APPENDICES

APPENDICES

Appendix A
Management Strategic Plan

San Diego Thornmint (*Acanthomintha ilicifolia*)

Management Units with Known Populations[1]

San Diego thornmint occurs primarily in chaparral, scrub, and grassland habitats in the western portion of San Diego County and Baja California, Mexico (CNDDB 2013, Beauchamp 1986, SANDAG 2012). This species is an edaphic endemic restricted to clay soils or clay lenses in gabbro soils (Oberbauer and Vanderwier 1991). A total of 92 populations have been recorded for this species in San Diego County (Figure A-1, Table A-1). Of this total, 67 are extant or presumed extant (or *current*) and occur within the Management Strategic Planning Area (MSPA) in Management Units (MUs) 2, 3, 4, 5, 6, and 8 (Figure A-1), 19 populations within the MSPA have been verified as extirpated (CNDDB 2012, USFWS 2009), 5 populations are found outside the MSPA, and 1 population is reportedly inside the MSPA in MU 3, but the location is unknown. Populations in the presumed extant category include those identified by other sources as potentially extirpated (e.g., CNDDB 2012, USFWS 2009) but for which suitable habitat still exists, as well as those for which status is unknown due to lack of survey data. These presumed extant populations are included in management planning.

Although size is not the only consideration in identifying populations for management, maintaining both large and medium populations that are geographically dispersed is key to retaining a regional population structure that promotes resilience and long-term persistence. Eight populations on conserved lands are considered large (>10,000 individuals), based on available survey data. Populations were categorized into size classes based on the maximum number of plants observed as an indication of potential carrying capacity (Appendix C). Under this approach, some populations identified as 'large' may currently support fewer plants and may not have the potential to regain former population levels. Potential carrying capacity and current status and threats are important considerations for prioritizing populations for management.

[1] In keeping with discussions in the Adaptive Management Framework and Appendix C, we use the term 'population' rather than 'occurrence' throughout this document to minimize confusion. When referring to specific populations or element occurrences, the term population is synonymous to 'occurrence,' as used in the Management Strategic Plan and Master Occurrence Matrix (MOM) (SDMMP 2013), and does not necessarily infer a genetic relationship.

Figure A-1

Distribution of San Diego Thornmint in San Diego County

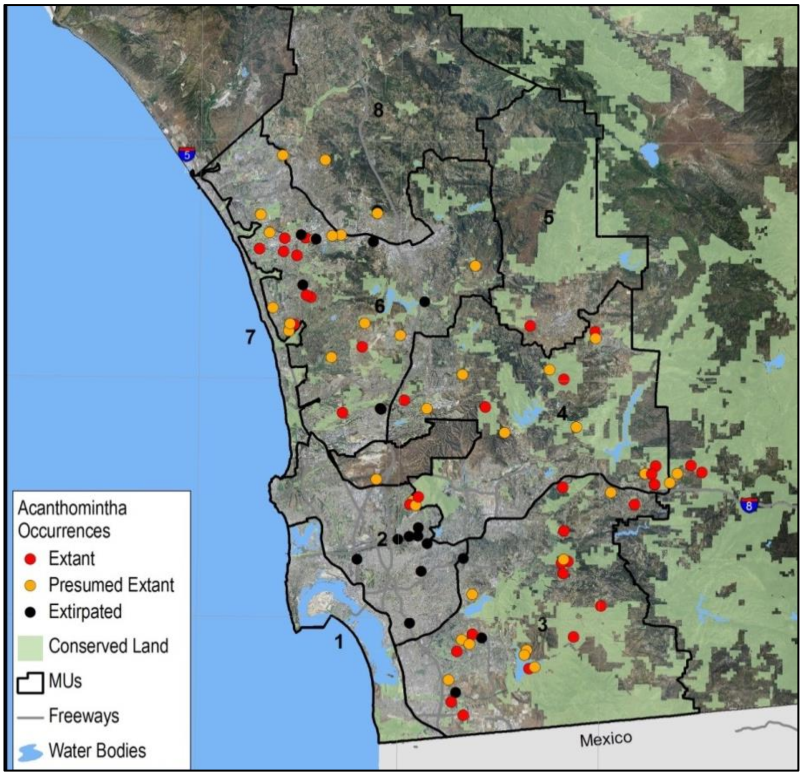

Table A-1

Summary of San Diego Thornmint Populations by Management Unit

Management Unit	Number of Occurrences[1]			
	Extant	Presumed Extant[2]	Extirpated	Total
2	1	1	8	10
3	13	9[3]	3	25
4	9	8	0	17
5	1	0	0	1
6	10	13	7	30
8	0	2	1	3
Outside MSPA	2	3	0	5
Total	36	36	19	91

1 Extant and presumed extant = current populations.
2 Presumed extant populations may be extant or extirpated; however, further surveys are required to determine status.
3 An additional, presumed extant population has been described for MU (Alpine); however, there is no spatial data to indicate the location of this population, and it is not considered for management planning at this time.

Large populations include:

- MU 3: Hollenbeck Wildlife Area (EO 86) and Rice Canyon (EO 90);
- MU 4: Sycamore Canyon (EO 32), Mission Trails Regional Park (EO 33), Sabre Springs (west) (EO 36), and Viejas Mountain (southwest slope) (EO 51);
- MU 6: Lux Canyon east (Manchester Avenue Mitigation Bank) (EO 28) and Palomar Airport Road (EO 70).

Seven populations on conserved lands are considered medium (>1,000-10,000 plants), based on available survey data:

- MU 3: McGinty Mountain (southwest slope) (EO 21), McGinty Mountain (summit and ridgeline) (EO 22), Suncrest (South Crest) (EO 72), and McGinty Mountain (EO 87);
- MU 4: Viejas Mountain (west-southwest flank) (EO 75) and Simon Reserve (EO 77);
- MU 6: Los Peñasquitos Canyon (EO 19).

Selected small populations are also important for their role as refugia, steppingstones, or unique genetic structure. Small populations in proximity to large or medium populations may have enhanced resilience due to unidirectional gene flow from larger populations. The following discussion summarizes San Diego thornmint populations within each MU and the overall importance of the MU to thornmint persistence.

Management Unit 2

Historically, MU 2 supported ten populations of San Diego thornmint; eight have been extirpated primarily as a result of development. The two current populations (EO 34, near Mission Trails Regional Park, and EO 79, near Mission Gorge) are considered presumed extant and extant, respectively (Figure A-2, Table A-2). Survey information indicates that both populations are small and subject to direct and indirect threats. Neither population is on conserved lands; therefore, neither is included in management planning at this time.

Management Unit 3

A total of 22 current (13 extant, 9 presumed extant) and 3 extirpated San Diego thornmint populations have been documented in MU 3, from the coastal terraces of Otay Mesa eastward to Alpine (Figure A-3). Current populations occur on conserved lands unless otherwise noted; they include 2 large (>10,000 individuals, EOs 86, 90), 4 medium (>1,000-10,000 individuals, EOs 21, 22, 72, 87), and 7 small populations (≤1,000 individuals, EOs 15, 63, 81, 83, 84, 85, Bonita Meadows), as well as 7 populations of unknown status with respect to size, location, threats, and/or management needs (EOs 45, 55, 56, 71, 88, 89, McGinty Mountain). The remaining two current populations (EOs 66, 96) are not on conserved lands or occur in degraded habitat, so are not included in management planning. Primary threats to San Diego thornmint in MU 3 include invasive plants, altered fire regimes, nitrogen deposition, and climate change (Table A-3, Appendix C). Additional direct and indirect impacts have been noted at individual preserves, including competitive native plants, herbivory, altered hydrology, mountain-biking, off-road vehicles, and trampling (Appendix B). For many populations, a site-specific threats assessment has not yet been conducted. In general, conserved San Diego thornmint populations in the western portion of MU 3 are in fragmented habitat, while populations in the east are found in larger blocks of connected habitat. This spatial distribution may influence management needs, as populations in fragmented habitat may be more susceptible to direct impacts, edge effects, and genetic erosion due to loss of connectivity.

MU 3 is particularly important for thornmint because of the presence of (1) unoccupied, suitable habitat that may support additional populations and (2) potentially suitable future habitat in proximity to existing populations that may allow for response to climate change (Appendix C).

Figure A-2

Current San Diego Thornmint Populations in Management Unit 2

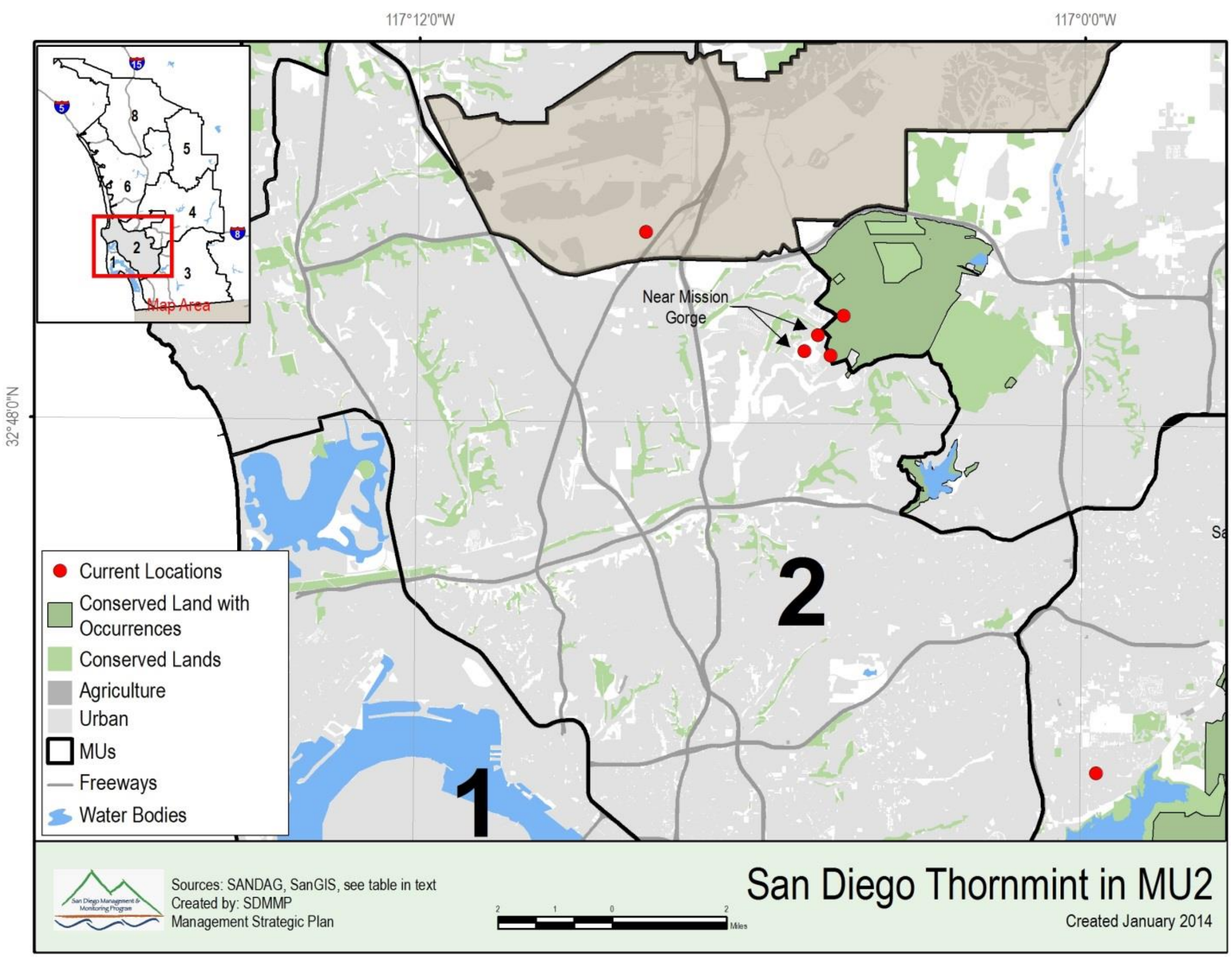

Table A-2

Current San Diego Thornmint Populations in Management Unit 2

EO[1]	Status[2]	Preserve	LO[3]	LM[4]	Max. # (year)[5]	Max # Since 2000 (year)[6]	# Last Survey (year)[7]	Threats[8]	Sources[9]
Populations not on conserved lands									
34	PE	Near Mission Trails	PVT	PVT	200 (1986)	0 (2010)	0 (2010)	AFR, DP, IP, TR?, ND	CNDDB 2013; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
79	EXT	Near Mission Gorge	PVT	PVT	50 (2003)	50 (2003)	1 (2009)	AFR, CC, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.

1 EO = element occurrence number from CNDDB (2012).
2 Status: EXT = Extant population; PE = Presumed extant population.
3 LO = Land Owner. PVT = Private.
4 LM = Land Manager. PVT = Private.
5 Max # (year): Maximum census number observed for population; number in parentheses = year of observation.
6 Max # since 2000 (year): Maximum census number observed for population since 2000; number in parentheses = year of observation.
7 # Last Survey: Census number at last survey; number in parentheses = year of last survey.
8 Threats: Reported threats according to land managers, literature, or GIS spatial datasets. AFR = Altered fire regime, CC = Climate change; DP = Dumping; IP = Invasive plants; TR = Trampling; ND = Nitrogen deposition. Information on threats may not be comprehensive.
9 Sources: Refer to reference list for full source citations.

Figure A-3

Current San Diego Thornmint Populations in Management Unit 3

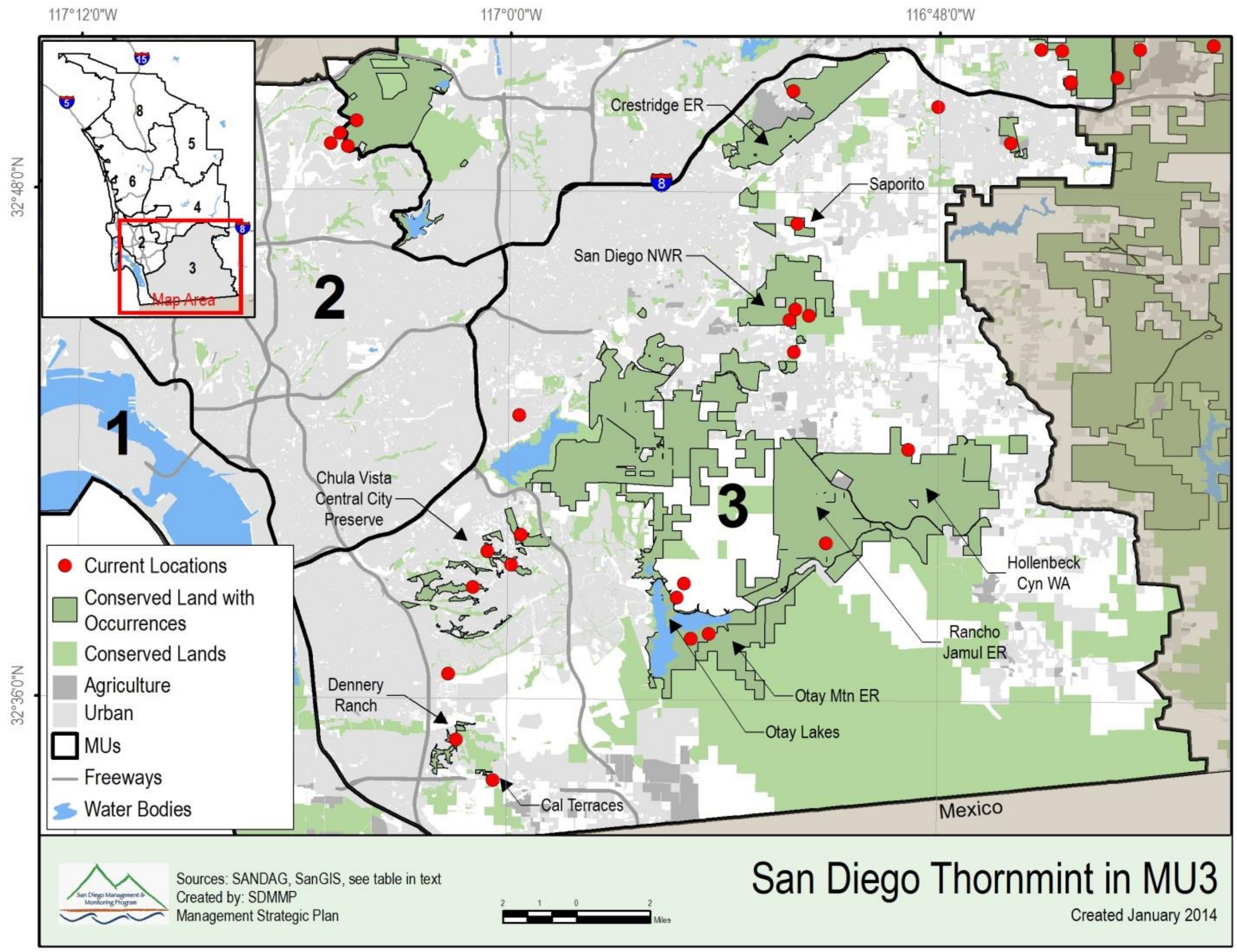

Table A-3

Current San Diego Thornmint Populations in Management Unit 3

EO[1]	Status[3]	Preserve	LO[4]	LM[5]	Max. # (year)[6]	Max # Since 2000 (year)[7]	# Last Survey (year)[8]	Threats[9]	Sources[10]
Large populations (>10,000 individuals)									
86	EXT	Hollenbeck Wildlife Area	CDFW	CDFW	32,777 (2003)	32,777 (2003)	5,000 (2010)	AFR, CC, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
90	EXT	Rice Canyon	City Chula Vista	City Chula Vista	32,200 (2012)	32,200 (2012)	11,543 (2013)	**IP,** CC, MB, ND, TR	CNDDB 2013; Bennett 2013; Conlisk et al. 2012; Tonnesen et al. 2007; RECON 2004.
Medium populations (>1,000-10,000 individuals)									
21	EXT	McGinty Mountain (southwest slope)	TNC	TNC	>1,000 (2011)	>1,000 (2011)	>1,000 (2011)	AFR?, ND	CNDDB 2013; Godfrey and McConnell 2013; Martin 2013; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
22	EXT	McGinty Mountain (summit and ridgeline)	TNC	TNC, USFWS	2,559 (2010)	2,559 (2010)	30 (2011)	**IP,** AFR?, CC?, CNP, HY, ND, TR	CNDDB 2013; Martin 2013; Conlisk et al. 2012; Cal Fire 2011; Martin 2005, 2009; USFWS 2009; Tonnesen et al. 2007.
72	EXT	Suncrest (South Crest)	EHC	EHC	1,135 (2012)	1,135 (2012)	1,135 (2012)	**IP,** AFR, CC, CNP, HE, ND, OHV	CNDDB 2013; CBI 2012a,b, 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
87	EXT	McGinty Mountain	USFWS	USFWS	6-7,000 (2011)	6-7,000 (2011)	6-7,000 (2011)	AFR?, CC, ND	CNDDB 2013; Conlisk et al. 2012; CalFire 2011; Tonnesen et al. 2007.

Table A-3

Current San Diego Thornmint Populations in Management Unit 3

EO[1]	Status[3]	Preserve	LO[4]	LM[5]	Max. # (year)[6]	Max # Since 2000 (year)[7]	# Last Survey (year)[8]	Threats[9]	Sources[10]
Small populations (≤1,000 individuals) that may be enhanced by proximity to larger populations (population groups)									
15	EXT	Wheeler Ridge (Long Canyon)	City Chula Vista	City Chula Vista	500 (2003)	500 (2003)	37 (2013)	**IP, TR,** CC, MB, ND	CNDDB 2013; Bennett 2013; Conlisk et al. 2012; Tonnesen et al. 2007; RECON 2004.
Small populations (≤1,000 individuals) that may be important as refugia, steppingstones, or due to unique genetic structure									
63	EXT	Wright's Field	BCLT	BCLT	800 (1995)	200 (2013)	200 (2013)	**IP**, CC, CNP, MB, ND, OHV, TR	CNDDB 2013; Conlisk et al. 2012; Klein 2009; McMillan 2013; USFWS 2009; Tonnesen et al. 2007.
81	EXT	Crestridge Ecological Reserve	CDFW	EHC	505 (2000)	17 (2010)	3 (2013)	**IP, CNP,** CC, AFR, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; CBI 2009, 2011a,b, 2012a,b; CBI and EHC 2009; Tonnesen et al. 2007.
83	EXT	Dennery Canyon East	City San Diego	City San Diego	536 (2012)	536 (2012)	0 (2013)	**IP**, CC?, ND	CNDDB 2013; Miller 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
85	EXT	Rancho Jamul Ecological Reserve	CDFW	CDFW	125 (2010)	125 (2010)	125 (2010)	AFR, ND	CNDDB 2013; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
Small populations (≤1,000 individuals) at highest risk due to isolation, population size, and other threats									
--[2]	EXT	Bonita Meadows	Caltrans	Caltrans	5 (2002)	5 (2002)	5 (2002)	CC, IP, MB, ND, TR	Scatolini 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.

