a comprehensive threats assessment, and (3) accurate mapping. Modeling efforts are based on available data and should be refined and updated as new information becomes available.

1.3 Summary of Results

Appendix A. The Management Strategic Plan addresses San Diego thornmint populations by Management Unit, summarizes threats, stressors, and management opportunities, and identifies goals, objectives, and management actions. This appendix serves as the working document for management implementation and will be incorporated into the regional MSP (SDMMP 2013).

Appendix B. In conjunction with SDMMP and informed by the 5-year review (USFWS 2009), we developed a matrix of historic and current San Diego thornmint populations in San Diego County that includes the most current information on population location, status, land owner, land manager, management unit, conservation status, survey year(s), census data, threats, management actions, and research studies. Data in the matrix were further augmented by interviews with land managers and other biologists knowledgeable about San Diego thornmint.

Appendix C. We used existing data to develop a conceptual model characterizing life history traits, as well as natural drivers, anthropogenic drivers, and critical uncertainties (threats and stressors) that may affect those traits. Existing spatial datasets (e.g., vegetation, soils, fire history, climate change, nitrogen deposition) were used to assess potential correlates, as well as threats and stressors across the landscape. Habitat suitability and climatic influences for both thornmint and invasive species were modeled as predictive tools to guide monitoring and management.

Based on census data and guiding principles of rare plant conservation, we developed a hypothesis of regional population structure and assessed gaps in connectivity that might impact population persistence by restricting gene flow. Our results are characterized as spatially explicit opportunities for further surveys, population enhancement or translocation, and priority research questions to be incorporated into a monitoring strategy.

Appendix D. Best Management Practices were compiled for key aspects of San Diego thornmint, using existing literature as well as experience of biologists and land managers.

Appendix E. Monitoring metrics were developed in coordination with the SDMMP to ensure a seamless integration of thornmint monitoring data into the regional monitoring database.

2.0 Management Strategies

Management strategies for San Diego thornmint are based on a 'top-down' or landscape-level approach that considers the entire species distribution in the MSPA, connectivity within and between populations and MUs, and critical gaps in distribution or connectivity that threaten species persistence. This approach facilitates identification and prioritization of management actions that would provide the greatest benefit to San Diego thornmint. Management actions will occur at both the regional and preserve levels.

2.1 Regional Population Structure

The distribution of San Diego thornmint populations across the landscape, the relationship between populations, and proximity of existing populations to suitable habitat for expansion or migration in the context of climate change is termed *regional population structure*. Management at the regional level focuses on maintaining key populations or population groups and enhancing gaps within this structure to improve overall resilience and long-term persistence of this species.

In the absence of genetic studies or historical data regarding past relationships, the assessment of regional population structure is based on a number of assumptions (e.g., Menges 1991, Ellstrand and Elam 1993, Kolb 2008):

- Small populations are more susceptible to extirpation than large populations, especially those with recent reductions in population size.
- Small population size reduces reproductive success, particularly in fragmented landscapes.
- Relatively low levels of gene flow may be sufficient to offset effects of genetic drift in small populations.
- Small populations are more likely to receive gene flow from large populations than from other small ones, even if the latter are closer.

Based on these assumptions, we recommend the following strategies:

1. Maintain large populations (>10,000 individuals) of San Diego thornmint within a MU or preserve complex. Refer to Appendix C for a discussion of population size classes used in this framework. In general, large populations (a) are less susceptible to extirpation, (b) possess higher levels of genetic diversity, (c) have higher reproductive success than small populations, (d) function as a source of gene flow to smaller populations in proximity, and (e) function as a seed source for restoration/augmentation efforts. Large populations may occur alone and function independently or may occur as part of a population group (*metapopulation*), which consists of noncontiguous populations of various sizes that potentially interact through gene flow or dispersal.

2. Maintain or enhance medium (1,000-10,000 individuals) or ‘mixed’ (medium and small) population groups within a MU or preserve complex. In the absence of a large population, a population group that consists of medium populations or a combination of medium and small populations in proximity may or may not retain adequate levels of genetic diversity for long-term persistence and adaptation. Based on an assessment of size, threats, and connectivity between these populations, one or more populations within medium or mixed population groups may require enhancement for long-term persistence.

3. Enhance or expand selected small (<1,000 individuals) populations or population groups within a MU or preserve complex. Population groups that consist only of small populations are at increased risk of extirpation due to genetic degradation (e.g., inbreeding depression, lowered reproductive success). Based on an assessment of threats and connectivity, one or all small populations within a small population group will require enhancement or expansion for long-term persistence. Where threats cannot be reasonably controlled or the potential for connectivity is lacking, these populations are not likely to contribute significantly to regional population structure and, therefore, would be low priority for regional management.

4. Maintain isolated populations within a MU or preserve complex that appear stable, especially where threats are minimal and there is suitable habitat between them. This situation may approximate historical conditions, i.e., either populations are stable despite their isolation, or gene flow exists between them, despite their distance. For these groups, survey suitable intervening habitat for the presence of additional populations, and manage them to minimize threats.

5. Maintain, enhance, or expand select populations that may be important to the regional population structure as (a) steppingstones between key populations or population groups, (b) refugia from specific threats and stressors, or (c) a source of genetic diversity. Depending on size and threats, these populations may require enhancement or expansion for long-term persistence.

6. Establish San Diego thornmint or thornmint habitat in suitable but unoccupied habitat within the current species’ range (establishment) to fill gaps in connectivity and promote genetic flow, or translocate San Diego thornmint into suitable habitat beyond the current species’ range (translocation) to facilitate dispersal in response to climate change. Because of the relatively large number of thornmint populations, management should focus first on maintaining, enhancing, or expanding existing populations.

7. Some extant populations may not be critical to maintaining a viable regional population structure. Continue management of these populations at a local (preserve) level. In some cases, effective management may elevate the status of a population in the future.

Figure 2 presents an idealized regional population structure, based on underlying assumptions and available data. This structure should be refined as data gaps are filled and genetic studies conducted that identify levels of genetic diversity within and among populations. For MUs 3, 4, and 6, which support the majority of current San Diego thornmint populations, population structure should include large and/or medium or mixed population groups distributed across the MU, with steppingstone populations facilitating gene flow between these population groups and groups in adjacent MUs, if possible. For some MUs, selected populations or population groups are identified as potential refugia. Still other populations may be important based on genetic studies. Regional population structure is discussed below for each MU; populations are discussed in more detail in Appendix A.

Management Unit 2

Small Populations

Historically, MU 2 likely played an important role in thornmint population dynamics, supporting at least 10 populations and providing connectivity between the western portions of MU 3 and 4, and possibly, to MU 6, as well. At this time, only remnants of suitable habitat remain.

<u>Tierrasanta</u>. This group includes two populations: EO 34 (near Mission Trails) and EO 79 (near Mission Gorge). Neither population is on conserved lands, although both are in proximity to a larger, conserved population in MU 3 (EO 33, Mission Trails Regional Park). Although this group may function as a refugium from climate change or catastrophic events (e.g., fire) to the east (Appendix C), it is not on conserved lands, so is not prioritized for regional management at this time.

Management Unit 3

This MU supports two large population groups and at least one *mixed* population group important for maintaining regional population structure. Mixed population groups include both medium and small populations. Additional, selected populations or population groups may be important, as described below.

Large Populations

<u>Rice Canyon</u>. This group includes EO 90 (Rice Canyon, one of the largest populations recorded in recent years), as well as three small populations (EO 15 [Bonita, Wheeler Ridge], EO 89 [Long Canyon], and Bonita Meadows [no EO #]). Populations in this group occupy fragmented canyon habitat, but are in proximity to one another and to additional, potentially suitable habitat per the habitat suitability model (Appendix C). These populations may also function as refugia from fire (Appendix C). Additional information on status and threats is needed for two of these populations (Bonita Meadows, Long Canyon), and all will likely require management.

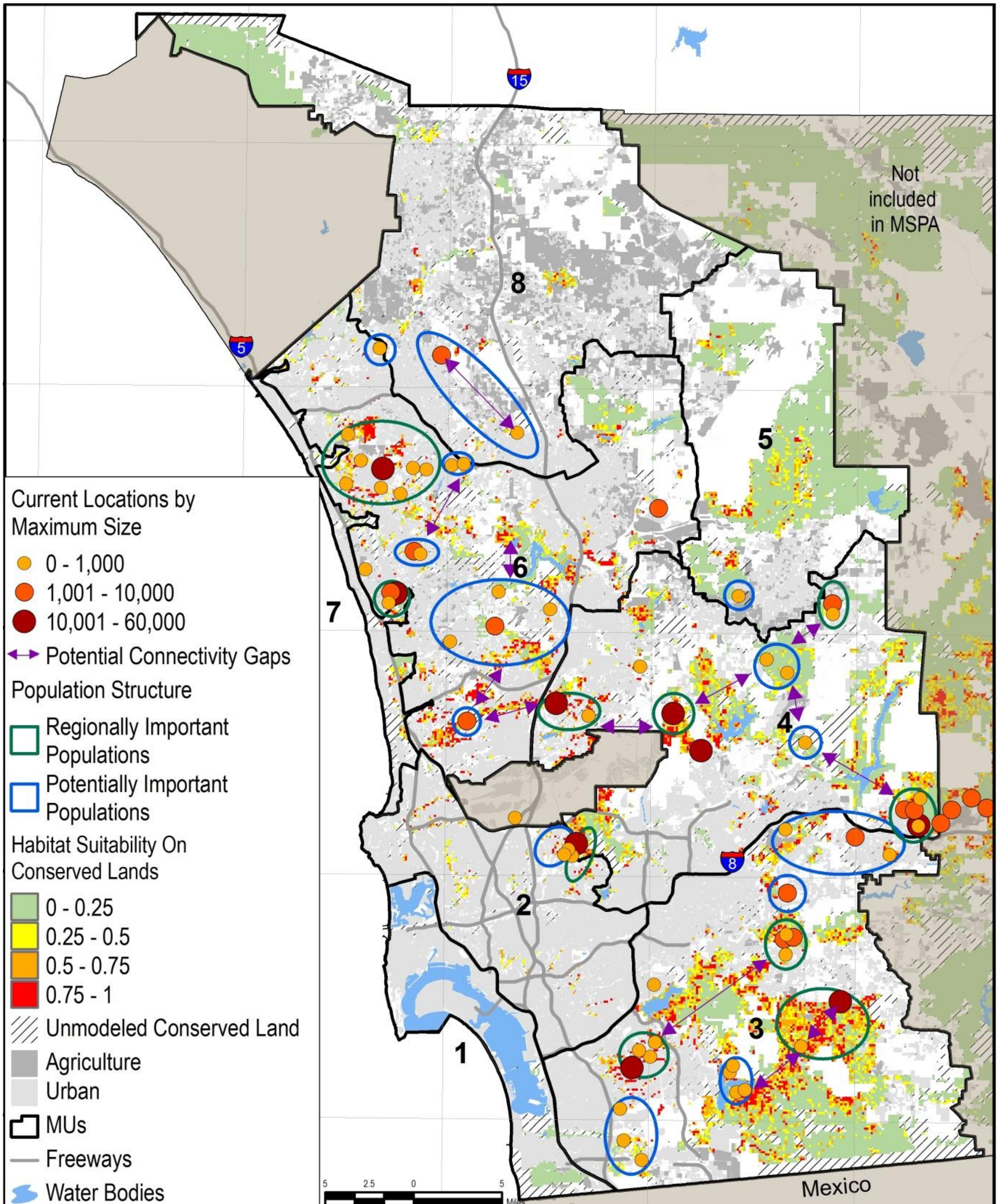

Fig. 2. San Diego Thornmint Regional Structure

Jamul Mountains. This group includes a large population (EO 86, Hollenbeck Wildlife Area) and small population (EO 85, Rancho Jamul Ecological Reserve). Although the distance between these populations is greater than within other population groups, the intervening area is largely conserved, relatively undisturbed, and supports suitable habitat per the habitat suitability model and soils dataset (Appendix C). Thus, there is the potential for additional (as yet undetected) populations, migration in response to climate change, and/or population translocation or establishment (if determined necessary).

Mixed Populations

McGinty Mountain. This group consists of three extant medium populations and one small (presumed extant) population on McGinty Mountain: EO 21 (McGinty Mountain, southwest slope), EO 22 (McGinty Mountain, summit and ridgeline), EO 87 (McGinty Mountain), and McGinty Mountain (no EO #), respectively. All populations are on relatively large blocks of conserved lands, with only EO 21 in proximity to residential development. EO 21 and the small McGinty Mountain population appear resilient to climate change under several modeled climate change scenarios (Appendix C).

Small Populations

Poggi Canyon-Otay Mesa. This group includes one small, extant population and two small, presumed extant populations: EO 83 (Dennery Canyon East), EO 71 (Poggi Canyon), and EO 96 (Cal Terraces), respectively. All occur in fragmented habitat near development and are likely subject to ongoing threats. Based on presumed small population size and threats, these populations are probably not critical to regional population structure. They should be re-evaluated after an assessment of status, threats, and genetic structure.

Otay Reservoir. This group includes one extant and three presumed extant, small populations: EO 84 (Otay Lakes south), EOs 55 and 56 (Otay Lakes, northeast side), and EO 88 (Lower Otay Reservoir), respectively. Only EOs 84 and 88 are on conserved lands, but all are adjacent to additional, suitable habitat per the habitat suitability model (Appendix C). All populations also occur within or near suitable soils and are in relatively large blocks of habitat (Appendix C). This group lies between two large population groups (the Rice Canyon group to the west and the Jamul Mountains group to the east) and could function as a steppingstone to facilitate gene flow. Additional surveys should assess current status and threats of these populations and their potential for long-term persistence. It is likely that one or more populations would require enhancement or expansion.

Additional Populations or Population Groups that may be Regionally Important

Suncrest (South Crest). This medium population (EO 72) occurs north of the McGinty Mountain population group; genetic studies would be required to determine if gene flow occurs between the Suncrest and McGinty Mountain populations. This population occurs on a relatively large block of conserved land adjacent to additional, suitable habitat, and may function as one of several steppingstones between larger population groups in MUs 3 and 4. This population is subject to a number of threats but is currently under active management.