Table A-3

Current San Diego Thornmint Populations in Management Unit 3

EO[1]	Status[3]	Preserve	LO[4]	LM[5]	Max. # (year)[6]	Max # Since 2000 (year)[7]	# Last Survey (year)[8]	Threats[9]	Sources[10]
84	EXT	Otay Lakes South	City San Diego, PUD	City San Diego, PUD	89 (2001)	89 (2001)	0 (2013)	AFR, CC?, IP, ND	CNDDB 2013; Miller 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
Populations for which additional surveys are required to determine status, location, and/or appropriate management									
--[2]	PE	McGinty Mountain	USFWS, CDFW	USFWS, CDFW	No data	No data	No data (1978)	ND	CCH 2013; Tonnesen et al. 2007.
45	PE	Sky Mesa Ranch	PVT	PVT	1,500 (1990)	No data	No data (1992)	AFR, CC?, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
55	PE	Otay Lakes (northeast side)	PVT	PVT	33 (1990)	No data	33 (1990)	AFR, CC?, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
56	PE	Otay Lakes (northeast side)	PVT	PVT	40 (2000)	No data	40 (2000)	AFR, CC, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
71	PE	Poggi Canyon (PMA 3)	City Chula Vista	City Chula Vista	No data	No data	No data (2003)	CC, ND	CNDDB 2013; Bennett 2013; Conlisk et al. 2012; Tonnesen et al. 2007; RECON 2004.
88	PE	Lower Otay Reservoir	CDFW	CDFW	No data	No data	No data (2001)	CC, ND	CNDDB 2013; Conlisk et al. 2012; Tonnesen et al. 2007.
89	PE	Long Canyon (PMA 4-2b)	City Chula Vista	City Chula Vista	75 (2003)	75 (2003)	75 (2003)	CC, ND	CNDDB 2013; Bennett 2013; Conlisk et al. 2012; Tonnesen et al. 2007; RECON 2004.

Table A-3

Current San Diego Thornmint Populations in Management Unit 3

EO[1]	Status[3]	Preserve	LO[4]	LM[5]	Max. # (year)[6]	Max # Since 2000 (year)[7]	# Last Survey (year)[8]	Threats[9]	Sources[10]
Populations not recommended for regional management at this time									
96	EXT	Cal Terraces	PVT	PVT	No data	No data	No data	CC, ND	Conlisk et al. 2012; Tonnesen et al. 2007.
66	PE	Sweetwater Reservoir (north side)	UNK	UNK	No data	No data	No data	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.

[1] EO = element occurrence number from CNDDB (2012).

[2] Population(s) for which there is no element occurrence number.

[3] Status: EXT = Extant population; PE = Presumed extant population.

[4] LO = Land Owner. BCLT = Back Country Land Trust; Caltrans = California Department of Transportation; CDFW = California Department of Fish and Wildlife; City Chula Vista = City of Chula Vista; EHC = Endangered Habitat Conservancy; City San Diego = City of San Diego; City San Diego, PUD = City of San Diego, Public Utilities Department; TNC = The Nature Conservancy; USFWS = U.S. Fish and Wildlife Service.

[5] LM = Land Manager. BCLT = Back Country Land Trust; Caltrans = California Department of Transportation; CDFW = California Department of Fish and Wildlife; City Chula Vista = City of Chula Vista; EHC = Endangered Habitat Conservancy; City San Diego = City of San Diego; City San Diego, PUD = City of San Diego, Public Utilities Department; TNC = The Nature Conservancy; USFWS = U.S. Fish and Wildlife Service.

[6] Max # (year): Maximum census number observed for population; number in parentheses = year of observation.

[7] Max # since 2000 (year): Maximum census number observed for population since 2000; number in parentheses = year of observation.

[8] # Last Survey: Census number at last survey; number in parentheses = year of last survey.

[9] Threats: Reported threats according to land managers, literature, or GIS spatial datasets. AFR = Altered fire regime; CC = Climate change (CC = potential impacts under all 4 scenarios addressed in Conlisk et al. 2012; CC? = potential impacts under some, but not all scenarios addressed in Conlisk et al. 2012); CNP = Competitive native plants; IP = Invasive plants; HE = Herbivory; HY = Hydrology; MB = Mountain bikes; ND = Nitrogen deposition; OHV = Off-highway vehicles; TR = Trampling. Threats in **bold** have been identified as primary threat by land managers. Information on threats may not be comprehensive.

[10] Sources: Refer to reference list for full source citations.

Management Unit 4

MU 4 supports 17 (9 extant, 8 presumed extant) populations, from Mission Trails Regional Park north to Poway, northeast to Ramona, and east to Viejas Mountain (Figure A-4), with no records of extirpated populations. Current populations are listed in Table A-4 and occur on conserved lands unless otherwise noted. Conserved lands support 4 large (>10,000 individuals, EOs 32, 33, 36, 51), 2 medium (>1,000-10,000, EOs 75, 77), and 2 small populations (≤1,000, EOs 78, 80), as well as 7 populations of unknown size, location, threats, and management needs (EOs 11, 26, 35, 69, Viejas Hills, Simon Preserve, Poway Grade). Two additional populations in Table A-4 are not on conserved lands and are not included in management planning (EOs 64, 73). Primary threats are similar to those in MU 3. The majority of populations (exclusive of those in the northwestern portion of the MU) are in relatively large blocks of conserved habitat. MU 4 is of particular importance because it supports (1) some of the largest populations throughout the species' range, (2) unoccupied, currently suitable habitat, and (3) potentially suitable future habitat in proximity to existing populations that may allow for response to climate change. Populations around Viejas Mountain are in proximity to conserved populations within the Cleveland National Forest.

Management Unit 5

MU 5 supports one San Diego thornmint population on conserved lands, with no records of extirpated populations (Figure A-5, Table A-5). The Wildlife Research Institute manages this small population (EO 92, Ramona). The primary threat is invasive plants, which may be exacerbated by high levels of atmospheric nitrogen (Appendix C). This population may have regional value due to its geographic location, particularly if additional populations are detected in proximity. Based on habitat suitability and climate change modeling, suitable habitat may occur on conserved lands to the north and northeast of the Ramona grasslands. Climate change scenarios indicate that conditions at the Ramona grasslands will remain suitable to support thornmint in the future (Appendix C), thus increasing the importance of this MU over time.

Figure A-4

Current San Diego Thornmint Populations in Management Unit 4

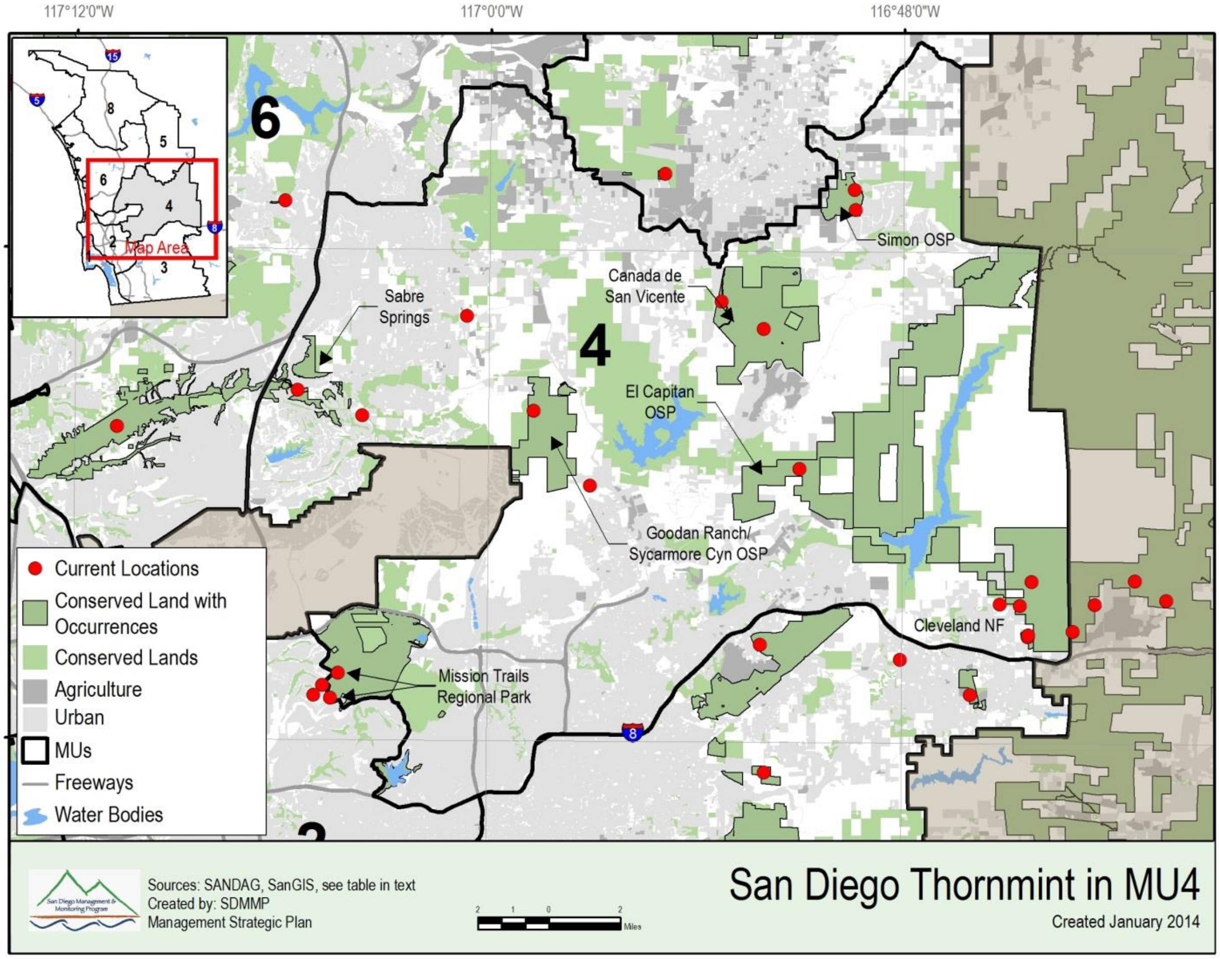

Table A-4

Current San Diego Thornmint Populations in Management Unit 4

EO[1]	Status[4]	Preserve	LO[5]	LM[6]	Max. # (year)[7]	Max # Since 2000 (year)[8]	# Last Survey (year)[9]	Threats[10]	Sources[11]
Large populations (>10,000 individuals)									
32	EXT	Sycamore Canyon	SDC, CDFW, PVT	SDC, CDFW	>37,500 (1994)	>32,160 (2010)	>32,160 (2010)	AFR, CC?, HY, IP, ND, TR	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; Crafts 2010; USFWS 2009; Tonnesen et al. 2007.
33	EXT	Mission Trails Regional Park	City San Diego	City San Diego	30-50,000 (1995)	737 (2013)	737 (2013)	**IP**, AFR, HE, MB, ND	CNDDB 2013; Miller 2013; McMillan 2013; USFWS 2009; Tonnesen et al. 2007.
36	EXT	Sabre Springs (west)	City San Diego	City San Diego	19,721 (2003)	19,721 (2003)	61 (2013)	**IP**, CC, HE, ND	CNDDB 2013; Miller 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
51	EXT	Viejas Mountain (southwest slope)	CNF	CNF	21,015 (2010)	21,015 (2010)	21,015 (2010)	**IP**, AFR, CC?, ND	CNDDB 2013; Winter 2013; Conlisk et al. 2012; Cal Fire 2011; Tonnesen et al. 2007.
Medium populations (>1,000-10,000 individuals)									
75	EXT	Viejas Mountain (west-southwest flank)	CNF	CNF	1,638 (2010)	1,638 (2010)	1,638 (2010)	**IP**, AFR, ND	CNDDB 2013; Winter 2013; Cal Fire 2011; Tonnesen et al. 2007.

Table A-4

Current San Diego Thornmint Populations in Management Unit 4

EO[1]	Status[4]	Preserve	LO[5]	LM[6]	Max. # (year)[7]	Max # Since 2000 (year)[8]	# Last Survey (year)[9]	Threats[10]	Sources[11]
77	EXT	Simon Reserve	SDC	SDC	5,000-10,000 (2009)	5,000-10,000 (2009)	5,000-10,000 (2009)	AFR, CC, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; San Diego County Parks and Recreation Department 2010; USFWS 2009; Tonnesen et al. 2007.
Small populations (≤1,000 individuals) that may be enhanced by proximity to larger populations (population groups)									
80	EXT	Viejas Mountain (northwest slope)	CNF	CNF	44 (2010)	44 (2010)	44 (2010)	AFR, CC?	CNDDB 2013; Winter 2013; Conlisk et al. 2012; Cal Fire 2011; Tonnesen et al. 2007.
Small populations (≤1,000 individuals) at highest risk due to isolation, population size, and other threats									
78	EXT	Monte Vista (Long's Gulch)/Canada San Vicente	CDFW	CDFW	25 (2006)	25 (2006)	0 (2011)	**IP**, AFR, CNP?, LG, ND	CNDDB 2013; Principe 2013, Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
Populations for which additional surveys are required to determine status, location, and/or appropriate management									
--[2,3]	EXT	Viejas Hills	PVT	PVT	No data	No data	No data	**IP?**, AFR, CC?, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; Tonnesen et al. 2007.

Table A-4

Current San Diego Thornmint Populations in Management Unit 4

EO[1]	Status[4]	Preserve	LO[5]	LM[6]	Max. # (year)[7]	Max # Since 2000 (year)[8]	# Last Survey (year)[9]	Threats[10]	Sources[11]
--[2]	PE	El Capitan	SDC	SDC	No data	No data	No data	AFR, CC, ND	Preston 2013; Conlisk et al. 2012; Cal Fire 2011; Tonnesen et al. 2007.
--[2]	PE	Simon Preserve	SDC	SDC	No data	No data	No data (1999)	AFR, CC, ND	CCH 2013; Cal Fire 2011; Tonnesen et al. 2007.
11	PE	Poway Grade	PVT	PVT	No data	No data	No data (2001)	AFR, CC, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
26	PE	Sabre Springs (east)	City Poway		No data	No data	No data (2001)	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
35	PE	Southwest Tierra Santa parcel, northwest of mouth of Mission Gorge	? (PVT or MTRP)	? (PVT or MTRP)	400-600 (1980)	0 (2010)	0 (2010)	IP, CC?, HY, ND, MW	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
69	PE	Monte Vista (Daney Canyon)/Canada San Vicente	CDFW	CDFW	100 (1995)	0 (2010)	0 (2010)	AFR, CC?, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.

Table A-4

Current San Diego Thornmint Populations in Management Unit 4

EO[1]	Status[4]	Preserve	LO[5]	LM[6]	Max. # (year)[7]	Max # Since 2000 (year)[8]	# Last Survey (year)[9]	Threats[10]	Sources[11]
Populations not on conserved lands but which may be important due to size or location									
64	PE	Slaughterhouse Canyon	Pioneer Concrete	None	1993 (± 60,000)	No data	1 (1996)	AFR, ND	CNDDB 2013; CalFire 2011; USFWS 2009; Tonnesen et al. 2007.
73	PE	East of Murphy Ranch	PVT	PVT	8,750 (1997)	No data	8,750 (1997)	AFR, CC?, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.

[1] EO = element occurrence number from CNDDB (2012).

[2] Population(s) for which there is no element occurrence number.

[3] Although census data are not available for this population, aerial imagery indicates that habitat is intact and largely undisturbed. Regardless of size, this population would likely be enhanced, in terms of gene flow, by proximity to population 51.

[4] Status: EXT = Extant population; PE = Presumed extant population.

[5] LO = Land Owner. CDFW = California Depart. Fish and Wildlife; City Poway = City of Poway; City San Diego = City of San Diego; CNF = Cleveland National Forest; MTRP = Mission Trails Regional Park; PVT = Private (conservation easement); SDC = County of San Diego; ? = Owner unknown.

[6] LM = Land Manager. CDFW = California Depart. Fish and Wildlife; City Poway = City of Poway; City San Diego = City of San Diego; CNF = Cleveland National Forest; MTRP = Mission Trails Regional Park; PVT = Private (conservation easement); SDC = County of San Diego; ? = Manager unknown.

[7] Max # (year): Maximum census number observed for population; number in parentheses = year of observation.

[8] Max # since 2000 (year): Maximum census number observed for population since 2000; number in parentheses = year of observation.

[9] # Last Survey: Census number at last survey; number in parentheses = year of last survey.

[10] Threats: Reported threats according to land managers, literature, or GIS spatial datasets. AFR = Altered fire regime; CC = Climate change (CC = potential impacts under all 4 scenarios addressed in Conlisk et al. 2012; CC? = potential impacts under some, but not all scenarios addressed in Conlisk et al. 2012); CNP = Competitive native plants; HE = Herbivory; HY = Hydrology; IP = Invasive plants; LG = Loss of grazing; MB = Mountain bikes; ND = Nitrogen deposition; TR = Trampling. Threats in **bold** have been identified as primary threat by land managers. Information on threats may not be comprehensive.

[11] Sources: Refer to reference list for full source citations.

Figure A-5

Current San Diego Thornmint Populations in Management Unit 5

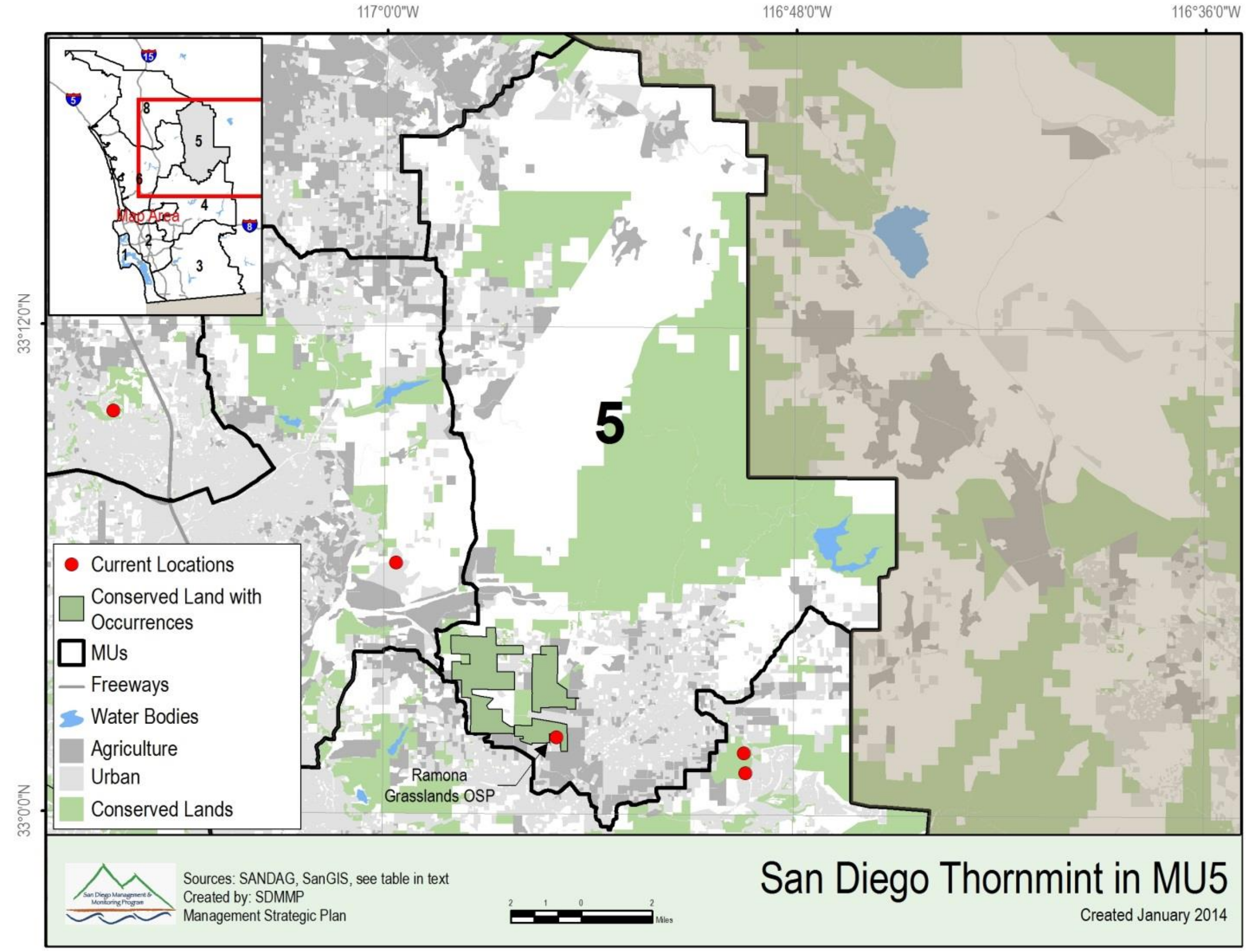

Table A-5

Current San Diego Thornmint Populations in Management Unit 5

EO[1]	Status[32]	Preserve	LO[3]	LM[4]	Max. # (year)[5]	Max # Since 2000 (year)[6]	# Last Survey (year)[7]	Threats[8]	Sources[9]
Small populations (≤1,000 individuals) that may be important as refugia, steppingstones, or due to unique genetic structure									
92	EXT	Ramona Grasslands/Hobbes Property	WRI, SDC	WRI, SDC	58 (2010)	58 (2010)	49 (2013)	**IP**, CNP?, ND	CNDDB 2013; Meador 2013; Principe 2013; USFWS 2009; Tonnesen et al. 2007.