Crestridge to Alpine. This group consists of two extant and one presumed extant populations: EO 81 (Crestridge Ecological Reserve), EO 63 (Wright's Field), and EO 45 (Sky Mesa Ranch), respectively. These populations could function as steppingstones to MU 4, if determined viable. The Crestridge population is small and has declined in recent years due to invasion by the nonnative grass, *Brachypodium distachyon*. Invasive control and habitat restoration measures are in progress. If these measures successfully restore habitat quality and there is an increase in population size during years of suitable climatic conditions, then EO 81 could function as a steppingstone population. EO 63 is small and in proximity to conserved populations in MU 4. It faces numerous threats and likely will require continued management for long-term persistence. EO 45 (presumed extant) was documented as a medium population in 1990; additional surveys are needed to confirm its presence and whether it occurs on conserved lands.

Management Unit 4

This MU supports four large populations or population groups and one mixed population group important for maintaining regional population structure: Viejas Mountain, Sycamore Canyon, Mission Trails Regional Park, Sabre Springs (west), and Simon Preserve. The Mission Trails Regional Park and Sabre Springs (west) populations have experienced population declines in recent years, and it is unclear whether they retain the potential to support large numbers of plants in the future. Additional, selected population groups or individual populations may be important, as described below.

Large Populations

Viejas Mountain. This group consists of three extant and one presumed extant populations:

- EO 51 (Viejas Mountain [southwest slope])
- EO 75 (Viejas Mountain [west-southwest flank])
- EO 80 (Viejas Mountain [northwest slope])
- Viejas Hills (no EO #)

EO 51 is a large population, EO 75 is medium, EO 80 is small, and no census data are available for the Viejas Hills population. An additional, medium, extant population, EO 73 (East of

Murphy Ranch), is in this group but does not occur on conserved lands. All populations occur within relatively large blocks of habitat in or adjacent to the Cleveland National Forest and are in proximity to suitable habitat (Appendix C) and additional, conserved populations to the east, outside the MSPA. Modeling indicates that these populations may be resilient under some climate change scenarios (Appendix C).

Sycamore Canyon. This large population (EO 32) has exhibited wide population fluctuations but consistently large size over almost 20 years. Recent census data indicate it is one of the largest extant populations in the MSPA. In addition to size, EO 32 is important because of its location in the center of MU 4 and between populations to the southwest, southeast, west, and northeast. In addition, it occurs adjacent to additional, suitable habitat (Appendix C) within the Goodan Ranch/Sycamore Canyon Open Space Reserve. An additional population (EO 64, Slaughterhouse Canyon) does not occur on conserved lands.

Mission Trails Regional Park (MTRP). This group consists of one large, extant population (EO 33, MTRP) and one small, presumed extant population (EO 35, southwest Tierrasanta parcel). Functionally, it also includes EOs 34 and 79 in MU 2, discussed separately above. The MTRP group faces numerous threats, supports apparently declining populations, and is adjacent to MU 2 to the west, where thornmint habitat has been largely extirpated. Nonetheless, this group may be important as a refugium from climate change and frequent fire (Appendix C). In addition, it occurs adjacent to additional, suitable habitat (Appendix C) to the north and northeast within MTRP and MCAS Miramar. Management that stabilizes or increases the population size of EO 33 would increase the regional importance of this group.

Sabre Springs: This group consists of the large, extant Sabre Springs (west) population (EO 36) and the small, presumed extant Sabre Springs (east) population (EO 26). This group is important because of its position between populations in MU 6 and other population groups in MU 4. Both EO 36 and 26 occur in fragmented habitat, but may provide refugia from fire (Appendix C).

Medium Populations

Simon Preserve. This group includes the extant, medium-sized population, EO 77 (Simon Reserve) and an additional population (Simon Preserve [no EO #]) nearby. It is possible that these two occurrences should be considered a single population. This group is important because of proximity to suitable soils to the north and west.

Small Populations

Monte Vista Ranch. This group includes two small populations on Monte Vista Ranch, extant EO 78 (Long's Gulch) and presumed extant EO 69 (Daney Canyon). This group is centrally located within the MU and is potentially important as a steppingstone between populations to the west, south, and north. It may have some resilience to climate change (Appendix C).

El Capitan. This isolated, presumed extant population occurs within the Bureau of Land Management's El Capitan Open Space Preserve, although the mapping accuracy is imprecise. If extant and viable, this population could be regionally important as a steppingstone between the Viejas Mountain group and populations to the west and north.

Poway Grade. This isolated, presumed extant population occurs within a private conservation easement adjacent to the Poway Grade and residential development; it probably does not contribute to the regional population structure.

Management Unit 5

MU 5 supports one population at the eastern edge of the species' range. If the species' distribution shifts east in response to climate change, MU 5 may be more important in the future.

Ramona Grasslands. MU 5 supports only one small, extant population, EO 92 (Ramona Grasslands/Hobbes Property). This population is relatively isolated from populations in other MUs; however, it may be somewhat resilient to both fire and climate change (Appendix C), so may have value as a refugium. In addition, it occurs in a matrix of clay and gabbro soils and is in proximity to similar soils on conserved lands to the north and west. The overall value of this population would increase with management that stabilizes or enhances population size and habitat quality, and if additional populations are detected in the MU.

Management Unit 6

Historically, MU 6 supported 30 thornmint populations, which was the greatest concentration of this species in the region. At present, the MU supports or potentially supports 10 extant and 13 presumed extant populations. Many of the current populations are threatened and will require management for continued persistence.

Large Populations

Lux Canyon. This group includes one extant and two presumed extant populations, respectively:

- EO 28 (Lux Canyon east, Manchester Avenue Mitigation Bank)
- EO 42 (Lux Canyon, west of Manchester Avenue Mitigation Bank)
- EO 38 (Lux Canyon west)

EO 28 is large, EO 42 is medium, and EO 38 is small; the latter two populations were both transplanted from EO 28. This population group occurs within an urban matrix and likely will be subject to ongoing edge effects. However, this group is also one of the few that may not be affected by nitrogen deposition due to its coastal location (Appendix C). This group is important largely for the presence of the large population, EO 28, which may function as a source of genetic diversity and provide material for restoration and population augmentation.

Carlsbad. This group may include up to eight populations; genetic studies would help determine if these populations function independently or within a metapopulation structure:

- EO 70 (Palomar Airport Road)
- EO 82 (La Costa Greens)
- EO 31 (Carlsbad Racetrack south)
- EO 59 (El Fuerte Street/Rancho Carillo)
- EO 58 (Emerald Pointe)
- EO 57 (Letterbox Canyon/Spyglass)
- EO 41 (Las Brisas Transplant Site)
- EO 94 (Calavera Hills)

The first five populations are extant and include a mix of population sizes. The latter three populations are all small and presumed extant. Most of these populations occur in relatively small blocks of conserved habitat within an urban matrix. This group is considered regionally important based on location (northwestern portion of species' range), potentially as a source of genetic diversity, and as a refugium from frequent fires that affect much of the rest of the MSPA (Appendix C). Many of the populations in this group are being actively managed (Appendix B).

Medium Populations

Southeast Carlsbad. This group includes two medium, extant populations: EO 47 (Southeast Carlsbad east) and EO 48 (Southeast Carlsbad west). Both occur in relatively small preserves within an urban matrix, which may affect long-term viability. This group potentially could function as a steppingstone between important population groups to the north and south within this MU. In addition, it may provide refugia from fire (Appendix C).

Black Mountain. This group includes the following four populations:

- EO 60 (Black Mountain)
- EO 25 (Thornmint Court)
- EO 91 (San Dieguito Valley)
- EO 46 (Rancho Santa Fe)

EO 60 is extant, while the other populations are presumed extant and require surveys to determine specific locality and conservation status. Only the Black Mountain population occurs in a relatively large block of conserved land. Suitable habitat and soils (Appendix C) occur in and adjacent to this group and may support additional populations. Based on location, this group may provide connectivity between populations to the northwest in MU 6 and southeast in MU 4.

Los Peñasquitos Canyon. EO 19 (Los Peñasquitos Canyon) is spatially distant from other populations in MU 6 and may function as an independent population. This population appears relatively stable and is adjacent to conserved lands and potentially suitable habitat to the north and west that might provide connectivity to other populations.

Small Populations

San Marcos. This group consists of two presumed extant populations, EO 17 (Upham) and EO 53 (Linda Vista and Bent Avenues), which require surveys to assess conservation and biological status. Both occur within an urban matrix with small isolated patches of conserved lands. If viable, these populations potentially could function as steppingstones between other population groups in MU 6 and MU 8. This group might function as a refugium from fire (Appendix C).

San Diego Botanic Garden. This population (EO 39) was transplanted from the Lux Canyon east population (EO 28) and may be extirpated (Erhlinger pers. comm. 2013). Even if extant, this population is relatively isolated and surrounded by development and probably does not contribute significantly to regional population structure.

San Diego Zoo Safari Park. This population (EO 49) was transplanted from EO 40, which is extirpated. Updated information is required to assess its current status. EO 49 is not near suitable habitat or soils (Appendix C) and probably does not contribute significantly to regional population structure.

Oceanside. The Taylor population (EO 97) is the northernmost population in the species' range; it is small, isolated, and surrounded by development. Although it could potentially function as a steppingstone between populations to the southwest in MU 6 and populations to the northeast in MU 8, most of the potential habitat linkages are also small patches within the urban matrix and are likely tenuous.

Management Unit 8

Management Unit 8 supports populations at the northeast edge of the species' range that, to date, have not burned frequently (Appendix C). Few populations have been documented in this MU, despite the presence of suitable soils, and it is unknown whether this is due to non-occurrence or lack of survey effort. As with MU 5, this MU may increase in importance in the future if the species' distribution shifts eastward in response to climate change.

Mixed Populations

San Marcos-Merriam Mountains. This group includes two presumed extant populations, EO 93 (Palisades Estates, medium) and EO 61 (Emerald Heights, small). Both are in private open space easements and in proximity to development. EO 93 is also adjacent to relatively large blocks of habitat to the east, although little of this is conserved. In addition, it is near large expanses of clay and gabbro soils in the San Marcos and Merriam mountains and more eastern reaches of the MU (Appendix C). This group would be regionally important if additional populations are discovered and existing and potentially suitable future habitat is conserved.

2.2 Habitat Connectivity

Connectivity is the degree to which the landscape facilitates or impedes movement among resource patches (Taylor et al. 2006). Connectivity of natural open space is widely regarded as essential to maintaining functional landscapes and evolutionary processes (e.g., Noss 1987, 1991, Saunders et al. 1991, Beier and Noss 1998). For plants, habitat connectivity allows for movement of pollinators and possibly, dispersal agents between populations; thus, facilitating gene flow. Habitat connectivity may also provide opportunities for species expansion or migration under existing conditions and in response to climate change (Primack 1996, Anacker et al. 2013).

Within the MSPA, gaps in connectivity occur largely as a result of habitat fragmentation and are most apparent in the urbanized portions of MUs. Populations that were connected historically are now separated completely or divided into smaller subpopulations as habitat is lost or degraded. The resultant reduction in population size and increase in edge effects will likely affect the persistence of these populations over time. In these cases, the challenge will be to recreate some measure of gene flow by (1) maintaining or enhancing suitable habitat for pollinators or (2) assisted migration of seed or pollen.

Potential gaps in connectivity may also occur where there are large distances between populations. Where isolated populations appear stable and there is suitable intervening habitat, gaps may approximate historic conditions in terms of gene flow and thus may not require targeted efforts to improve connectivity, although surveys of intervening habitat could inform future management efforts. Isolated populations that are small or declining may benefit by establishing new thornmint populations within identified gaps.

Using regional population structure and available data on population status, we identified potential connectivity gaps within and between population groups (Figure 2). Additional surveys and genetic studies are necessary to determine whether these gaps pose a threat to population persistence. Strategies for improving connectivity include (1) maintaining or improving habitat for pollinators between existing populations, (2) augmenting existing populations through assisted migration of pollen or seed, (3) identifying new thornmint populations between existing populations, (4) establishing new populations in unoccupied but suitable habitat between existing populations, and (5) translocating the species into suitable habitat outside the current species range to accommodate climate change.

2.3 Opportunity Areas

Opportunity Areas are conserved lands within the MSPA that have the potential to enhance regional population structure and long-term resilience of San Diego thornmint by supporting (1) new populations, (2) suitable sites for enhancement or establishment of thornmint populations or pollinator habitat, or (3) potential translocation sites. We reviewed regional population structure and connectivity maps (Figure 2) along with habitat suitability and climate change models (Appendix C) to identify opportunity areas for each MU (Figures 3-8). Areas with the highest habitat suitability on Figures 3-8 are considered opportunity areas.

Surveys

Although much of the MSPA has been surveyed for San Diego thornmint, inland regions may reflect limited survey efforts. In addition, San Diego thornmint can experience spatial and temporal population fluctuations; thus, even where surveys have been conducted and the species has not been observed, there is the potential for as yet undetected populations. We used the habitat suitability model and conserved land datasets (Appendix C) to identify potential survey areas in MUs 3, 4, 5, 6, and 8 where detection of new thornmint populations would enhance regional population structure by filling gaps in connectivity (Figures 4-8). Surveys for thornmint or thornmint habitat should focus on conserved lands where connectivity gaps have been identified within or between population groups (Figure 2).

Enhancement/Expansion and Establishment

Opportunities for enhancement and expansion exist adjacent to small, extant populations, while establishment opportunities occur in connectivity gaps (Figures 4-8). Delineation of these opportunity areas will require field assessments of both population and habitat status, with a focus on areas of high habitat suitability.