1 EO = element occurrence number from CNDDB (2012).

2 Status: EXT = Extant population.

3 LO = Land Owner. WRI = Wildlife Research Institute; SDC = County of San Diego.

4 LM = Land Manager. WRI = Wildlife Research Institute; SDC = County of San Diego.

5 Max # (year): Maximum census number observed for population; number in parentheses = year of observation.

6 Max # since 2000 (year): Maximum census number observed for population since 2000; number in parentheses = year of observation.

7 # Last Survey: Census number at last survey; number in parentheses = year of last survey.

8 Threats: Reported threats according to land managers, literature, or GIS spatial datasets. CC = Climate change; CNP = Competitive native plants; IP = Invasive plants; ND = Nitrogen deposition. Threats in **bold** have been identified as primary threat by land managers. Information on threats may not be comprehensive.

9 Sources: Refer to reference list for full source citations.

Management Unit 6

MU 6 supports 23 current (10 extant, 13 presumed extant) and 7 extirpated populations in fragmented habitat, from the coast inland to the Safari Park in Escondido (Figure A-6). Current populations are listed in Table A-6 and occur on conserved lands unless otherwise noted. Populations include 2 large (>10,000 individuals, EOs 28, 70), 1 medium (>1,000-10,000 individuals, EO 19), and 7 small populations (≤1,000 individuals, EOs 31, 47, 48, 58, 59, 60, 82), as well as 13 populations of unknown size, location, threats, and/or management needs (EOs 17, 25, 38, 39, 41, 42, 46, 49, 53, 57, 91, 94, 97); at least 7 of these are not on conserved lands, although 2 (Letterbox Canyon [EO 57] and Taylor [EO 97]) are expected to be conserved in the future (CNDDB 2013, USFWS 2009).

The primary threat appears to be invasive plants (Table A-6, Appendices B, C). Altered fire regimes are expected to affect only the most inland populations, with coastal populations possibly functioning as refugia from fire, based on fire history patterns (Appendix C). Nitrogen deposition likely impacts most populations except those along the immediate coast (Appendix C). Most populations may be adversely affected by climate change, although modeling scenarios indicate that a few populations (e.g., La Costa Greens, Black Mountain, Los Peñasquitos Canyon) may be resilient and serve as refugia (Appendix C). Additional direct and indirect impacts noted at individual preserves include competitive native plants, dumping, altered hydrology, mountain biking, mowing, and trampling. For many populations, a site-specific threats assessment has not yet been conducted. Their spatial distribution may influence management needs, as populations in fragmented habitat may be more susceptible to direct impacts, edge effects, and genetic erosion due to loss of connectivity.

In addition to supporting the largest number of documented occurrences, areas within MU 6 could serve as refugia in the face of both climate change and altered fire regimes. Because of the level of fragmentation, maintaining or improving connectivity within and beyond this MU is critical to San Diego thornmint persistence. MU 6 supports both (1) unoccupied, currently suitable habitat that may support additional populations and (2) potentially suitable future habitat in proximity to existing populations that may allow for movement in response to climate change.

Figure A-6

Current San Diego Thornmint Populations in Management Unit 6

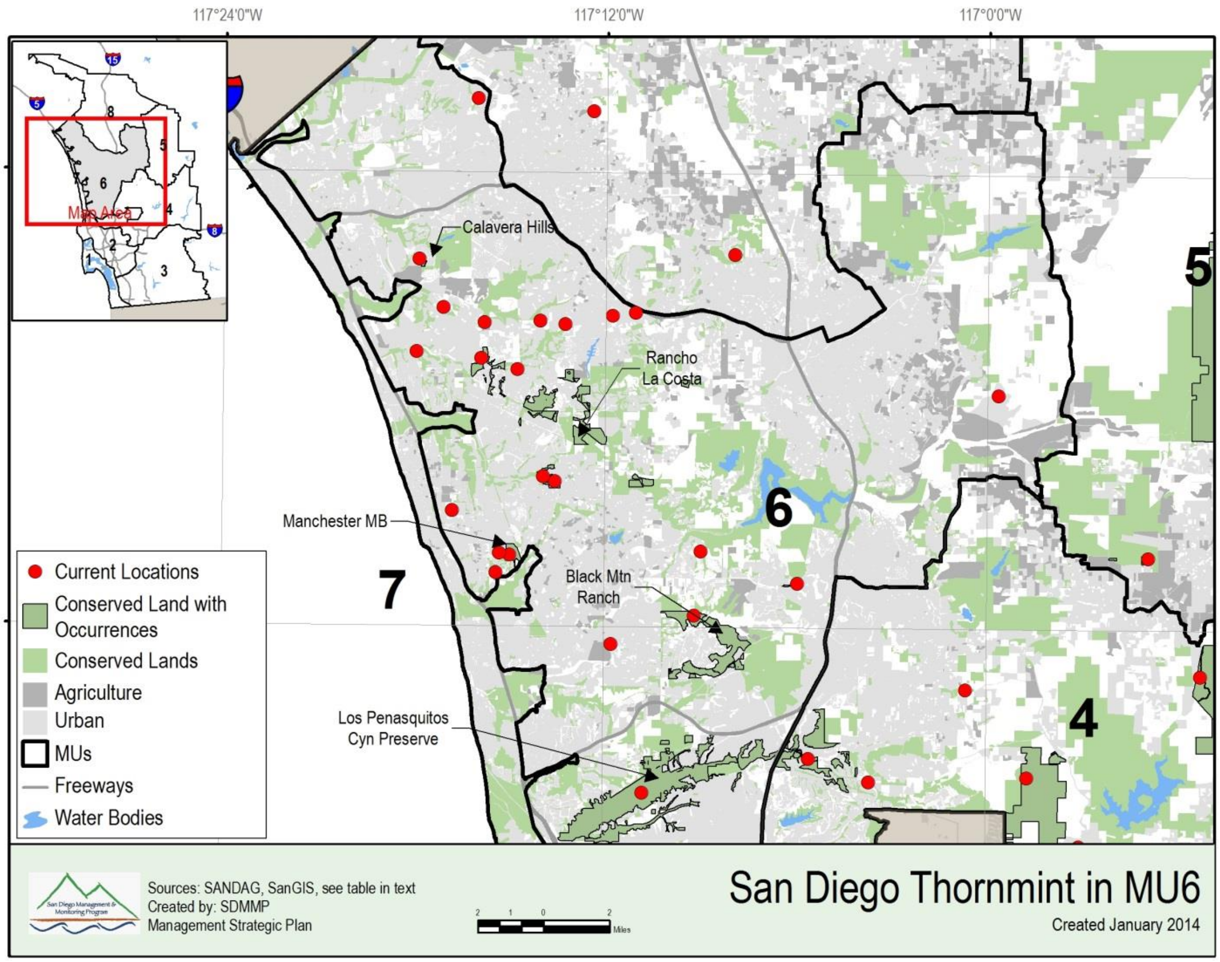

Table A-6

Current San Diego Thornmint Populations in Management Unit 6

EO[1]	Status[5]	Preserve	LO[6]	LM[7]	Max. # (year)[8]	Max # Since 2000 (year)[9]	# Last Survey (year)[10]	Threats[11]	Sources[12]
Large populations (>10,000 individuals)									
28	EXT	Lux Canyon (east), Manchester Avenue Mitigation Bank	CNLM	CNLM	11,400 (1989)	5,329 (2011)	1,943 (2013)	**IP**, CC, CNP, DP, MW, TR	CNDDB 2013; CNLM 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009.
70	EXT	Palomar Airport Road	SDC	CNLM	11,173 (2010)	11,173 (2010)	464 (2012)	**IP**, CC?, ND	CNDDB 2013; CNLM 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
Medium populations (>1,000-10,000 individuals)									
19	EXT	Los Peñasquitos Canyon	City San Diego	City San Diego	2,091 (2005)	2,091 (2005)	893 (2013)	**IP**, MB, ND	CNDDB 2013; Miller 2013; USFWS 2009; Tonnesen et al. 2007.
Small populations (≤1,000 individuals) that may be enhanced by proximity to larger populations (population groups)									
82	EXT	La Costa Greens	CNLM	CNLM	1,000 (2001)	1,000 (2003)	79 (2013)	**IP**, CNP, ND	CNDDB 2013; CNLM 2013; Vinje pers. obs. 2012-2013; Tonnesen et al. 2007.
Small populations (≤1,000 individuals) that may be important as refugia, steppingstones, or due to unique genetic structure									
31	EXT	Carlsbad Racetrack (south)	PVT	PVT	1,000 (1986)	85 (2009)	26 (2010)	**IP**, CC?, CNP?, ND, TR	CNDDB 2013, Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.

Table A-6

Current San Diego Thornmint Populations in Management Unit 6

EO[1]	Status[5]	Preserve	LO[6]	LM[7]	Max. # (year)[8]	Max # Since 2000 (year)[9]	# Last Survey (year)[10]	Threats[11]	Sources[12]
47	EXT	Southeast Carlsbad (east)	PVT	PVT	2,000 (1994)	500 (2006)	200 (2010)	**IP**, CC, HY, ND, TR?	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
48	EXT	Southeast Carlsbad (west)	PVT	PVT	1,000 (1994)	500 (2010)	500 (2010)	**IP**, **TR**, CC, MB, ND	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
60	EXT	Black Mountain	City San Diego	City San Diego	1,115 (2000)	777 (2001)	79 (2013)	**IP**, ND	CNDDB 2013; Miller 2013; USFWS 2009; Tonnesen et al. 2007.
Small populations (≤1,000 individuals) at highest risk due to isolation, population size, and other threats									
58	EXT	Emerald Pointe	SDHC	SDHC	110 (2009)	110 (2009)	20 (2013)	CC, CNP, HY, IP, ND	CNDDB 2013; Rocks 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
59	EXT	El Fuerte Street (Rancho Carillo)	PVT	PVT	170 (1991)	24 (2009)	10 (2010)	**IP**, CC, ND	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
Populations for which additional surveys are required to determine status, location, and/or appropriate management									
17[3]	PE	Upham	PVT	PVT	25 (1986)	No data	25 (1986)	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.

Table A-6

Current San Diego Thornmint Populations in Management Unit 6

EO[1]	Status[5]	Preserve	LO[6]	LM[7]	Max. # (year)[8]	Max # Since 2000 (year)[9]	# Last Survey (year)[10]	Threats[11]	Sources[12]
25	PE	Thornmint Court	PVT	PVT	1,000 (1983)	0 (2011)	0 (2011)	AFR?, CC?, IP	CNDDB 2013; Cal Fire 2011; USFWS 2009.
38	PE	Lux Canyon (west)	PVT	PVT	30 (1986)	0 (2006)	0 (2006)	**IP**, CC, CNP?, MW, TR	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009.
39	PE	San Diego Botanic Garden	SDBG	SDBG	200 (1993)	No data	No data	CC	CNDDB 2013; Ehrlinger 2013; Conlisk et al. 2012; USFWS 2009.
41	PE	Las Brisas Transplant Site	PVT	PVT	700-800 (1988)	0 (2006)	0 (2006)	**IP**, CC, ND, TR	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
42	PE	Lux Canyon (west of Manchester Ave. Mitigation Bank)	City Encinitas	PVT	5,000 (1994)	0 (2006)	0 (2006)	**IP**, CC, TR	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009.
46[3]	PE	Rancho Santa Fe	UNK	UNK	500 (1991)	No data (2001)	No data (2001)	AFR, ND	CNDDB 2013; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.
49	PE	San Diego Zoo Safari Park	SDZSP	SDZSP	1,500 (1992)	No data	1,500 (1992)	AFR, CC?, ND	CNDDB 2013; Conlisk et al. 2012; Cal Fire 2011; USFWS 2009; Tonnesen et al. 2007.

Table A-6

Current San Diego Thornmint Populations in Management Unit 6

EO[1]	Status[5]	Preserve	LO[6]	LM[7]	Max. # (year)[8]	Max # Since 2000 (year)[9]	# Last Survey (year)[10]	Threats[11]	Sources[12]
53[2]	PE	Linda Vista and Bent Avenue	City San Marcos	UNK	No data	No data	No data (1991)	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
57	PE	Letterbox Canyon (Spyglass)	PVT	PVT	No data	0 (2006)	0 (2006)	**MW**, **TR**, CC, DP, IP, HY, ND	CNDDB 2013; Vinje pers. obs. 2012-2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
91[3]	PE	San Dieguito Valley	UNK	UNK	No data	No data	No data	CC?, ND	CNDDB 2013; Conlisk et al. 2012; Tonnesen et al. 2007.
94	PE	Calavera Hills	PVT	CNLM	4 (2009)	4 (2009)	0 (2013)	CNP, IP, ND, TR	CNDDB 2013; CNLM 2013; Vinje pers. obs. 2012-2013; Tonnesen et al. 2007.
97[4]	PE	Taylor	PVT	PVT	185 (2001)	185 (2001)	185 (2001)	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.

[1] EO = element occurrence number from CNDDB (2012).

[2] Not included in Conserved Lands Database; however, population is within vernal pool preserve owned by the City of San Marcos.

[3] Unclear whether population is on Conserved Lands; in some cases, population appears to be mis-mapped.

[4] Currently in private ownership; however, property expected to be managed eventually by SDHC.

[5] Status: EXT = Extant population; PE = Presumed extant population.

[6] LO = Land Owner. CNLM = Center for Natural Lands Management; City Encinitas = City of Encinitas; City San Marcos = City of San Marcos; City San Diego = City of San Diego; SDC = San Diego County; PVT = Private (Home owner's Association and/or easement); SDBG = San Diego Botanic Garden; SDC = County of San Diego; SDHC = San Diego Habitat Conservancy; SDZSP = San Diego Zoo Safari Park; UNK = Unknown.

[7] LM = Land Manager. CNLM = Center for Natural Lands Management; City San Marcos = City of San Marcos; City San Diego = City of San Diego; PVT = Private (Home owner's Association and/or easement); SDBG = San Diego Botanic Garden; SDC = County of San Diego; SDHC = San Diego Habitat Conservancy; SDZSP = San Diego Zoo Safari Park; UNK = Unknown..

[8] Max # (year): Maximum census number observed for population; number in parentheses = year of observation.

[9] Max # since 2000 (year): Maximum census number observed for population since 2000; number in parentheses = year of observation.

[10] # Last Survey: Census number at last survey; number in parentheses = year of last survey.

[11] Threats: Reported threats according to land managers, literature, or GIS spatial datasets. AFR = Altered fire regime; CC = Climate change (CC = potential impacts under all 4 scenarios addressed in Conlisk et al. 2012; CC? = potential impacts under some, but not all scenarios addressed in Conlisk et al. 2012); CNP = Competitive native plants; DP = Dumping; IP = Invasive plants; HY = Hydrology; MB = Mountain bikes; MW = Mowing; ND = Nitrogen deposition; TR = Trampling. Threats in **bold** have been identified as primary threat by land managers. Information on threats may not be comprehensive.

[12] Sources: Refer to reference list for full source citations.

Management Unit 8

Two presumed extant populations and one extirpated population occur in MU 8, all in the San Marcos and Merriam mountains (Figure A-7, Table A-7). Emerald Heights [EO 61] is on conserved lands, in proximity to urban development; Palisades Estates [EO 93] is not on conserved lands per the SANDAG Conserved Lands Database, but is noted as conserved by other sources (CNDDB 2013, USFWS 2009). This is a medium (>1,000-10,000 individuals) population, subject to updated survey data. The MU 8 populations are at the northernmost portion of the species' range and subject to impacts from climate change and nitrogen deposition. They may be important if they are genetically distinct from populations in other MUs. The San Marcos and Merriam mountains, Oat Hills, and mountains surrounding Pala support gabbro soils in MU 8 that may provide suitable habitat. There are limited opportunities for connectivity with populations to the south and east, in MUs 4 and 6, respectively.

Figure A-7

Current San Diego Thornmint Populations in Management Unit 7

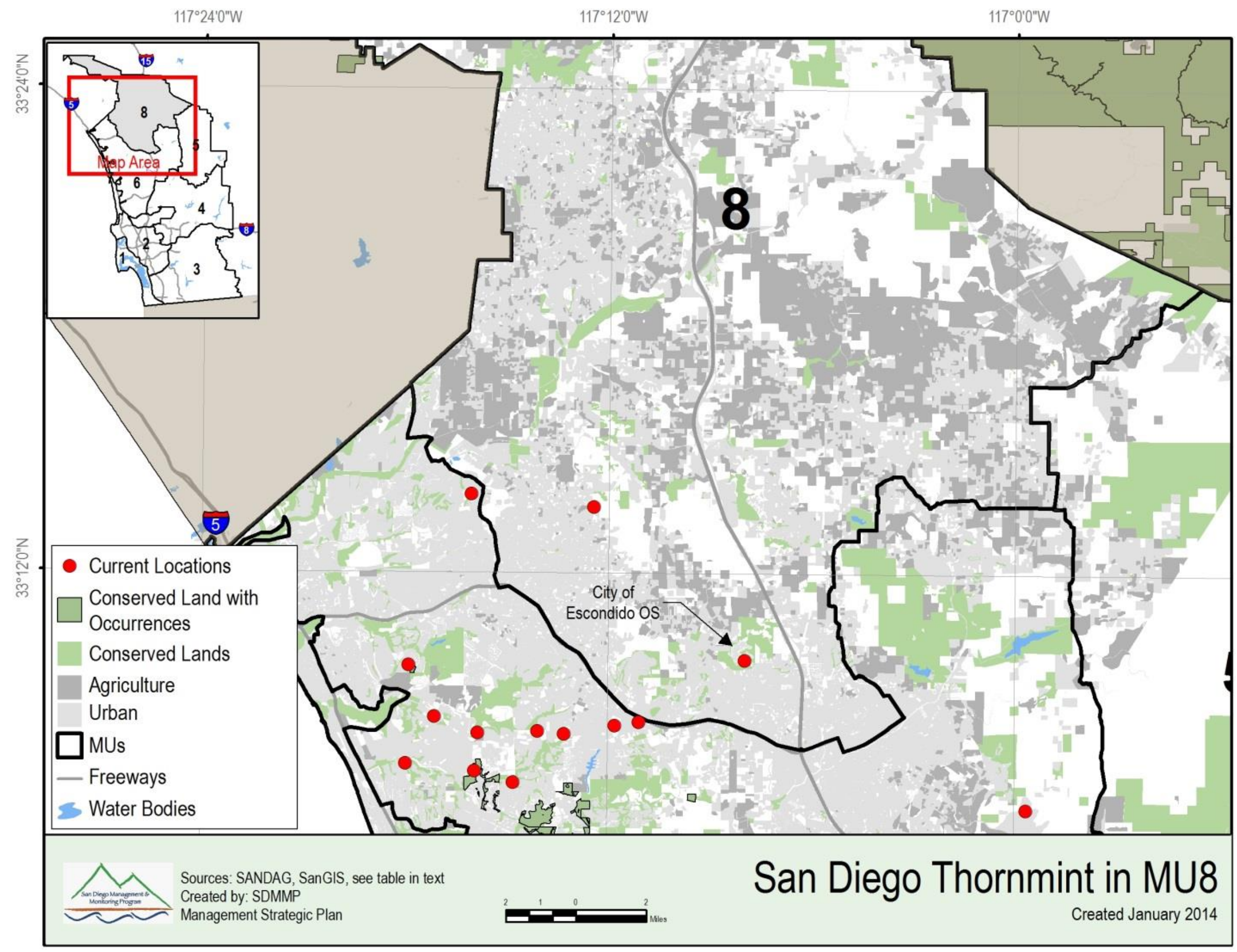

Table A-7

Current San Diego Thornmint Populations in Management Unit 8

EO[1]	Status[2]	Preserve	LO[3]	LM[4]	Max. # (year)[5]	Max # Since 2000 (year)[6]	# Last Survey (year)[7]	Threats[8]	Sources[9]
Populations for which additional surveys are required to determine status, location, and/or appropriate management									
61	PE	Emerald Heights	PVT	PVT	<100 (1992)	No data	5 (1994)	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009; Tonnesen et al. 2007.
93	PE	Palisades Estates	PVT	PVT	1,024 (2001)	1,024 (2001)	1,024 (2001)	CC, ND	CNDDB 2013; Conlisk et al. 2012; USFWS 2009.

1 EO = element occurrence number from CNDDB (2012).
2 Status: EXT = Extant population; PE = Presumed extant population.
3 LO = Land Owner. PVT = Private (Home owner's association).
4 LM = Land Manager. PVT = Private (Home owner's association).
5 Max # (year): Maximum census number observed for population; number in parentheses = year of observation.
6 Max # since 2000 (year): Maximum census number observed for population since 2000; number in parentheses = year of observation.
7 # Last Survey: Census number at last survey; number in parentheses = year of last survey.
8 Threats: Reported threats according to land managers, literature, or GIS spatial datasets. CC = Climate change; ND = Nitrogen deposition. Information on threats may not be comprehensive.
9 Sources: Refer to reference list for full source citations.

Management Categorization Rationale

San Diego thornmint is warranted for designation as a Management Focus Category SO species due to high risk of loss of one or more significant populations from MSPA conserved lands. Category SO species require management actions above and beyond daily maintenance activities to persist in the MSPA (SDMMP 2013). Factors contributing to this risk of loss include a limited range in western San Diego County and Baja California, soil endemism, an annual life cycle and probable outcrossing reproductive strategy, and a high degree of threats. In addition, thornmint often occurs in openings within the vegetation matrix that may require different management strategies than surrounding habitat. Therefore, San Diego thornmint is best managed with a species-specific focus.

The primary threat at both the regional- and preserve-levels appears to be invasive, nonnative plants, particularly nonnative grasses and forbs (Bauder et al. 1994, Bauder and Sakrison 1997, 1999, Klein 2009, USFWS 2009). In the last decade, the nonnative grass, purple falsebrome (*Brachypodium distachyon*) has posed a particular threat to many populations (CBI et al. 2012b, P. Gordon-Reedy pers. comm., B. Miller, pers. comm.). At the regional level, threats include small population size, altered fire regime, habitat fragmentation, nitrogen deposition, and climate change. At the preserve-level, threats include trampling, competitive native plants, mountain bikes, mowing, altered hydrology, dumping, off-highway vehicles, and herbivory. Some populations likely face adverse genetic consequences due to isolation, small size, and loss of pollinators. Landscape-level threats are discussed in detail in Appendix C.

Management Approach

Management will be directed at both the regional- and preserve- (local) levels. At the regional-level, the approach considers regional population structure and connectivity to maintain or enhance gene flow between populations, thus, enhancing long-term persistence: (1) maintain larger populations to retain demographic viability and genetic diversity, and enhance gene flow to smaller populations nearby; (2) enhance small populations or potentially important population groups (e.g., refugia, steppingstones, unique genetic structure) for which threats can be controlled or managed; (3) create new populations for regional population structure based on genetic studies, historic distribution, or adaptation to climate change; and (4) create or enhance habitat for pollinators to promote gene flow between recently isolated populations. Genetic studies that elucidate levels of diversity or relationships among populations, as well as adaptive diversity, are important to refine the regional management approach. Establish a regional seed bank to ensure a source of genetically appropriate material for both research and augmentation efforts. Management of some threats may be addressed most effectively at the regional or management-unit level, i.e., across multiple preserves.

At the preserve-level, the management approach will focus on controlling or managing threats to San Diego thornmint populations within individual preserves. Management recommendations are grouped by type of objective, as defined in the MSP (SDMMP 2013) and described below.

Baseline surveys (ISV). Baseline surveys are recommended at both the regional and preserve- (local) levels. Baseline surveys would (1) fill data gaps for extant and presumed extant populations and (2) identify new thornmint populations in potentially suitable habitat. Data collection should include information on population status, location, threats, habitat and edaphic covariates, and management needs (SDMMP 2013). Based on survey results, extant populations may be reclassified into a different management category, while presumed extant populations will be classified either into a management category or removed from management consideration if determined to be extirpated (see Tables A-2-A-7).

Inspect and manage populations (IMG). This objective includes routine monitoring and maintenance at the preserve-level to ensure species persistence and identify management issues; the latter should be addressed immediately, if possible (SDMMP 2013). Routine management may include (but is not limited to) fencing, signage or other barriers to prevent trampling from mountain bikes, off-highway vehicles, or other recreational uses, and invasive species control. Preserve-level monitoring and maintenance should be conducted for all conserved, extant thornmint populations on a yearly basis. The level of effort may vary based on degree of threats.

In some cases, invasive plant infestations may require regional-level management due to potentially severe detrimental effects of some invasive plants (e.g., *Brachypodium distachyon, Cynara cardunculus;* CBI et al. 2012) on San Diego thornmint persistence. Invasive plant control may be elevated to a regional objective in the following cases: (1) invasive plant cover is so dense that it inhibits germination and growth of San Diego thornmint; (2) affected populations are in proximity and would benefit from treatment across multiple preserves or management units; and (3) affected populations are regionally important to thornmint persistence. The highest priority for regional invasive plant management will be large populations. Note that not all invasive plant infestations will require regional-level management. For many invasives, routine, periodic management will be sufficient for control (see IMG, above).

Genetic studies (GN). Genetic studies are recommended to (1) refine regional population structure hypotheses, (2) identify existing populations that would benefit from enhancement or expansion, (3) identify gaps in 'genetic' connectivity that may require creation of new populations or pollinator habitat, (4) identify appropriate source populations for seed banking and restoration, and (5) identify appropriate seed transfer zones. At a minimum, genetic studies should include those populations determined to be regionally important based on size, importance as refugia, or steppingstones, or which potentially possess a unique genetic structure (e.g., populations at the periphery of the species' range or in unique habitats). For some populations, inclusion in a genetic study will depend on results of baseline surveys. The Center for Natural Lands Management (CNLM in progress) is conducting a genetic study of San Diego thornmint in San Diego County; results from this study may provide guidance for some or all of the questions above. A combination of neutral genetic and quantitative genetic studies is recommended to identify recent gene flow and genetic diversity within and among populations, as well as potentially adaptive genetic diversity.

Research studies (RS). Targeted research on biology, life history, seed bank dynamics, dispersal capabilities, habitat requirements, effective pollinators and host plants, and invasive species interactions is recommended to improve management of this species. While genetic studies also fall under research, they are discussed in a separate objective.

Best management practices (BMP). Best management practices for San Diego thornmint management are included in Appendix D; however, a number of experimental management studies are currently in progress that may result in BMP refinements, while recommended research studies may result in additional BMPs; therefore, updating San Diego thornmint BMPs is included as a management objective.

Establish and maintain a seed bank and/or bulk seed (SB). A regional seed bank would benefit conservation, restoration, and research activities for this species. SDMMP (2013) (Vol. 1) discusses potential seed bank facilities. Seed collections should follow established guidelines (RBGK 2001, Wall 2009) for collection and storage. Multiple year collections are recommended for populations selected for management, subject to seed availability. Large and medium populations (see Tables A-3, A-4, A-6 and Appendix C) will be priority targets for seed banking, as will additional populations determined to have a unique genetic structure

Enhance/expand existing populations (IEX). This objective is specific to small, extant populations identified for management (SDMMP 2013). For these populations, enhancement or expansion will likely be required to promote resilience and long-term persistence. While some small populations are identified for enhancement/expansion in Table A-9, determination of restoration needs for most small populations will be based on results from baseline (ISV), monitoring (IMG), and/or genetic (GN) studies.

Translocate or establish new populations (ITR). A relatively large number of thornmint populations exist within the MSP relative to other rare species, and species' management should focus on maintaining or enhancing existing populations. If results of baseline surveys or other studies indicate gaps in connectivity that threaten regional population persistence, then translocation or establishment may be considered. In this context, translocation refers to introducing new populations outside the current species' range in response to climate change, while establishment refers to creating new populations in suitable but unoccupied habitat within the current species' range to fill gaps in connectivity. Experimental translocations may be implemented where monitoring indicates that natural movement of thornmint is outpaced by changing habitat conditions or where natural barriers to dispersal are identified.

Prepare an implementation plan (PIP): Large-scale restoration efforts will require development of an implementation plan (IP), to be prepared in collaboration with stakeholders (SDMMP 2013). The IP will identify Implementation Entity/Organization and include a detailed description of management actions, timeline, and funding source(s). An IP format is included in the MSP, Vol. 3, Section 4.0 (SDMMP 2013).

Implement actions in implementation plan (IIP): This objective is included as a placeholder at this time, as it is contingent on the previous objective (PIP), which will contain details necessary for implementation (SDMMP 2013).

Table A-8 presents management goals, and Table A-9 presents management objectives and management actions; objectives are categorized as regional or local (SDMMP 2013).

Table A-8

Management Goals

Regional 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.
MU 2 Management Goal: Populations in MU 2 do not occur on conserved lands; therefore, there is no regional management goal for this MU.
MU 3 Management Goal: Same as regional management goal.
MU 4 Management Goal: Same as regional management goal.
MU 5 Management Goal: Maintain or enhance existing population at the Ramona Grasslands and any new populations (if identified) to buffer against environmental stochasticity and promote connectivity, thereby enhancing resilience within and among MUs over the long-term (>100 years) in native habitats.
MU 6 Management Goal: Same as regional management goal.
MU 8 Management Goal: Maintain or enhance existing populations or any new populations (if identified), and establish new populations on conserved lands to buffer against environmental stochasticity and promote connectivity, thereby enhancing resilience within and among MUs over the long-term (>100 years) in native habitats.

Table A-9

Management Objectives and Actions

Type[1]	Objectives	MUs	Management Actions
ISV; Regional or Local	In 2015, conduct baseline surveys of all extant and presumed extant populations, and *opportunity areas* on conserved lands. Survey objectives are to fill data gaps, identify new populations that can potentially enhance regional population structure, identify threats and management needs, and (in some locations) verify management entity and/or population location. Submit data to the SC-MTX website portal. Based on results, identify or refine appropriate management actions.	3,4,6, 8	• Collect covariate data on vegetation composition and cover (alliance and association-level mapping), soils, invasive plants and other threats for selected populations. • Conduct appropriately-timed surveys within *opportunity areas* to identify new populations. Correlate survey results with environmental conditions, using SDMMP Climate Model. • Map perimeter of populations and suitable habitat. • Verify status (extant, extirpated), location, ownership, and management. • Classify populations into appropriate management category and identify actions to maintain or enhance extant populations. • Use covariate data to refine habitat suitability models for thornmint and *Brachypodium distachyon*.
IMG; Local	Beginning in 2016, annually inspect extant, conserved populations selected for management, based on results of 2015 surveys. Use a regional monitoring protocol to record abundance and collect covariate data to determine management needs. Conduct routine management actions as necessary. Submit monitoring and management data to SC-MTX website portal.	3,4,5, 6,8	• Conduct annual monitoring surveys using standardized protocols to assess abundance and quantify threats. • Identify routine or intensive management. • Perform routine management (e.g., fencing, signage, invasive control). • Where intensive management is warranted and cannot be conducted within existing monitoring budget, prepare a detailed plan for implementation and secure funding.

Table A-9

Management Objectives and Actions

Type[1]	Objectives	MUs	Management Actions
IMG; Regional	Beginning in 2016, implement invasive plant control at large populations on Conserved Lands where invasives have been identified as a threat to thornmint persistence (e.g., *Rice Canyon, Mission Trails Regional Park, Sabre Springs, Sycamore Canyon, Viejas Mountain, Lux Canyon, and Palomar Airport Road*). Conduct treatment for a minimum of **3** years using BMPs, and monitor thornmint response. Submit monitoring and management data to SC-MTX website portal.	3,4,6	• Implement invasive control based on BMPs and experimental projects (e.g., *Brachypodium* removal project, South County Grasslands project), including thatch removal, herbicide, or mechanical methods. • Determine response to management actions; correlate results with environmental conditions (e.g., temperature, precipitation) in the year prior to and during implementation. • Determine need for further invasives control and habitat enhancement such as seeding of native plant species, that support pollinators; use methods that inhibit germination and growth of invasive species.
GN; Regional	Beginning in 2016, conduct any necessary genetic studies to facilitate thornmint management; submit data to the SC-MTX website portal.	2,3,4, 5,6,8	• Review CNLM genetic study results to refine regional population structure hypotheses. • Collect plant material for genetic samples at all or a subset of conserved populations. • Analyze genetic structure (e.g., neutral genetic studies) to determine recent gene flow and genetic diversity within and among populations. • Conduct quantitative genetic studies (e.g., common garden, reciprocal transplant studies) to identify potentially adaptive genetic diversity. • Identify (1) populations with lowered diversity that should be enhanced through augmentation, (2) gaps in functional connectivity that may require establishing new populations or creating pollinator habitat, (3) high diversity populations that may function as seed sources for augmentation, and (4) appropriate seed transfer zones to maximize short- and long-term restoration success by using genetic material locally adapted to site conditions or possesses (Kramer and Havens 2009).

Table A-9

Management Objectives and Actions

Type[1]	Objectives	MUs	Management Actions
RS; Regional	Beginning in 2015, initiate management-oriented research studies for San Diego thornmint (refer to ISV, above, for soil studies and GN, above, for genetic studies).	3,4,5, 6,8	• Develop protocols for seed bulking to conserve genetic diversity and enhance resilience to the local environment. • Conduct studies to determine seed bank presence, longevity, and susceptibility of buried seeds to fire. Determine if seed bank is adequate to moderate or offset genetic bottlenecks resulting from above-ground population fluctuations. • Determine seed longevity, dormancy factors, and germination and viability rates. • Identify *effective* pollinators and their host plants and maximum pollinator migration/travel distance; assess whether shifts in phenology and pollinator communities may affect thornmint persistence. • Identify dispersal agents and dispersal. • Conduct studies to determine effects of invasive plant species.
BMP; Regional	In 2015-2018, refine or develop additional BMPs, as appropriate.	3,4,5, 6,8	• Refine BMPs by incorporating results of management experiments to control invasive species that threaten populations (e.g., *Brachypodium* removal and South County Grasslands projects) and based on research studies (e.g., seed bulking guidelines, seed transfer zones).
SB; Regional	Beginning in 2017, establish a permanent seed source (seed bank) consisting of conservation and propagation collections held in long-term storage to preserve genetic diversity and provide a seed source in the event of catastrophic disturbance. This collection may also function as source material for management-oriented research, seed bulking, or out-planting to augment extant populations or establish new populations.	2,3,4, 5,6,8	• Implement a seed collection and storage strategy (RBGK 2001, Wall 2009): (1) collect over multiple years, collect multiple times within a season, collect across populations, and (2) sample from multiple habitats and ecological niches. • Collect seed from all conserved populations of sufficient size to accommodate harvest or based on genetic studies. Harvest seed from populations planned for development or not conserved. • Maintain records for collected seed to document donor and receptor sites, collection dates, and amounts, and submit to the SC-MTX website portal and a regional seed bank database.

Table A-9

Management Objectives and Actions

Type[1]	Objectives	MUs	Management Actions
			• Store seeds at a qualified seed bank by population, date, and for small populations (<1,000 plants), along maternal lines. Test seed for viability upon accession and regularly thereafter (Appendix D). • Structure seed testing program to obtain information on dormancy, germination, and rates. • Bulk seed at a qualified facility for enhancement, expansion, establishment, or transplantation projects using seed from genetically appropriate donor accessions in the propagation seed bank collection. • Out-plant seed to enhance existing populations or establish or translocate new populations.
PIP; Regional	Beginning in 2016, prepare implementation plan(s) including delineation of suitable habitat for expanding existing populations and establishing new populations, as determined necessary from results of surveys, modeling, and research. Implementation plan(s) should follow the implementation template in the MSP, Vol. 3 (SDMMP 2013).	3,4,5, 6,8	• Using the Adaptive Management Framework as a guideline, develop an implementation plan(s) to reduce threats and promote resilience of populations. • Identify management needs beyond routine maintenance (e.g., invasives control, enhancement or expansion of extant populations). • Use habitat suitability and climate change modeling to prioritize sites for enhancement or expansion. • Use genetic studies to identify populations for augmentation to bolster genetic diversity, as well as appropriate source populations for augmentation. • Use BMPs to control threats and bulk seed. • Include the implementation organization/entity and names of stakeholders, identify the MSP goal and objectives addressed, and provide an overview and description of management actions (including scope, budget, and schedule).
IIP; Regional and/or Local	Beginning in 2017, implement the highest priority management actions identified in approved implementation plans(s) for populations on Conserved Lands.	3,4,5, 6,8	• Management actions will be determined by the Implementation Plan.

Table A-9

Management Objectives and Actions

Type[1]	Objectives	MUs	Management Actions
IEX; Regional and/or Local	Beginning in 2017 (or completion of genetic studies and preparation of IPs), enhance/expand selected small populations regionally important for long-term persistence, based on baseline surveys, soil testing, genetic studies, and other research. This includes formerly large populations that have experienced declines due to threats (e.g., invasive species).	3,4,5, 6,8	• Prioritize populations for management based on assessment of size, status (including genetic structure), and threats; potential to significantly reduce threats; and availability of adjacent, suitable habitat for population expansion. • Incorporate BMPs into restoration design; include an experimental design to test effectiveness of any new methods used (e.g., seed bank augmentation).
ITR; Regional and/or Local	Beginning in 2017 (or completion of genetic or other research studies and preparation of IPs), establish new populations and pollinator habitat on Conserved Lands to enhance genetic connectivity, determined through baseline surveys, soil testing, habitat suitability modeling, and other research.	3,4,5, 6,8	• Use genetic studies and land use patterns to elucidate historic genetic flow patterns. • Identify potential gaps in genetic connectivity. • Use habitat suitability and climate change modeling, plus opportunity areas map, to identify suitable sites for establishing new populations or habitat for pollinators to fill gaps in connectivity. • Use vegetation and soils correlates, as well as results from other pertinent research (e.g., pollinator studies) to refine site selection. • Test soils at potential expansion sites and compare to reference sites to determine site suitability based on soils. • Use seed for augmentation from genetically appropriate seed collection zones. Collect and bulk seed according to approved BMPs.

[1] BMP = Develop and test BMPs (Best Management Practices); GN = Genetic studies; IEX = Enhance/expand existing populations; IIP = Implement actions identified in implementation plan. IMG = Inspect and manage populations as necessary; IPC = Invasive plant control; ISV = Conduct surveys to collect baseline data on population locations, status, and habitat/threat covariates; PIP = Prepare an implementation plan; RS = Conduct research studies; SB = Establish and maintain a seed bank and/or bulk seed.

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Appendix B

San Diego Thornmint (*Acanthomintha ilicifolia*) Matrix

See Excel spreadsheet

Appendix C

Conceptual Model, Habitat Suitability, and Climate Change

Models were developed or reviewed to develop an Adaptive Management Framework for future research, monitoring, and management of San Diego thornmint. We used model outputs directly or indirectly to (1) assess threats and identify monitoring and management needs (conceptual model); (2) identify potential research needs (all models); (3) develop tools to assist in managing this species (habitat suitability and climate influences models); and (4) elucidate potential future risks from specific threats and stressors (e.g., climate change models).

C.1 Conceptual Model

CBI assembled a conceptual model for San Diego thornmint to visualize life history traits that influence species persistence, as well as drivers and uncertainties that may affect those traits (Figure C-1). Model development follows the principles and format elucidated in Hierl et al. (2007) and refined by the Institute for Ecological Monitoring and Management (IEMM) in a conceptual model workshop (IEMM 2012) and species-specific models (Strahm 2012, Strahm et al. 2013). Per these sources, we used the following format to promote consistency among species conceptual models in the region:

- Anthropogenic drivers (change agents or threats and stressors) are shown in pink boxes; natural drivers are in blue boxes.
- Elements outlined in red may be monitored to assess population status and effectiveness of management actions. Elements outlined in gray contribute to population status, but are not influenced by management actions.
- Elements in the green circle are San Diego thornmint life history traits (species variables) that can be measured to assess the response to management actions.
- Relationships between model elements are depicted with arrows. Black arrows depict direct or primary relationships; blue arrows depict secondary or putative relationships. The model focuses on primary relationships that are expected to affect population status and be influenced by management and monitoring.

The thornmint conceptual model summarizes available information and identifies critical uncertainties that may warrant focused research. Table C-1 describes model elements and provides the primary source(s) used in model development. Natural drivers and threats and stressors are discussed below. Monitoring will measure response of species variables identified in the conceptual model and Table C-1 to management actions (Appendix A, Table A-8).