Translocation

In this context, translocation is used to refer to the experimental introduction of San Diego thornmint into habitat that supports suitable environmental variables. Translocations may be particularly important where there are no suitable soils between existing populations, primarily in the eastern portion of the species' range (e.g., north of Lake Wohlford, northeast of Dixon Lake). Selection of receptor sites and propagule transfer must consider genetics and soils of donor sites.

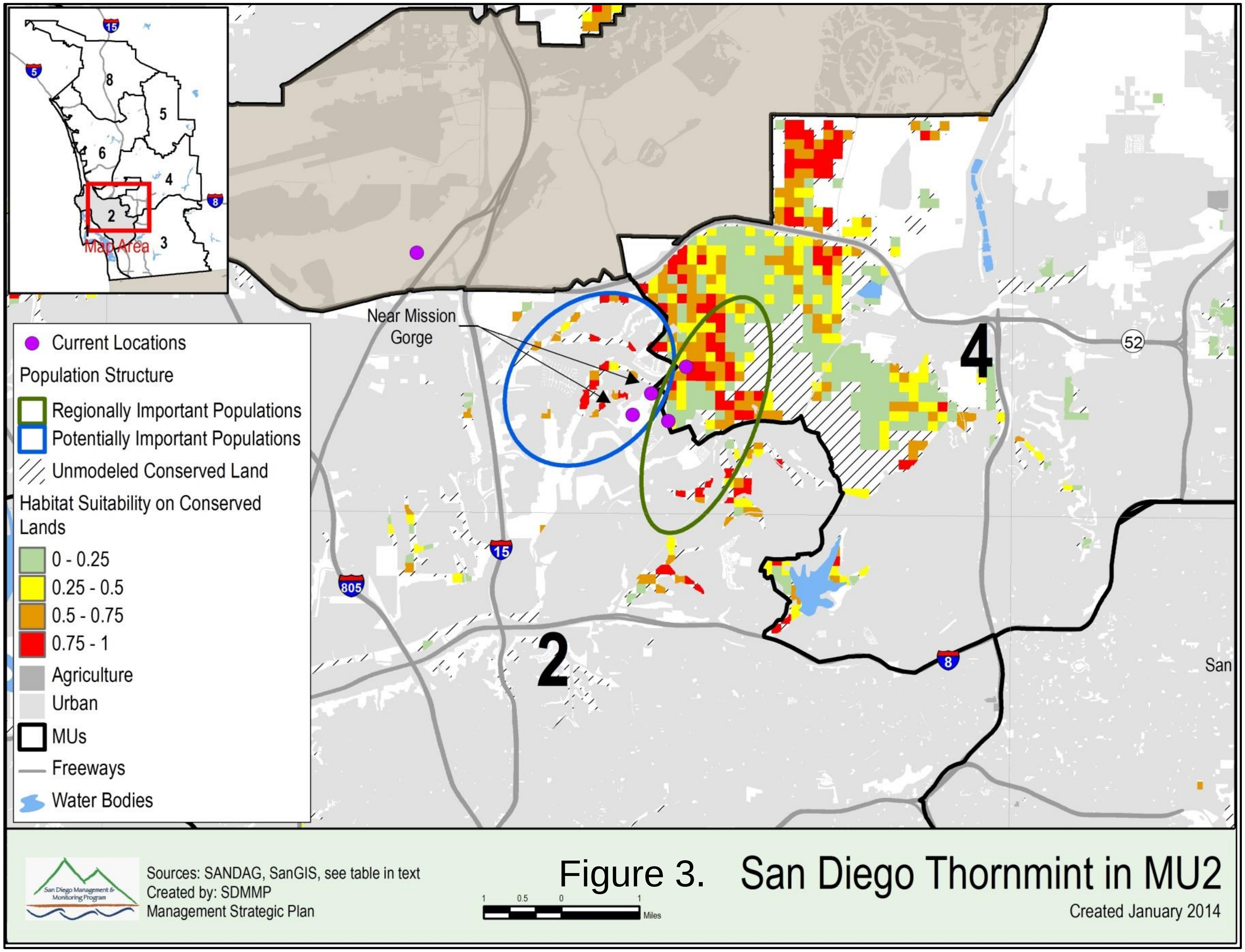

Figure 3. San Diego Thornmint in MU2

Created January 2014

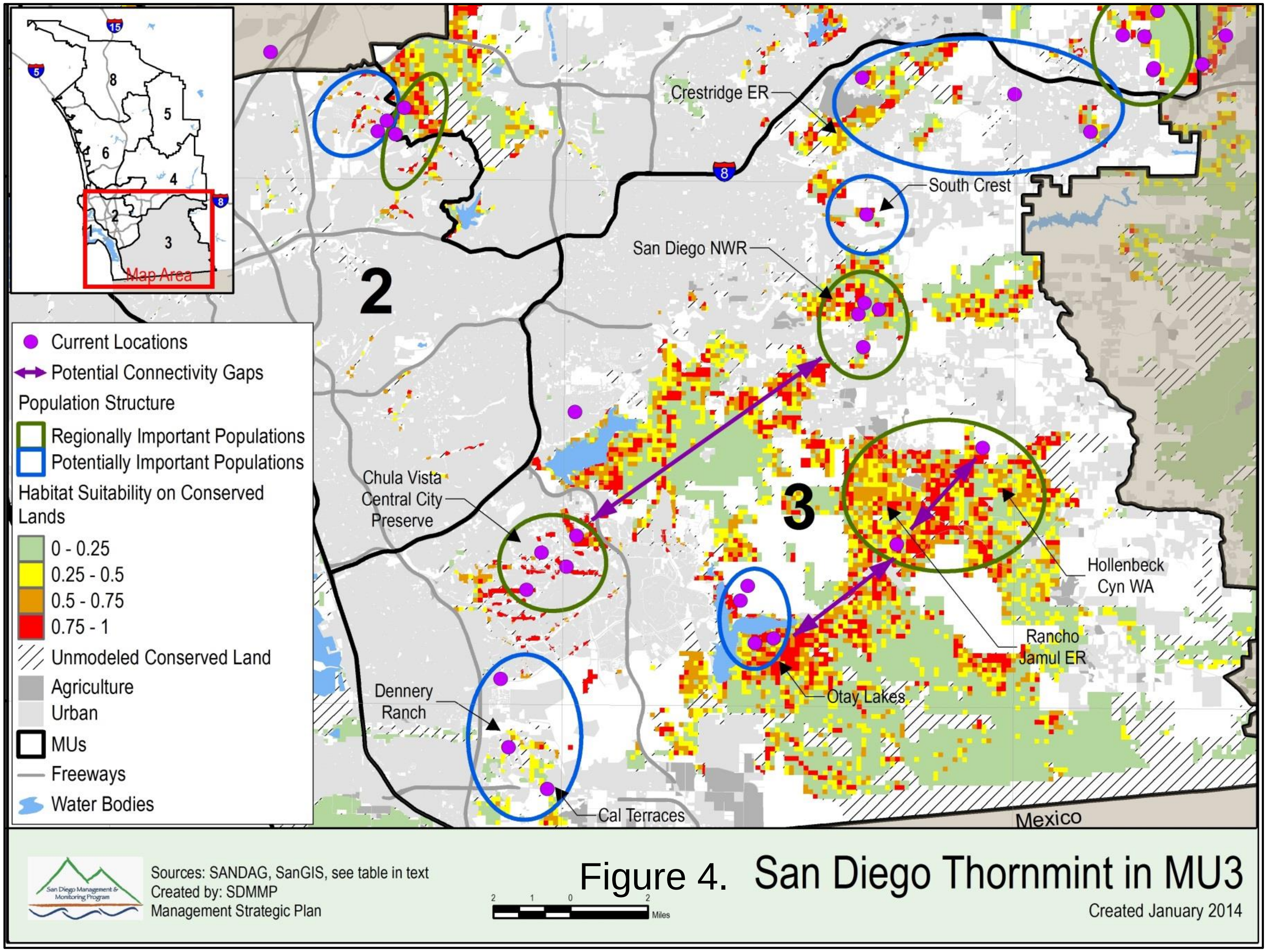

Figure 4. San Diego Thornmint in MU3

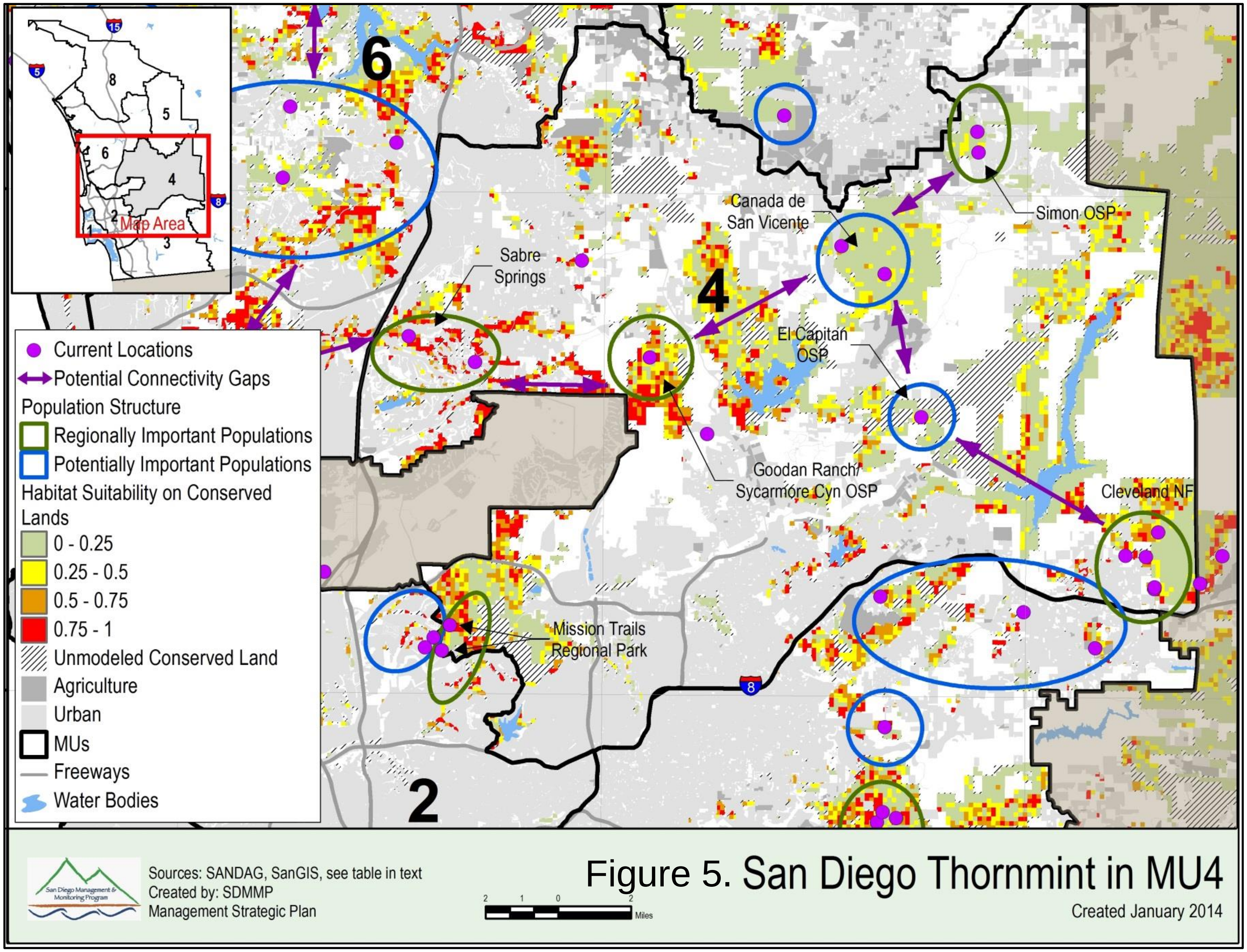

Figure 5. San Diego Thornmint in MU4

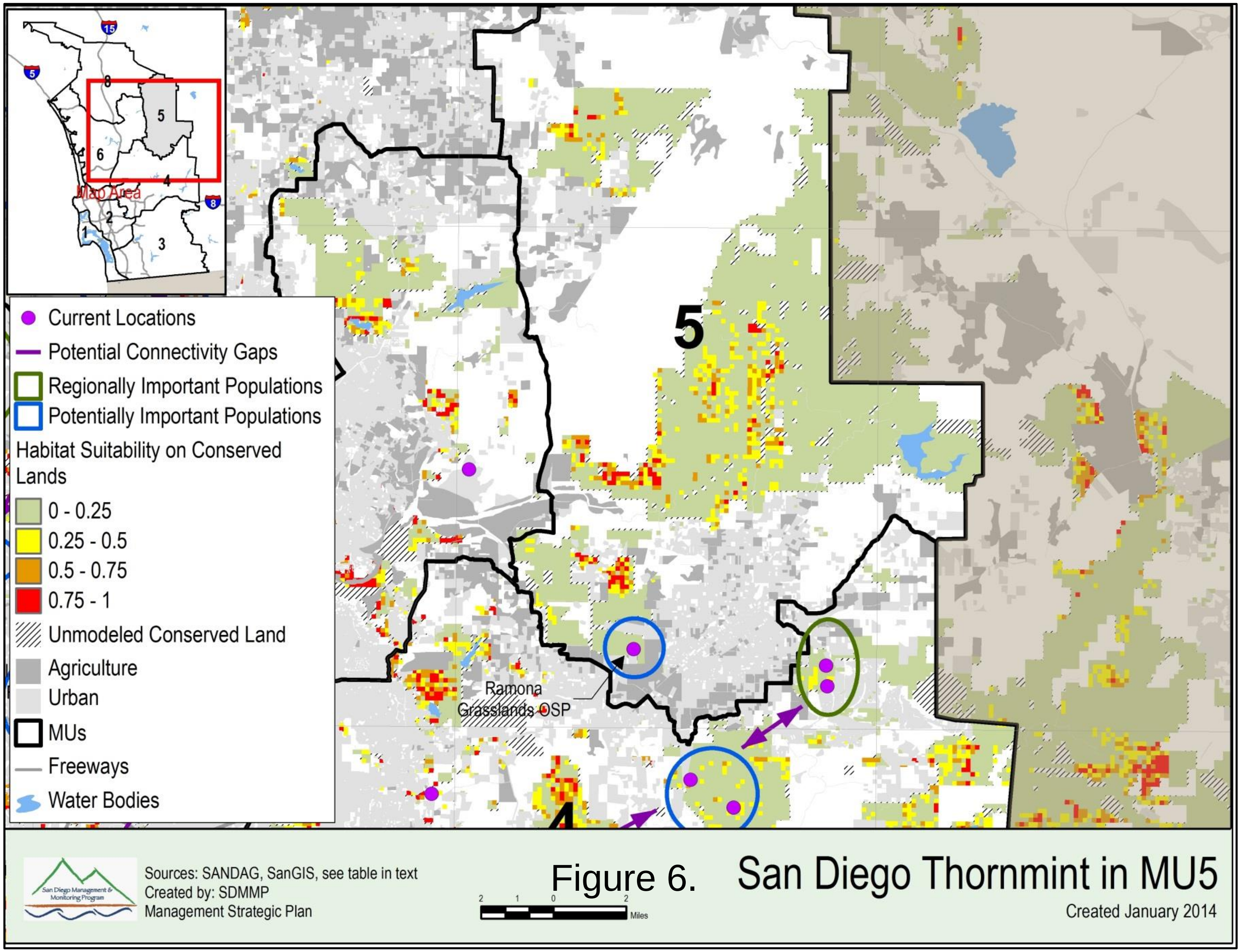

Figure 6. San Diego Thornmint in MU5

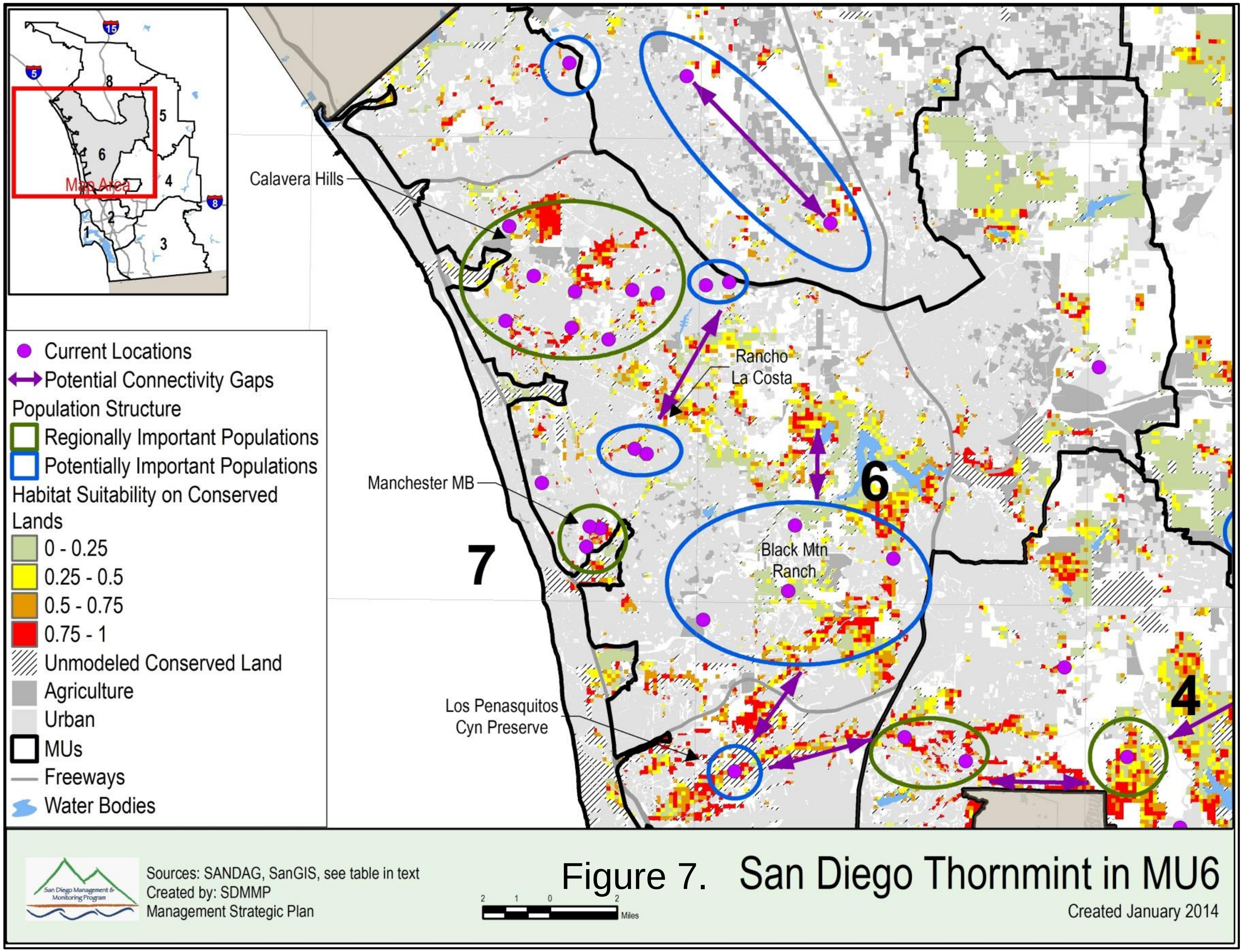

Figure 7. San Diego Thornmint in MU6

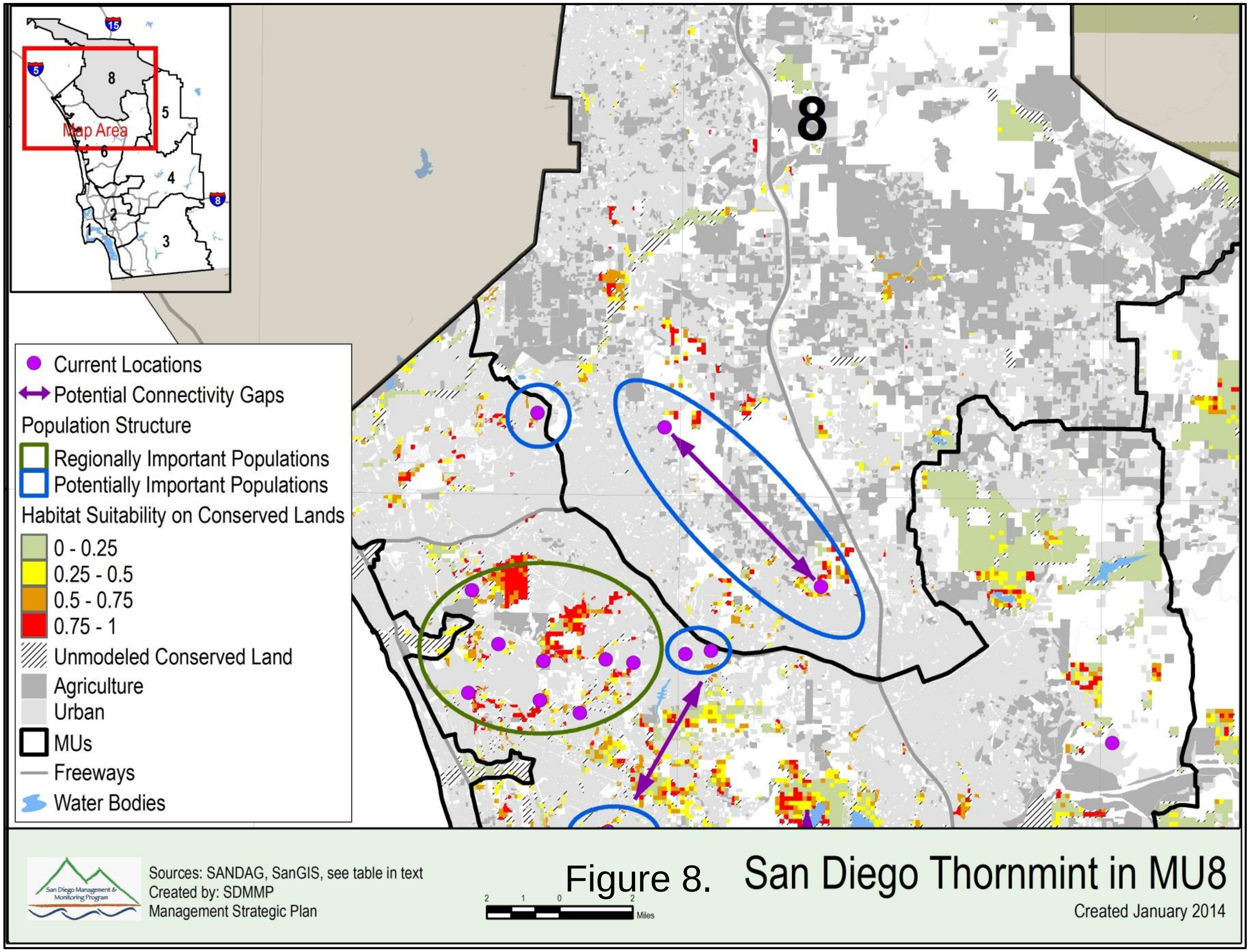

Figure 8. San Diego Thornmint in MU8

3 Regional and Preserve Level Actions and Research

This section summarizes management and monitoring actions and research needs to maintain and enhance thornmint conservation in the region (detailed in Appendix A). Results will be coordinated by SDMMP and used to adapt management strategies over time. For example, attribute data that refine regional population structure hypotheses and habitat suitability models will be used to prioritize populations for regional management and identify suitable habitat to accommodate species migration. Data that assess population status and health will determine specific management needs (e.g., enhancement, restoration), while threats assessments that identify existing and emerging issues of concern will enable appropriate management responses in a timely fashion. Research studies will inform many aspects of management, including model and regional population structure