Figure C-1

San Diego Thornmint Conceptual Model

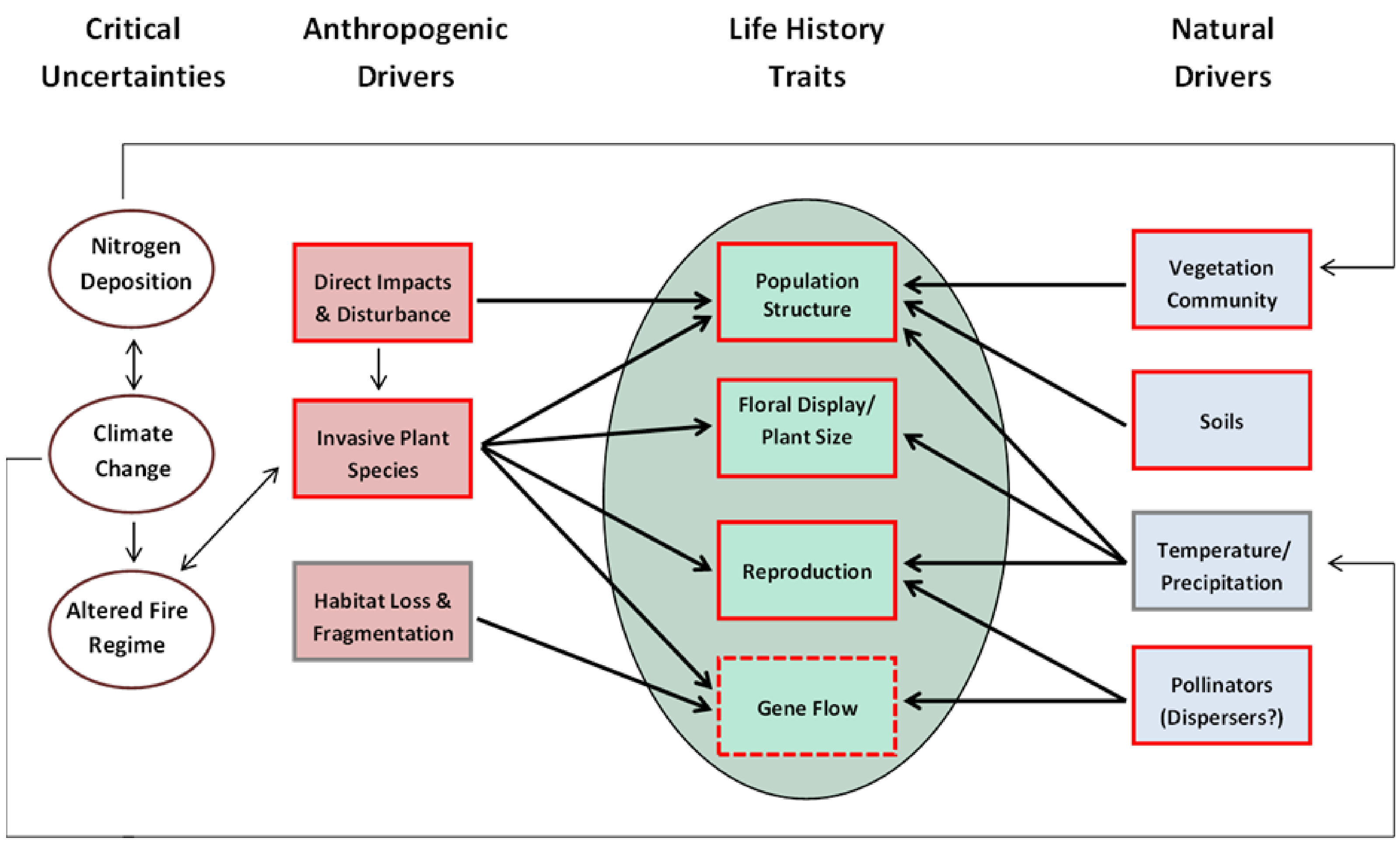


Table C-1

San Diego Thornmint Conceptual Model Elements

Goals:		
Management	Enhance resilience of San Diego thornmint within and among MUs over the long-term (>100 years) by maintaining larger populations, enhancing or expanding smaller populations that contribute to regional population structure (e.g., steppingstones, refugia, genetics), and establishing new populations or pollinator habitat to buffer against environmental stochasticity, maintain genetic diversity, and promote connectivity.	
Monitoring	Refer to Appendix A (Table A-8) and thornmint variables (below).	
Anthropogenic Drivers (Change Agents or Threats and Stressors):		
Invasive Species	Invasive species (primarily grasses and forbs) are the primary threat to San Diego thornmint persistence. Invasives 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 2009; Klein 2009.
Direct Impacts and Disturbance	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 2009.
Habitat Loss/Fragmentation	Habitat loss has been reduced) since listing and is no longer the primary threat. Fragmentation due to development or other disturbance may result in population isolation. Conserved populations in proximity to development are subject to increased invasive species, herbivory, erosion, trampling.	USFWS 2009.

Natural Drivers:		
Vegetation Community	Grasslands, coastal sage scrub, and chaparral; suitable associations must support thornmint pollinators.	USFWS 2008; SANDAG 2012.
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.	Oberbauer and Vanderwier 1991; USFWS 2008; USFWS no date.
Climate (Precipitation and Temperature)	Rainfall and temperature both affect germination rate and successful reproduction.	Bauder and Sakrison 1997; USFWS 2009.
Pollinators and 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.	Klein 2009; Bauder and Sakrison 1997.
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.	USFWS 2009; City of San Diego 2005.
San Diego thornmint Variables (Measurable Aspects of Species Response):		
Population Structure	Includes population size, shape, topographic distribution, and fluctuations associated with demographic stochasticity.	Bauder and Sakrison 1999; USFWS 2009.
Floral Display and Plant Size	Important components are biomass of plants and visibility of flowers; includes 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; Bauder and Sakrison 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.
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 levels of self-compatibility; however, the presence of sterile upper stamens suggests that self-pollination may be limited in San Diego thornmint. Small populations may be susceptible to inbreeding and genetic drift.	Bauder and Sakrison 1997; USFWS 2009; Steek 1995; Klein 2009; Sclafani 2005.

Critical Uncertainties (Process):		
Grassland Conceptual Model (Natural Process)	No San Diego thornmint-specific literature. Includes effects of the grass-fire cycle (e.g., habitat alteration/type conversion, altered fire regimes, increase in invasive plants, altered soil chemistry). 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.
Climate Change (Anthropogenic Process)	Predicted warming temperatures may result in drier and hotter conditions in southern California in the future. Potential impacts to San Diego 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.	Bauder and Sakrison 1999; Zavaleta et al. 2003; USFWS 2009; Conlisk et al. 2013.
Altered Fire Regime (Anthropogenic Process)	Altered fire regimes may affect population abundance by increasing seed mortality or promoting invasive species.	Bauder and Sakrison 1999; USFWS 2009; Conlisk et al. 2013.
Nitrogen Deposition (Anthropogenic Process)	No San Diego thornmint-specific literature. Nitrogen deposition may alter soil properties (including soil microbial community) and, subsequently, plant species composition and structure, at least for some vegetation communities. 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; Talluto and Suding 2008; Vourlitis and Pasquini 2009; Fenn et al. 2010; Ochoa-Hueso and Manrique 2010; Ochoa-Hueso et al. 2011; Henry et al. 2006; Tonnesen et al. 2007.

Natural Drivers

We examined two natural drivers─soils and vegetation─to identify potential correlates that might be used to target areas for focused thornmint surveys or restoration efforts.

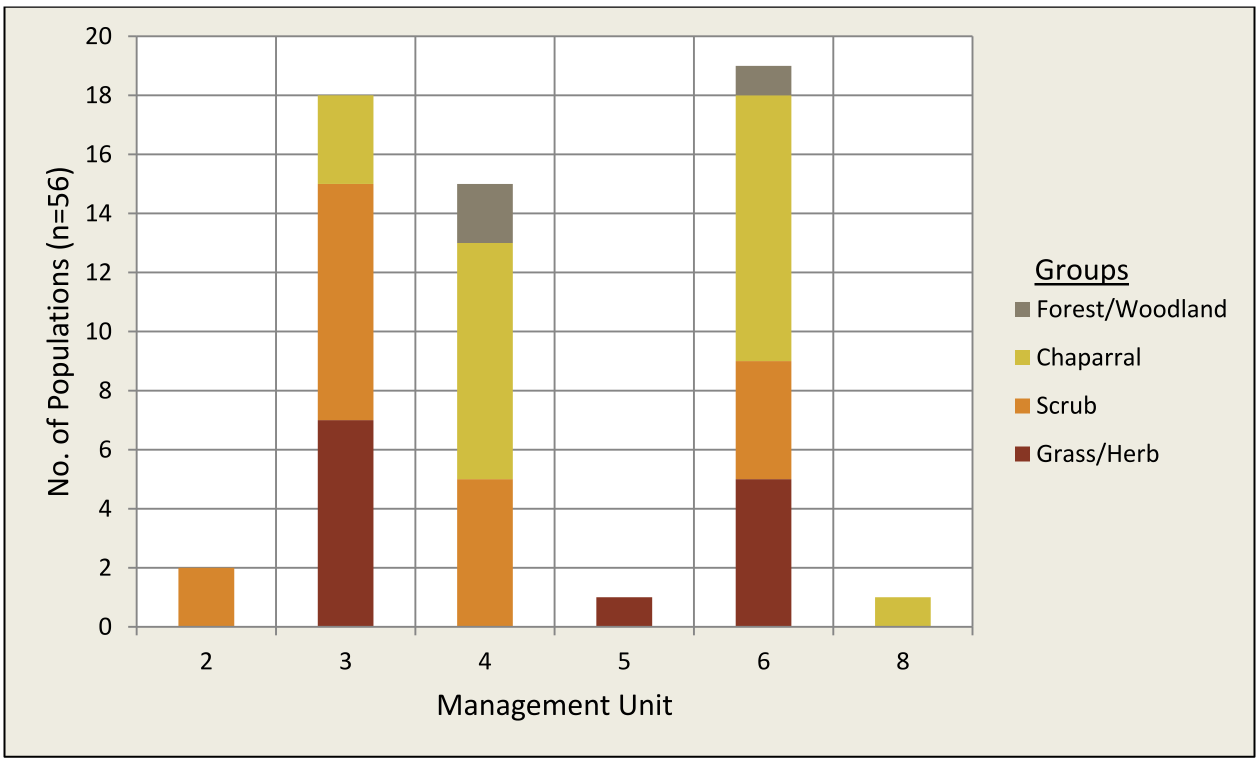
Potential Vegetation Correlates

San Diego thornmint occurs in openings in chaparral, scrub, and grassland habitats (USFWS 2009). For this assessment, we overlaid the current thornmint distribution (extant and presumed extant populations) on the 2012 San Diego vegetation dataset (SANDAG 2012) to determine whether additional information on vegetation correlates could be detected at the group, alliance, and association levels from the regional vegetation map.

Group-level Vegetation. At the group level, 37% of thornmint populations are associated with chaparral, 37% with scrub, 21% with grass/herb, and 5% with forest/woodland habitats. Figure C-2 presents the breakdown of these groups by management unit.

Figure C-2

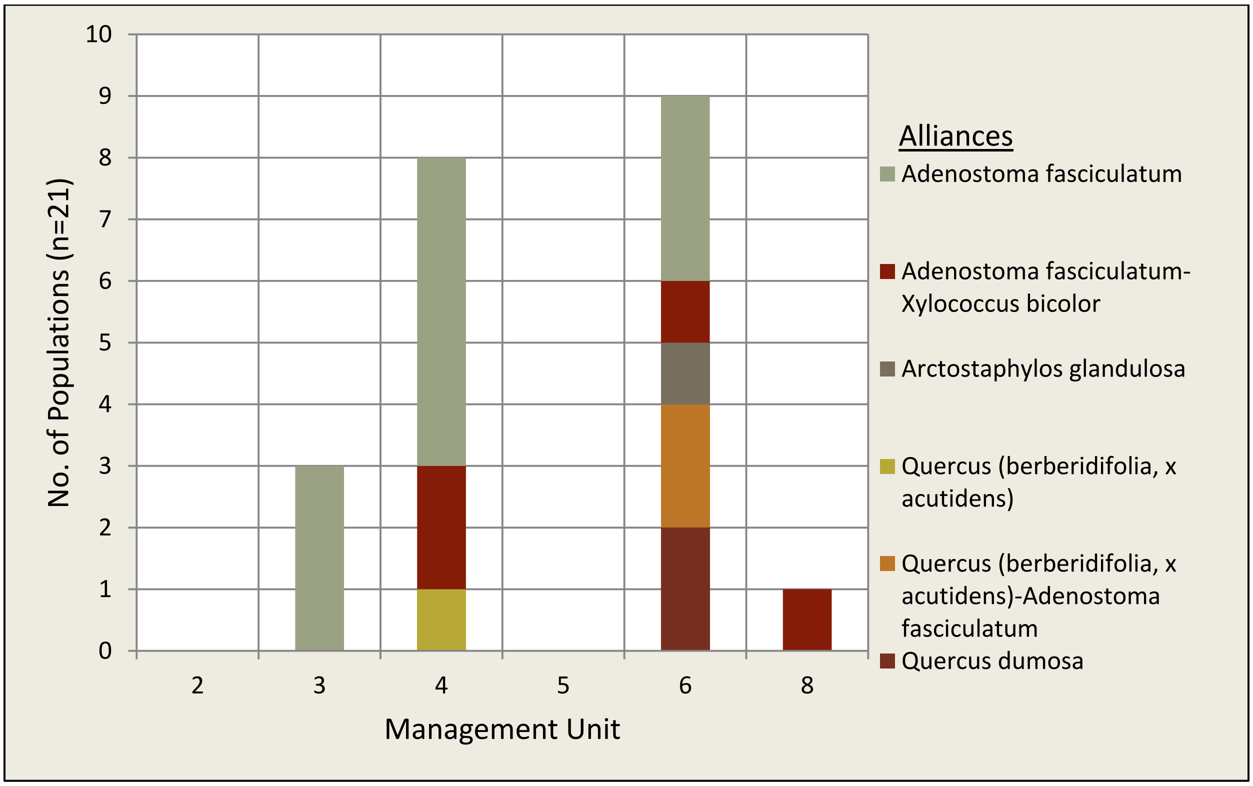
Vegetation Groups



Alliance-level Vegetation. San Diego thornmint occurs in six chaparral alliances, nine scrub alliances, four grass/herb alliances, and two forest/woodland alliances. It is associated with chaparral alliances in MUs 3, 4, 6, and 8. The majority of chaparral-associated populations (71%) are found within alliances dominated or co-dominated by *Adenostoma fasciculatum*, with 52% of populations in the *Adenostoma fasciculatum* alliance and 19% of populations in the *Adenostoma fasciculatum-Xylococcus biocolor* alliance. Figure C-3 depicts thornmint populations within chaparral alliances by management unit.

Figure C-3

Chaparral Alliances

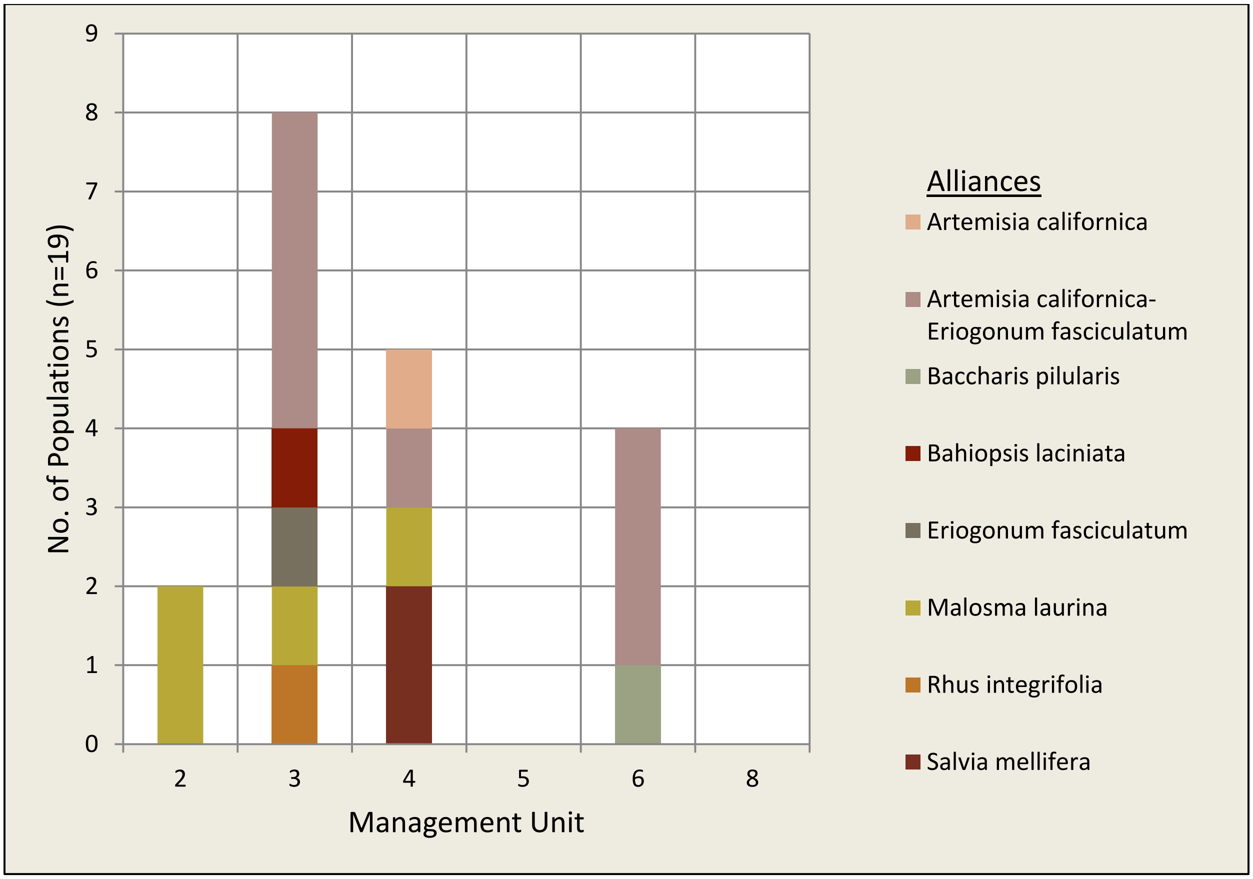


San Diego thornmint is associated with scrub alliances in all MUs except 5 and 8. Populations are most commonly associated with the *Artemisia californica-Eriogonum fasciculatum* (42%) and the *Malosma laurina* alliances (21%). Approximately 47% of scrub-associated populations are found in alliances with *Artemisia californica* as a dominant or co-dominant species. Figure C-4 depicts thornmint populations within scrub alliances by management unit.

A total of 14 thornmint populations are associated with grass/herb alliances in MUs 3, 5, and 6. Of these, the majority (79%) are in Mediterranean California Naturalized Annual and Perennial Grassland Semi-Natural Stands. Figure C-5 depicts thornmint populations within grass-herb alliances by management unit. The accuracy of grass-herb alliances may be low due to the difficulty in identifying herbaceous species from imagery.

Figure C-4

Scrub Alliances



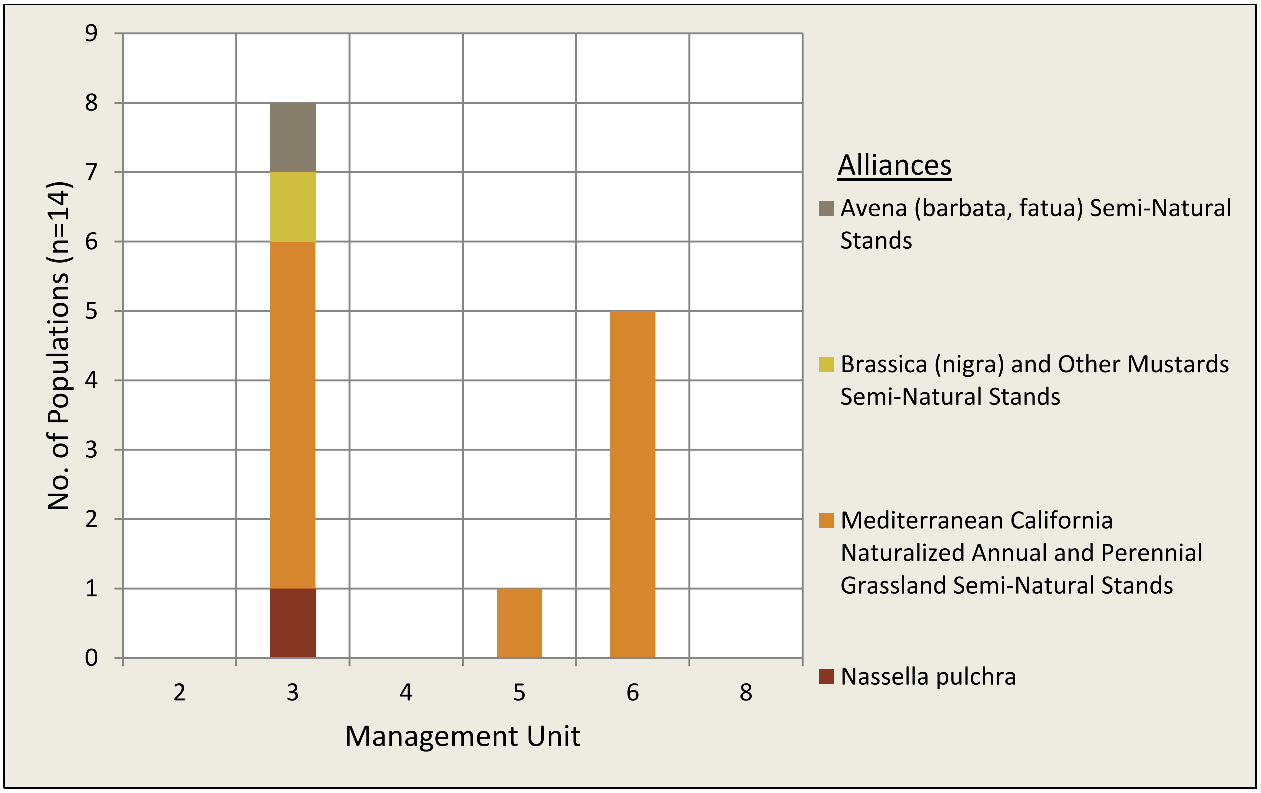
Association-level Vegetation. San Diego thornmint populations occur in ten chaparral associations, eight scrub associations, four grass/herb associations, and two forest/woodland associations. For some populations in chaparral and scrub, mapping was available only at the alliance level. For grass-herb and forest/woodland vegetation, association-level mapping categories are identical to alliance-level categories; thus, these types are not discussed further.

Chaparral-associated thornmint populations are found most commonly in the *Adenostoma fasciculatum*-(*Eriogonum fasciculatum, Artemisia californica, Salvia mellifera*) association (24%), but are otherwise fairly evenly distributed throughout the remaining chaparral associations.

Scrub-associated thornmint populations are found most commonly in the *Artemisia californica-Eriogonum fasciculatum-Malosma laurina* Association (44%), followed by the *Malosma laurina-Lotus scoparius* Association (25%).

Figure C-5

Grass/Herb Alliances



Summary. At the group level, the regional vegetation mapping corresponds relatively closely with formerly described vegetation correlates for San Diego thornmint, i.e., the species is found primarily in chaparral, scrub, and grass-herb habitats. Additional mapping detail is apparent at the alliance level. *Adenostoma fasciculatum* is a dominant or co-dominant species in two-thirds of the chaparral-associated thornmint populations. Targeting *A. fasciculatum* alliances may help focus survey efforts within chaparral. However, the high percentage of *A. fasciculatum* at thornmint sites may also be a reflection of its distribution within the study area, where it is one of the most common species in chaparral. Almost half of the scrub-associated thornmint populations are associated with *Artemisia californicum*-dominated alliances; *A. californicum* is one of the most common species in scrub. Within grass-herb alliances, thornmint populations have a high correlation (77%) with Mediterranean California Naturalized Annual and Perennial Grassland Semi-Natural Stands; however, field verification of some of these sites indicated a low level of mapping accuracy for these alliances. The sample size of populations associated with forest/woodland habitats is too small to draw conclusions.

At the association level, the regional mapping does not further elucidate relationships within chaparral habitats, as populations are largely distributed evenly between multiple associations. Within scrub, populations occur within three associations, and this information may be useful in focusing survey efforts. No additional mapping detail is available for the grass-herb or forest/woodland associations.

Although some vegetation correlate information was obtained from the regional vegetation map, several factors limit its usefulness for this purpose, including mapping scale, mapping methodology (some areas were mapped from imagery rather than on-the-ground which may have affected mapping accuracy), and occurrence of San Diego thornmint in some areas that are smaller than the minimum mapping unit. Preserve-level vegetation mapping of all thornmint populations, using the San Diego vegetation classification (Sproul et al. 2012), is important to refine vegetation correlates at the alliance- and association-levels. These conclusions are supported by preliminary results from the accuracy assessment of the regional vegetation map, which indicate that alliance and association level accuracy are below the expected accuracy standard of 80% (Strahm pers. comm.).

Potential Soil Correlates

San Diego thornmint is an edaphic species restricted to clay soils or clay lenses in gabbro soils (USFWS 2009, Oberbauer and Vanderwier 1991, Beauchamp 1986). For this assessment, we overlaid current and historic thornmint distribution on clay and gabbro soils (USDA, NRCS 1973) to examine the species-soil relationship.

Over half of the San Diego thornmint populations (52%) in the MSPA occur (or formerly occurred) on clay soils, 15% on gabbro soils, and 33% on ‘other’ soil types (Figure C-6). The ‘other’ category includes 17 non-clay or non-gabbro soil series or formations. San Diego thornmint is associated exclusively with clay soils in MU 5 and with gabbro soils in MU 8. In MUs 3 and 4, the species occurs on both clay and gabbro soils, and on ‘other’ soil types. In MU 6, the species occurs on clay soil and ‘other’ soil types. Figure C-7 provides a breakdown of thornmint populations by soil type and management unit, and Table C-2 lists clay and gabbro soils that support thornmint populations.

San Diego thornmint is often found on small clay lenses within other soil types (Oberbauer and Vanderwier 1991), and this may account, in part, for its occurrence on soils in the ‘other’ soils category. Two populations on ‘other’ soil types are transplanted and two are mapped imprecisely (e.g., one location occurs in water at Lake Hodges). Of the remaining populations, 91% occur within 1,000 meters (m) and 70% occur within 250 m of mapped clay or gabbro soils. As the soils mapping is relatively coarse, the siting of thornmint populations on ‘other’ soil types may be a reflection of mapping. Soil testing of thornmint-occupied ‘other’ soil types would refine/confirm edaphic relationships of this species.

Figure C-6

San Diego Thornmint on Clay and Gabbro Soils

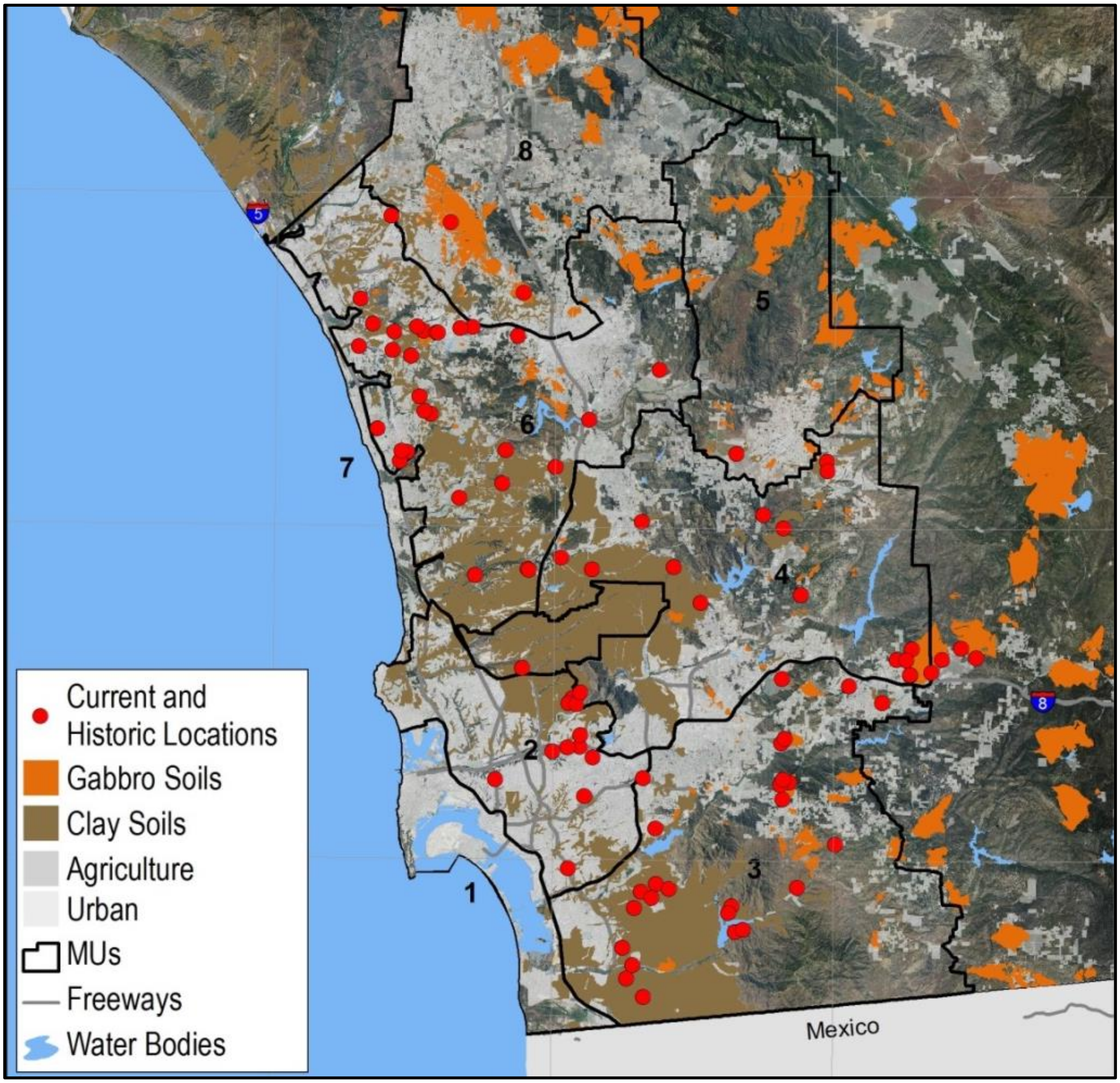


Figure C-7

Distribution of San Diego Thornmint Populations by Soil Types

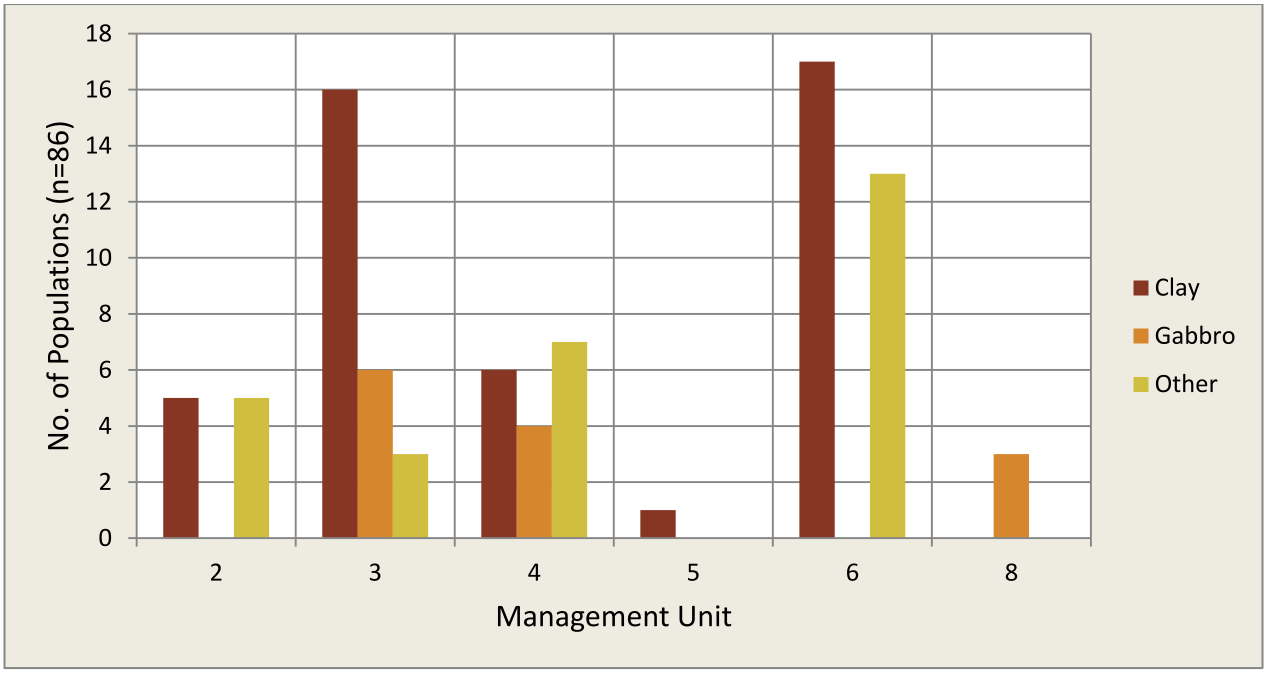


Table C-2

Clay and Gabbro Soils that Support San Diego Thornmint Populations in the MSPA

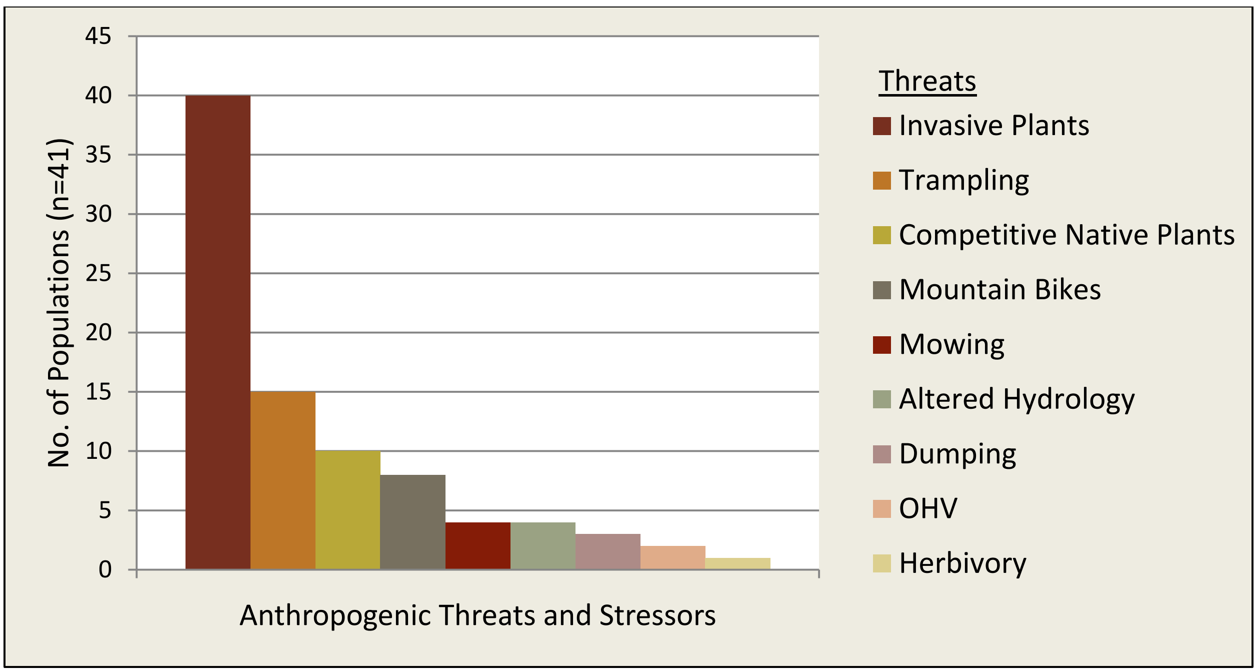
Management Unit	Soil Series	Soil Type
6	Altamont	Clay
3, 5	Bosanko	Clay
3, 6	Diablo	Clay
2, 6	Diablo-Olivenhain complex	Clay
2, 3, 6	Huerhuero	Clay
3, 4, 8	Las Posas	Gabbro
3	Linne	Clay
2, 3, 4, 6	Olivenhain	Clay
2, 4, 6	Redding	Clay
3	Salinas	Clay
3	Stockpen	Clay

Threats and Stressors

Threats and stressors are factors or processes that may impact San Diego thornmint populations or habitat and which may require management to ensure species persistence. Threats and stressors—both natural (e.g., fire) and anthropogenic (e.g., invasive species)—were identified through input from land managers (Appendix B, CBI et al. 2012) and development of the San Diego thornmint conceptual model (Figure C-l). Figure C-8 summarizes threats and stressors reported by land managers. Most of these are a result of direct disturbance or edge effects and should be managed at the preserve level.

Figure C-8

Preserve-level Threats and Stressors



Additional threats and stressors are more widespread; these may affect regional population persistence and require management within or among management units or preserve complexes for effective control:

- Invasive plants
- Population size
- Altered fire regime
- Habitat fragmentation
- Nitrogen deposition
- Climate change

Invasive Plant Species. Non-native, invasive plants pose one of the greatest threats to native species and habitats because of their ability to displace native species, degrade wildlife habitat, and alter ecosystem processes (Belnap et al. 2005, Ehrenfeld 2003, Evans et al. 2001, Cox 1999, Wilcove et al. 1998, D'Antonio and Vitousek 1992, Huenneke et al. 1990, Vitousek et al. 1990, and many others). Invasive plant species have been recognized as a threat to San Diego thornmint by multiple sources (e.g., Bauder and Sakrison 1997, Bauder and Sakrison 1999, USFWS 2009, San Diego Thornmint Working Group 2010, CBI et al. 2012). Bauder and Sakrison (1997, 1999) demonstrated that competition from nonnative, invasive plants (*Centaurea melitensis, Avena barbata*) decreased biomass and fecundity, but not survivorship, of San Diego thornmint. In addition, native plants have been identified as a potential concern at 11 populations where they may out-compete thornmint for resources (Appendix B). Competitive native plant species of concern include *Deinandra fasciculata, Plantago rhodosperma, Apiastrum angustifolium*, annual *Acmispon* spp., and *Euphorbia spathulata*.

Table C-3 lists 34 nonnative, invasive plants identified at San Diego thornmint locations. Note that (1) several of these reports are over a decade old, and invasive species presence and distribution may have changed over time, (2) few reports provide any information on invasive species cover or impacts to San Diego thornmint, and (3) for the majority of thornmint populations, there has not been a targeted assessment of invasive species presence and impacts. Presence alone is not necessarily an indication of the effect of these invasives on thornmint persistence. Of these species, the most commonly reported are *Centaurea melitensis, Bromus madritensis*, *Brassica nigra*, *Brachypodium distachyon*, *Anagallis arvensis*, *and Sonchus asper*. In a survey of land managers for the Invasives Strategic Plan (CBI et al. 2012), the invasive species reported by land managers as having a high impact on San Diego thornmint were (in order of number of reports) *Brachypodium distachyon, Cynara cardunculus, Centaurea melitensis*, and *Hedypnois cretica*.

Because of its potential effect on San Diego thornmint and other clay endemic species, *Brachypodium distachyon* (purple false-brome) has become an invasive species of interest in terms of both impacts and potential management actions (CBI 2012a,b, CBI in progress). Although the species has been present in San Diego County since the 1950s (CCH 2013), it appears to have persisted in low levels in (primarily) urban habitats until the late 1990s-early 2000s, when it spread into wildland areas and across the landscape. The large wildfires of 2003 and 2007 may have enhanced its spread by leaving large areas of bare ground susceptible to invasion. The densest stands of *Brachypodium* appear to occur on clay and gabbro soils at the present time; however, the species is likely still spreading. In the last decade, several land managers/biologists have observed lack of thornmint germination/presence in previously occupied thornmint habitat now dominated by *Brachypodium*. In a risk assessment of invasive species identified in the literature or by land managers or other biologists as impacting or

Table C-3

Nonnative, Invasive Species that May Impact San Diego Thornmint[1]

Scientific Name	Common Name	Number of Reports[2]
Centaurea melitensis	Tocalote	33
Bromus madritensis	Foxtail brome, foxtail chess	19
Brassica nigra	Black mustard	15
Brachypodium distachyon	Purple false-brome	12
Anagallis arvensis	Scarlet pimpernel	10
Sonchus asper	Prickly sow thistle	10
Erodium spp.	Filaree	9
Festuca myuros	Rattail sixweeks grass	9
Plantago virginica	Virginia plantain, dwarf plantain	9
Sonchus oleraceus	Common sow thistle	8
Avena barbata	Slender wild oats	5
Bromus hordeaceus	Soft brome, soft chess	4
Hedypnois cretica	Hedypnois	4
Hypochoeris glabra	Smooth cat's ear	4
Avena fatua	Common wild oats	3
Cynara cardunculus	Artichoke thistle, cardoon	3
Festuca perennis	Italian ryegrass	3
Foeniculum vulgare	Sweet fennel	3
Helminthotheca echioides	Bristly ox-tongue	3
Logfia gallica	Narrowleaf cottonrose	3
Medicago polymorpha	Bur clover	3
Bromus diandrus	Ripgut grass	2
Melilotus indica	Yellow sweetclover	2
Asphodelus fistulosus	Asphodel, onion weed	1
Carpobrotus sp.	Sea fig, iceplant	1
Euphorbia peplus	Petty spurge	1
Hordeum murinum	Foxtail barley	1
Lactuca serriola	Prickly lettuce	1
Lythrum hyssopifolium	Hyssop loosestrife	1
Nicotiana glauca	Tree tobacco	1
Phalaris sp.	Canary grass	1
Reseda luteola	Dyer's mignonette	1
Silybum marianum	Blessed milkthistle	1

[1] Information from land managers or other sources (e.g., CNDDB).