refinement, and Best Management Practices for enhancement, restoration, translocation, and invasive species control. Finally, establishment of sentinel populations for monitoring and the use of tools such as the Climatic Influences Model (Appendix C.3) will help evaluate results and focus management efforts in years where effects are expected to be the most beneficial.

3.1 Regional Actions

It is anticipated that the following actions will be conducted or directed by a regional entity across MUs and preserves:

- Survey all extant and presumed extant populations on conserved lands to fill data gaps and determine population status and management needs.
- Survey opportunity areas to identify new thornmint populations or suitable thornmint or pollinator habitat.
- Test soils of all or a sample of populations to examine potential soil correlates for use in future expansion/establishment/translocation efforts.
- Based on survey results, refine the regional population structure hypothesis, habitat suitability model, and opportunity areas for enhancement/expansion, establishment, and translocation.
- Based on survey results, identify isolated populations that may serve as refugia, as well as isolated populations not prioritized for management.
- Based on existing data and future survey results, identify populations to monitor regularly as “sentinels.” At a minimum, these should include all large populations on conserved lands.

- Implement invasive plant control at regionally important (typically, large) populations where invasives have been identified as a threat to thornmint persistence.
- Refine Best Management Practices included in Appendix D at regular intervals based on results of management experiments and research studies.
- Develop a permanent seed source (seed bank) that consists of both conservation and propagation seed collections.