[2] Number indicates number of times reported as occurring in association with San Diego thornmint.

potentially impacting narrow endemic species (including San Diego thornmint) in San Diego County, *Brachypodium* was identified as having a high potential to impact San Diego thornmint based on the types of effects it may exert on the ecosystem. These include altering resource allocation, stand structure, and recruitment, and forming monotypic stands that exclude other species (CBI et al. 2012). In this risk assessment, *Cynara cardunculus* was also ranked as having a high potential to impact San Diego thornmint, although the putative mechanisms of impact differ somewhat from *Brachypodium* (CBI et al. 2012). *Cynara* has been reported from three thornmint populations.

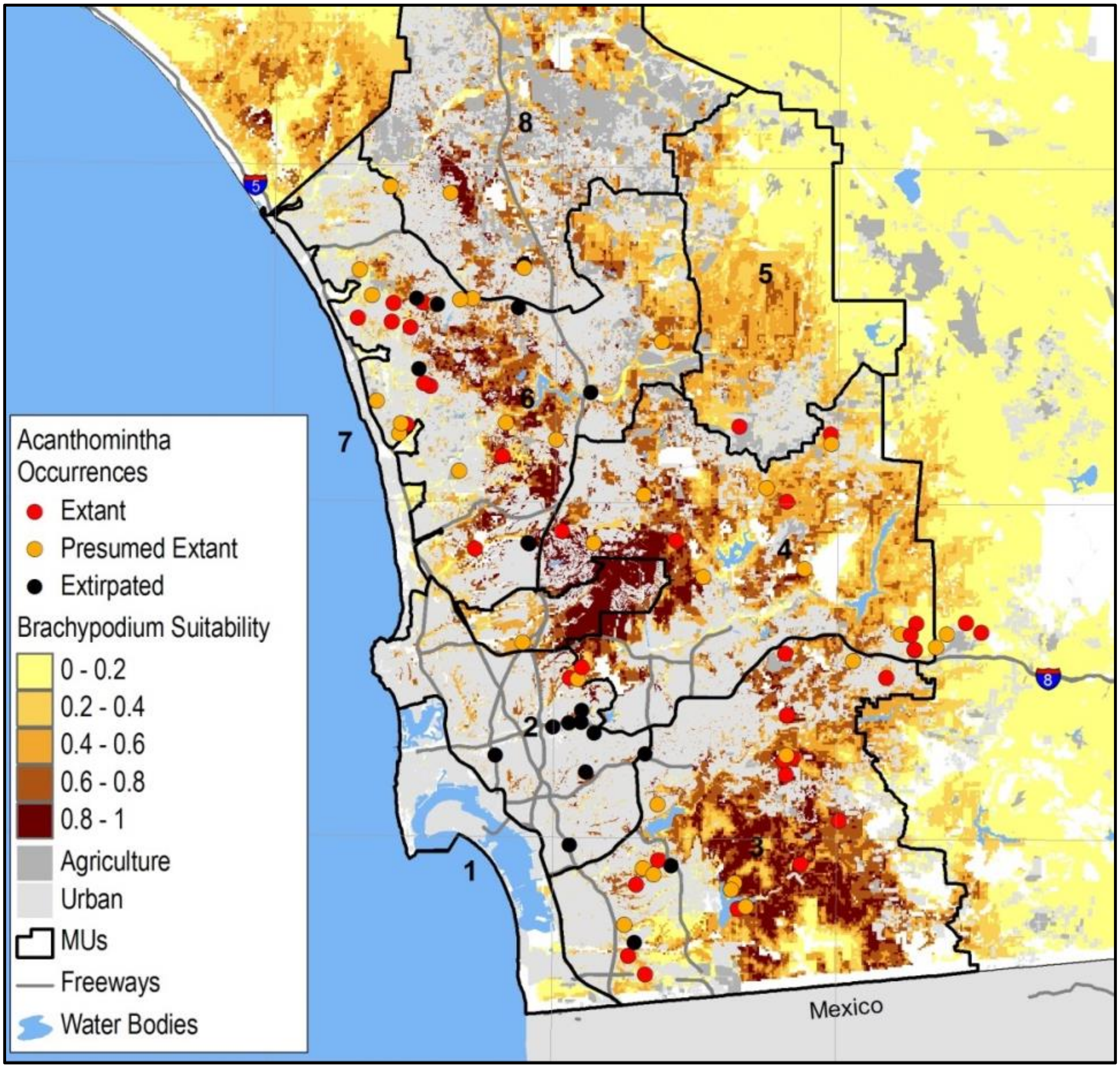
Based on available data, SDMMP developed a habitat suitability model for this species as a tool to predict areas of potential invasion (Figure C-9). Refer to the sections on Habitat Suitability and Climatic Influences (Appendix C.2, C.3) for a description of model development. This model will be particularly useful in managing thornmint populations that have not yet been invaded by *Brachypodium* or where *Brachypodium* cover is relatively low, because at this stage, the species is most controllable. In addition, CBI (in progress) is conducting experiments to determine effective short-term treatments for *Brachypodium*. Early indications suggest that short-term *Brachypodium* control can be achieved through different methods (grass-specific herbicide, mowing) with comparable levels of success, particularly if treatments are timed appropriately.

<u>Population Size</u>. For annual plants, in particular, population size can provide an indication of a species' potential to persist under changing conditions. Large populations are generally more resilient to stochastic events and natural catastrophes, and are less affected by demographic and genetic stochasticity than small populations (Menges 1991 and others). While there is debate in the literature regarding the use and validity of a set population size (e.g., minimum viable population) as a conservation target, there is consensus that larger populations are more resistant to extinction or extirpation than smaller populations (e.g., Flather et al.2007, Traill et al. 2010, Brook et al. 2011, Flather et al. 2011, Jamison and Allendorf 2012). For plants, estimates of total population size necessary to buffer against environmental stochasticity range from 10^3-10^6 individuals (Shaffer 1987 and others), while estimates of *effective* population size range from 5-30% of the total population size (see Espeland and Rice 2010). Assessment of population size is further confounded by the presence of a seed bank, which may increase effective population size (Nunney 2002).

Regardless of guidelines on total and effective population sizes, many rare plants persist in small populations. For this reason, it is important to consider both published guidelines and available San Diego thornmint census data in categorizing populations based on size. San Diego thornmint clearly has the potential to exist in large populations (>10,000 individuals) under certain conditions. In addition, it may form a persistent seed bank.

Figure C-9

Brachypodium distachyon Habitat Suitability Model



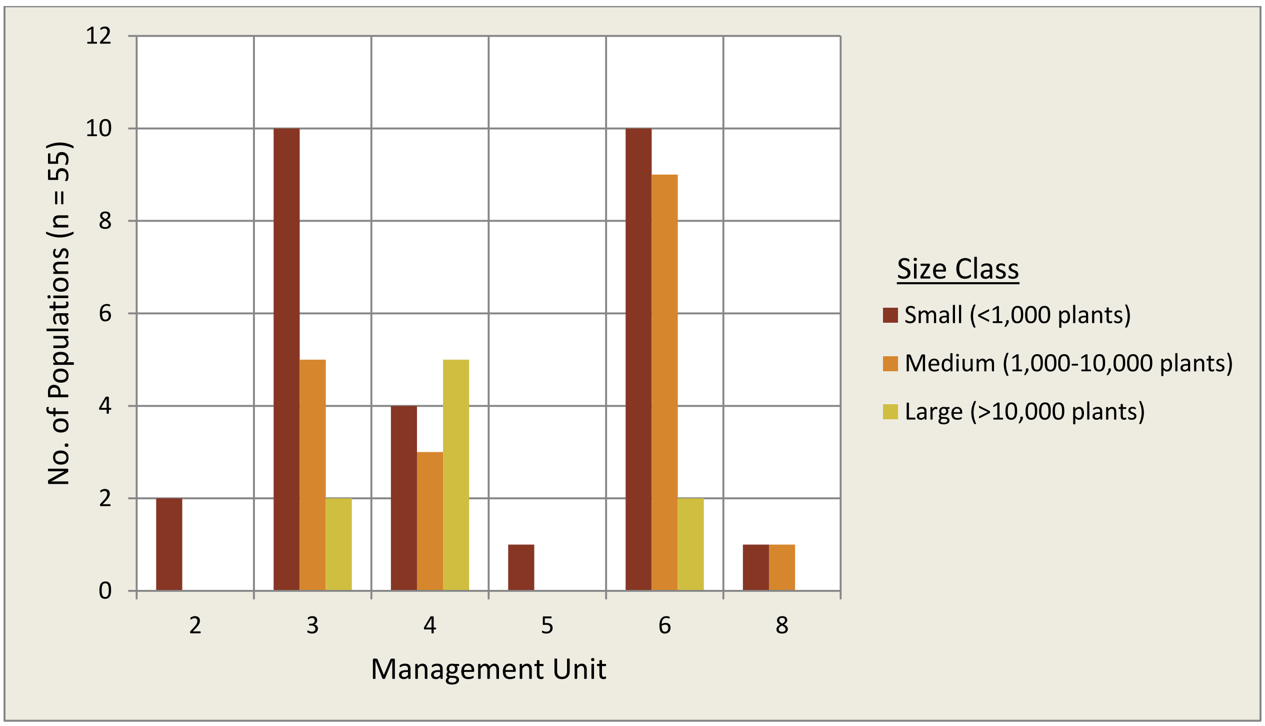
With these factors in mind, we stratified populations into the following size classes to assess potential for long-term resilience:

- Large populations: > 10,000 individuals
- Medium populations: 1,000-10,000 individuals
- Small populations: <1,000 individuals

Number of populations per size class is depicted in Figure C-10 for populations with census data. Of this total, 16% of populations in the MSPA are classified as large, 33% as medium, and 51% as small. Populations were categorized into size class based on the maximum number of plants observed. In a species with wide population fluctuations, maximum number may provide an indication of potential carrying capacity. We recognize that some populations may no longer have the ability to reach this 'potential,' based on threats and site history. Nonetheless, population potential may be an important consideration in management priorities, particularly where threats can be controlled.

Figure C-10

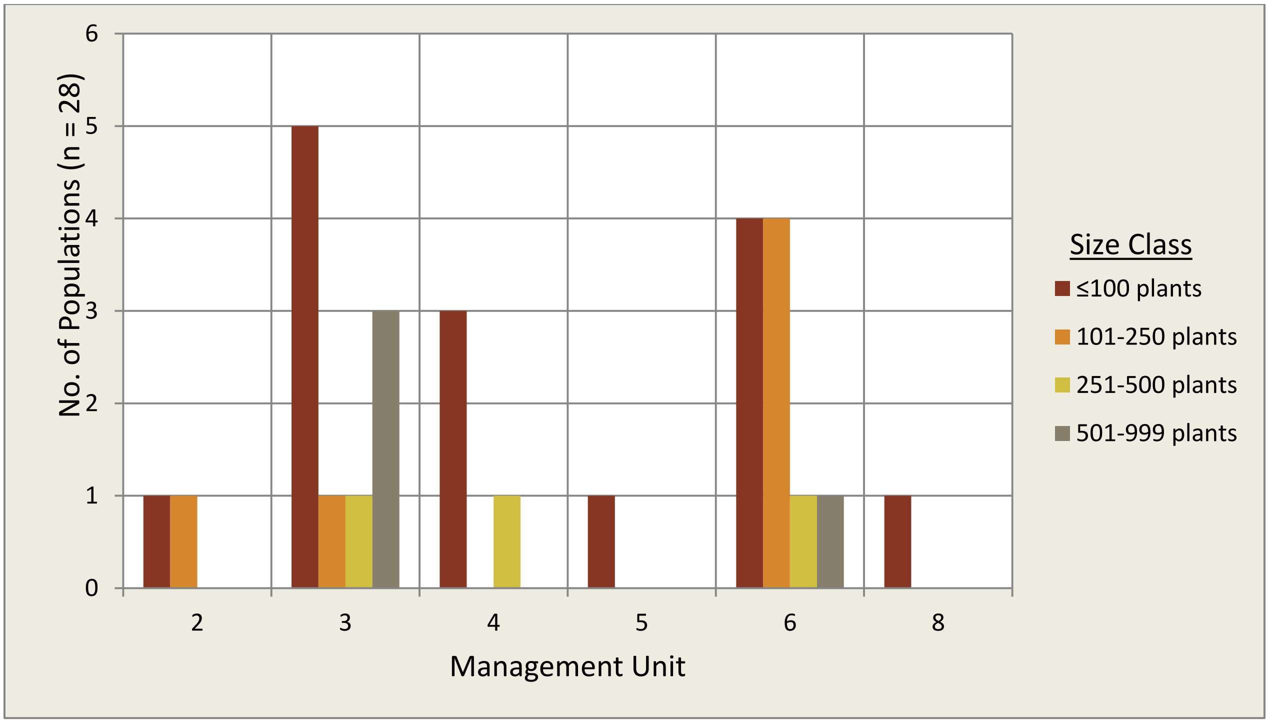
San Diego Thornmint Populations by Size Class



Size classes were stratified further to assess short-term persistence. Genetic and demographic considerations become more important with a decrease in population size; thus, the smallest populations are most at risk due to these factors (e.g., Lacy 1987, Barrett and Kohn 1991, Menges 1991, Lesica and Allendorf 1992). Maintaining or increasing genetic diversity is an important objective for small populations selected for management. Figure C-11 depicts the finer level of size class detail for small populations (<1,000 plants) in the MSPA. Based on available census data, 54% of small populations support 100 plants or less, while 86% of small populations support 500 plants or less.

Figure C-11

Small San Diego Thornmint Populations by Size Class



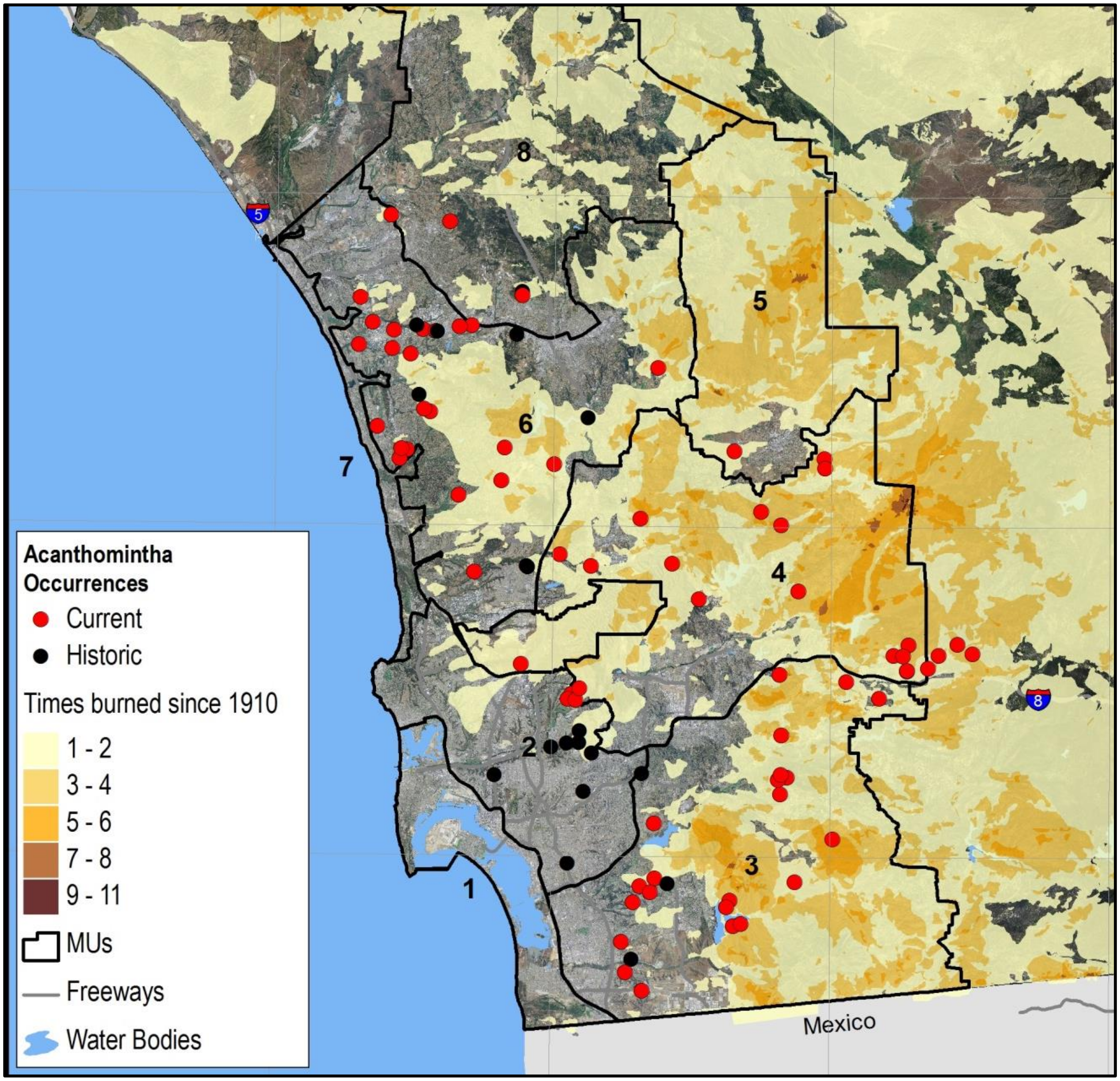
Altered Fire Regime. Although the fire response of San Diego thornmint is unknown, frequent fires may impact populations by reducing the seed bank, promoting invasive species infestations, and possibly resulting in habitat type conversions. To assess potential effects of fire on San Diego thornmint, we overlaid current thornmint distribution on the comprehensive fire perimeter database for public and private lands in California (CalFire 2011). The CalFire database for 1910-2010 indicates:

- Fire frequency ranged from 0-5 burns/population during the period of record;
- 48% of current thornmint populations and 46% of all populations did not burn during this time period;
- The large wildfires of 2003 represented the first burn for six thornmint populations; and
- Fire threat differs among MUs.

Figure C-12 depicts number of fires since 1910, while Figure C-13 illustrates the burn history of thornmint populations within MUs. Fire frequency is highest in MUs 3 and 4, with unburned populations occurring primarily in the western portion of MUs. Areas with a low history of fire and no recent increases in fire frequency may be important as refugia.