- Based on survey and research results, enhance selected small populations determined to be important for long-term persistence, establish new populations and/or pollinator habitat (if determined necessary), and conduct experimental translocations (if determined necessary). Prepare implementation plans to guide these efforts.

3.2 Preserve Actions

It is anticipated that the following actions will be conducted by land managers at the preserve level.

- Collect census and spatial data, conduct a threats assessment, validate vegetation alliances and associations, and conduct general soils testing for extant populations not identified for regional surveys. Collect data using a standardized protocol and data sheet (Appendix E), and submit it to the SC-MTX website portal.
- Conduct annual inspections of extant populations using the thornmint monitoring protocol (Appendix E).
- Perform routine management, as necessary, to protect populations from impacts. Routine management may include (but is not limited to) fencing, signage, and invasive plant control.

3.3 Research

The San Diego thornmint conceptual model was instrumental in identifying potential research needs (Appendix C). This model identified life history traits that influence species persistence, as well as drivers and uncertainties that may affect those traits. For example, the conceptual model identified gene flow as a potentially important life history trait. The mechanisms of gene flow in this species are not well known; thus, genetic studies have been identified as a priority research recommendation that will inform adaptive management of this species across the region. Recommended research studies will provide information for specific life history traits, as follows:

- Genetic and greenhouse studies – gene flow, population structure
- Seed studies – reproduction, population structure
- Pollinator studies – gene flow, reproduction
- Invasive plant studies – gene flow, reproduction, population structure, floral display/plant size

Prioritization of research studies should follow a top-down approach, with the highest priority on studies that guide management at the landscape-level (i.e., *which* populations to manage), followed by management at the preserve-level (i.e., *how* to manage populations). Some recommendations (e.g., pollinator studies) will be a higher priority in fragmented versus intact landscapes.

Research recommendations to guide management of San Diego thornmint (detailed in Appendix A, Table A-9) include:

- Determine the genetic structure of thornmint populations on conserved lands (high priority) to:
    - Refine the regional population structure hypothesis.
    - Identify existing populations that would benefit from enhancement or expansion.
    - Identify gaps to inform establishment of new populations or pollinator habitat to promote connectivity and genetic diversity.
    - Identify appropriate source populations of genetic material for use in augmentation.
    - Inform seed bulking protocols to conserve genetic diversity.
- Conduct common greenhouse studies in conjunction with results from genetic studies to assess adaptive genetic diversity (high priority).
- Determine seed bank dynamics (including presence, longevity, and susceptibility to fire) (medium priority).
- Determine seed dormancy factors, germination cues, and viability rates (high priority).
- Determine effective pollinators and their host plants, maximum pollinator migration/travel distance, and potential effects of climate change on pollinator communities in relation to thornmint phenology (high-medium priority, depending on location).
- Determine dispersal agents and dispersal capabilities of thornmint seed (medium priority).
- Determine effects of invasive plant species on thornmint survival and persistence (high priority).

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