Figure C-12

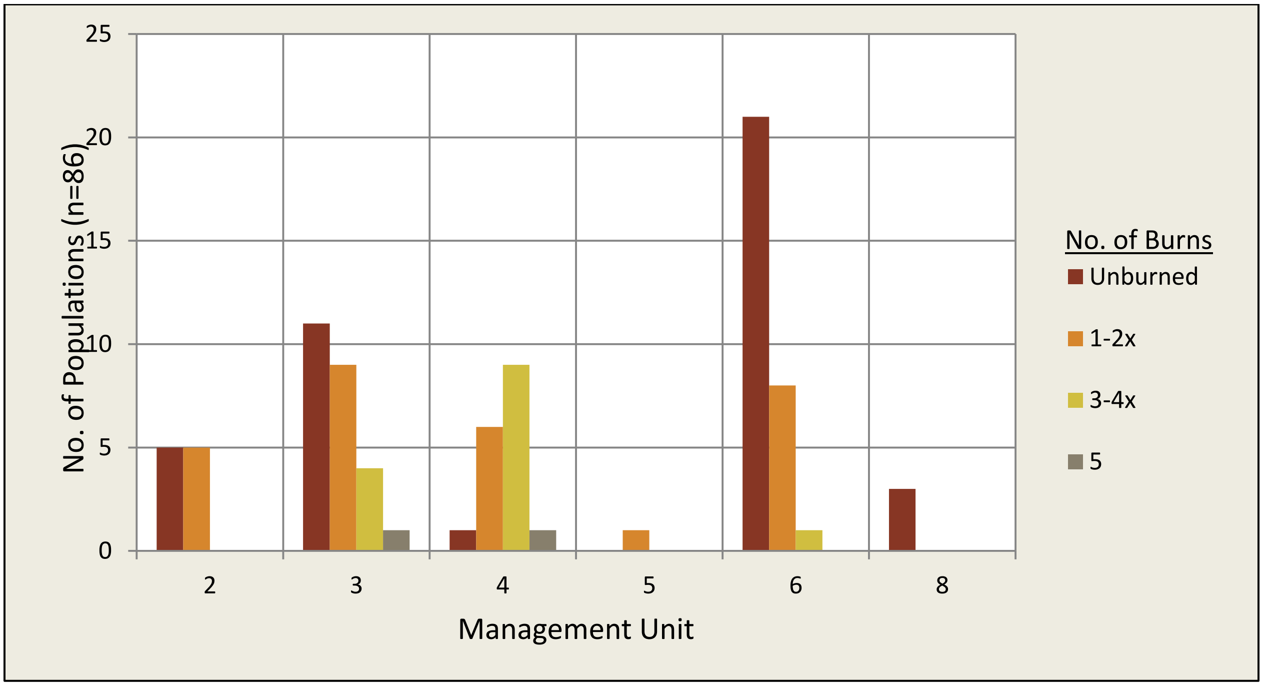
Number of Fires since 1910



Fire data were also examined to assess whether fire history affects thornmint population size. Both small and large populations experience a range of fire frequencies, and initial analyses indicated no clear relationship between fire and population size. However, results may be affected by small sample size; there is little post-fire thornmint census data, including population response in the first two years following a burn. Collection of annual post-fire data on both thornmint and invasive plant response is important for understanding species dynamics and formulating cost-effective management options.

Figure C-13

San Diego Thornmint and Fire History (1910-2010)



Habitat Fragmentation. Habitat fragmentation refers to the reduction of habitat into small, isolated patches, some of which may be too small to support viable populations of species. Small habitat patches are particularly vulnerable to habitat degradation concentrated near the interface of natural and disturbed areas (edge effects). Edge effects from fragmentation may include altered physical conditions (Saunders et al. 1991, Pickett et al. 2001) and fire regimes (Keeley and Fotheringham 2001), increased invasions by invasive plant and animal species (Suarez et al. 1998, Brothers and Spingarn 1992), changes in vegetation structure (Pickett et al. 2001), changes in interspecific interactions (Kolb 2008), altered population dynamics (Soulé et al. 1992), and disturbance from recreational users.

Figure C-14 depicts the distribution of current thornmint populations on conserved lands of various patch sizes. For these purposes, a patch is defined as a contiguous parcel of land that is not fragmented by urban development or major roads (SDMMP 2013). Fragmentation is highest in the western portion of the species' range, notably in MUs 2, 3, 4, and 6. Figure C-15 presents a breakdown of conserved lands by patch size and management unit. Based on available census data, there is no strong correlation between population size and patch size; however, populations on smaller patches likely will be subject to edge effects that may not affect populations on larger patches, and these effects may impact population viability or persistence over time.

Figure C-14

Patch Size, Conserved Lands within MSPA

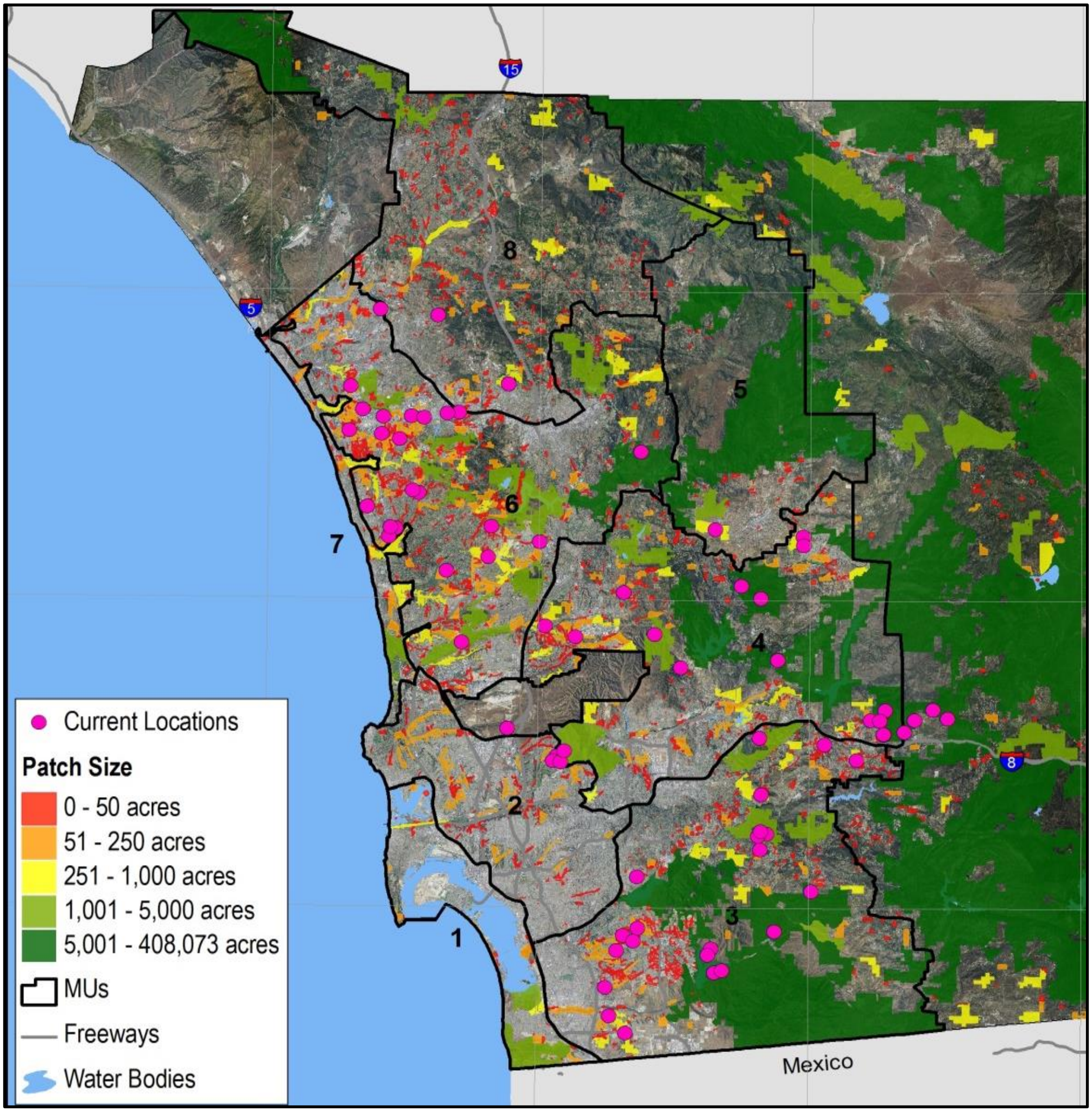
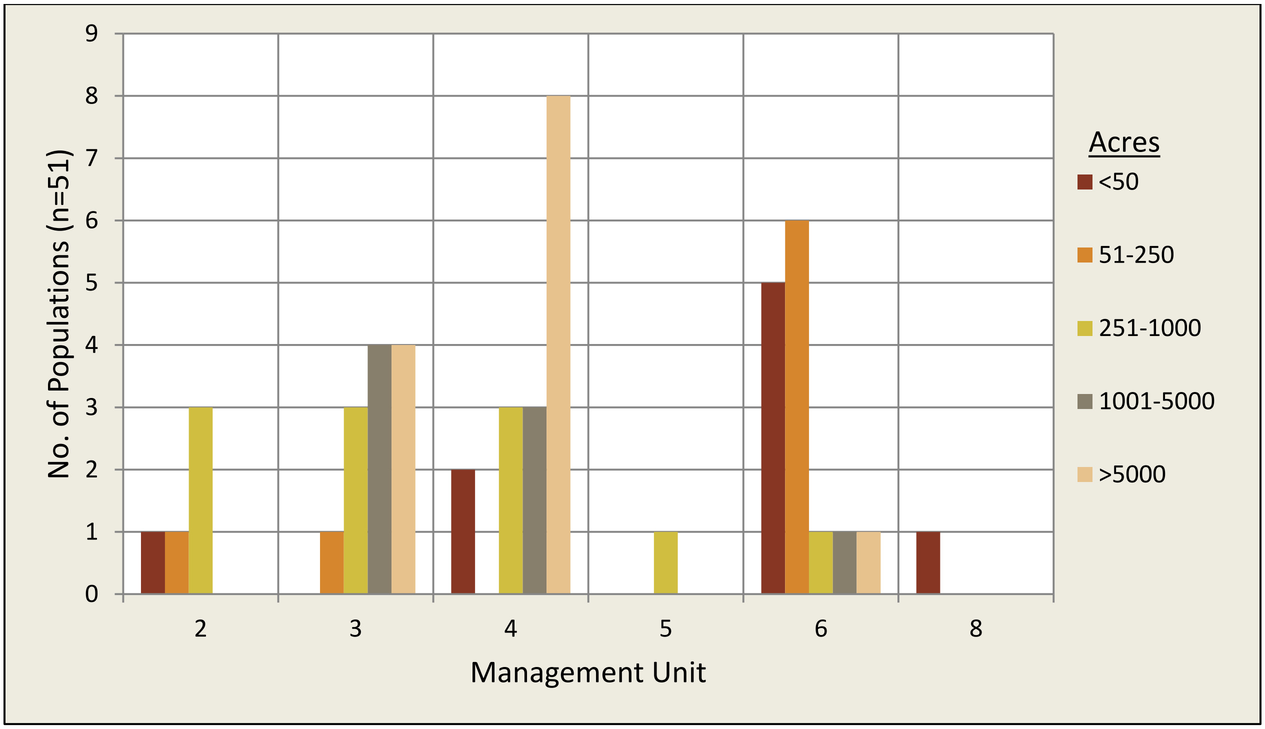


Figure C-15

San Diego Thornmint Distribution by Patch Size



Nitrogen Deposition. Petroleum burning vehicles are a major producer of nitrogen emissions, and deposition of these nutrients on terrestrial and aquatic environments can degrade sensitive ecosystems (Weiss 2006). Impacts can be direct or indirect and may include decreased plant function, altered plant community composition, nonnative species invasions, toxic effects on freshwater species, eutrophication of water bodies from excess nutrients, and loss of biodiversity (e.g., Weiss 2006, Fenn et al. 2003, Allen et al. 1998, Fenn et al. 2005). Among the impacts most relevant to San Diego thornmint are the potential increase in invasive grass biomass and the subsequent alteration of fire regimes (grass-fire cycle) and decrease in native plant species (D'Antonio and Vitousek 1992, Rao et al. 2010, Ochoa-Hueso et al. 2011, Fenn et al. 2010).

Figure C-16 presents total nitrogen deposition levels across the MSPA in relation to thornmint populations. Deposition levels were derived from modeled results by the University of California, Riverside (CCB 2002) and indicate the amount of monthly total nitrogen deposited in southern California in 2002. Model results were compared with critical load thresholds (Fenn et al. 2010) for key thornmint habitats within each MU to identify habitats—and by inference, populations—at risk for impacts from chronic nitrogen deposition (Table C-4). Results indicate that all MUs, and most populations other than a few along the coast in MU 6, are affected by elevated nitrogen levels (Figure C-17). Although land managers will not be able to reduce nitrogen deposition levels, invasive plant control may partially offset impacts from chronically high levels of nitrogen deposition.

Figure C-16

Nitrogen Deposition Levels across the MSPA

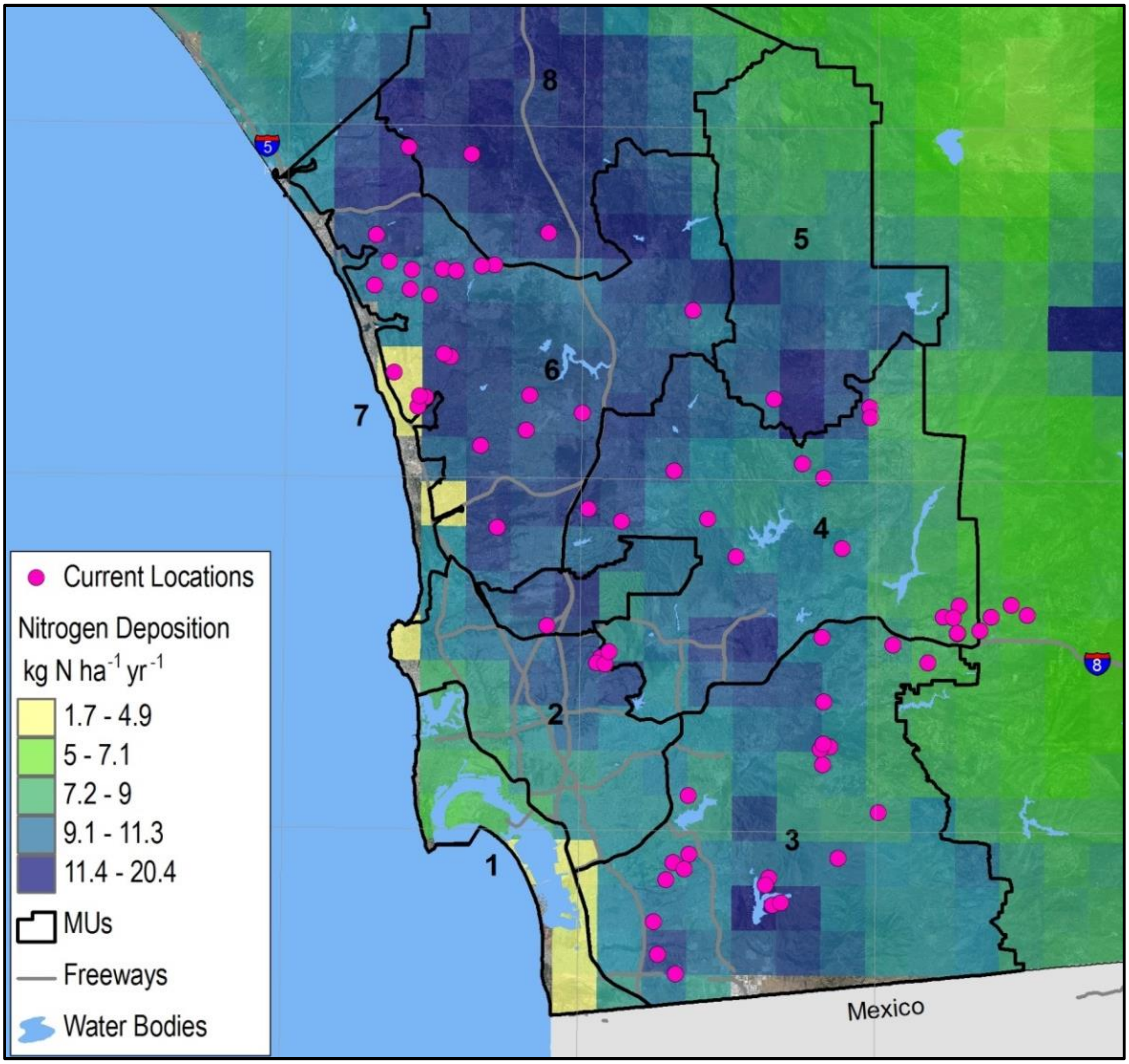


Table C-4

Habitats Potentially Affected by Nitrogen Deposition

MU[1]	Average Nitrogen Deposition[2] (kg N ha^{-1} yr^{-1})	Critical Load Levels (kg N ha^{-1} yr^{-1})[3]		
		Chaparral (5.5-[10.0]-14.0)	Coastal Sage Scrub (7.8-10.0)	Grassland (6.0-7.5)
2	12.39	X	X	X
3	10.27	X	X	X
4	10.18	X	X	X
5	13.62	X	X	X
6	10.42	X	X	X
8	12.46	X	X	X

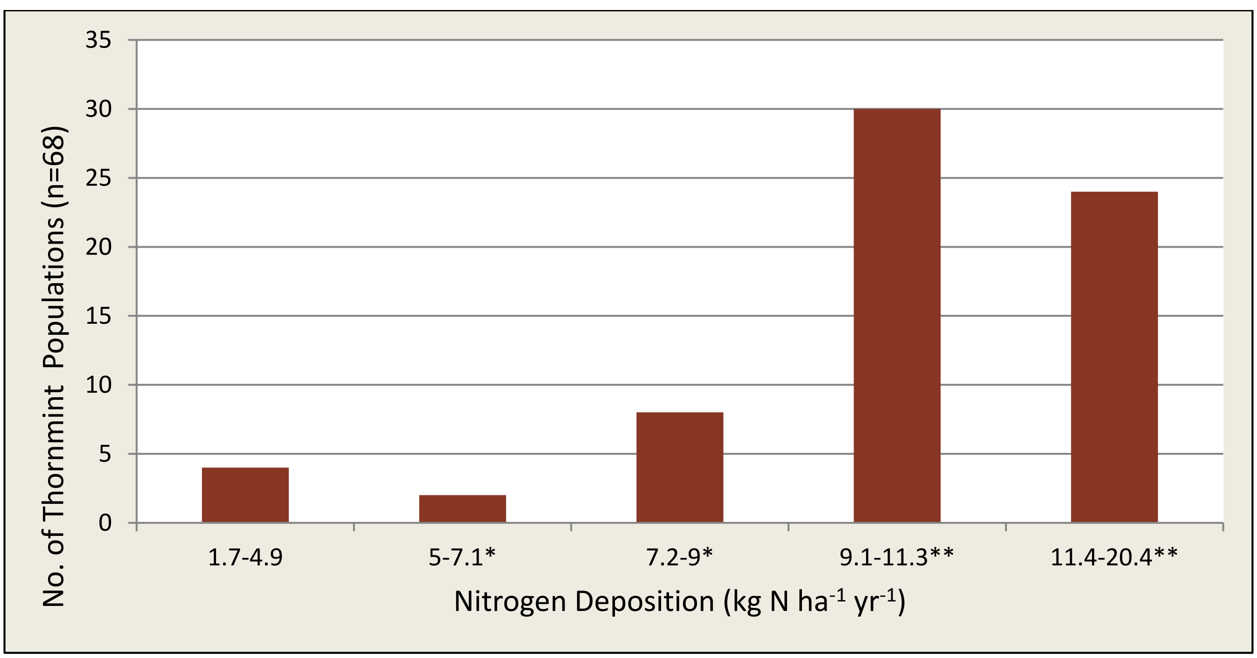
[1] MU = Management Unit

[2] Average nitrogen deposition levels are derived from modeled results (CCB 2002).

[3] Critical Load = A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge (UBA 2004); Number range = thresholds at which habitat in California is impacted by chronic N deposition (Fenn et al. 2010); X = habitat within MU affected by elevated N levels based on average N deposition. Average N deposition levels may be below critical load levels in some areas within a MU (e.g., coastal regions of MU 6).

Figure C-17

San Diego Thornmint Populations and Nitrogen Deposition[1]



[1] * = potentially impacted by nitrogen deposition; ** = likely impacted by nitrogen deposition.

Climate Change. Climate change has the potential to adversely affect plant species in various ways, including (1) altered climatic conditions (e.g., temperature, rainfall) that may affect a species' ability to persist in a given location; (2) shifts in flowering times that may result in lowered pollination success and/or loss of compatible pollinators; (3) altered photosynthetic rates and nutrient uptake that may result in increased growth and competition or an increase in herbivores; (4) increased rate of spread of invasive species that may outcompete native plant species; and (5) increased fire frequency that may result in loss of individuals or habitat type conversion (Anacker et al. 2013, Loarie et al. 2008, Parmesean and Yohe 2003, Walther et al. 2002, and others). In addition, 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 changing climatic conditions, thus affecting the ability of some species to persist. The most vulnerable species are those that occur in small populations, are limited in distribution, or are closely associated with certain habitats or edaphic conditions (Loarie et al. 2008). For the latter, the presence of suitable habitat near existing habitat and within range of dispersal capabilities may be important to long-term survival.

To assess the threat of climate change to San Diego thornmint, we reviewed recent modeling that evaluated potential thornmint habitat suitability and abundance under various species distribution models (SDMs) and future climate change predictions (Conlisk et al. 2012, A. Syphard pers. comm.). We selected both SDMs and climate models to bracket the range of differences in predictions (see Conlisk et al. 2012) and assessed current thornmint populations for future habitat suitability under each scenario (Table C-5). In this table, higher numeric values indicate higher habitat suitability in 2050. Modeled results represent potential scenarios only, and are based on underlying assumptions in the models regarding thornmint biology, environmental correlates, and future climatic conditions.

Under all scenarios, populations that appear most resilient to the effects of climate change, and that might persist under changing climatic conditions, occur primarily in the central and eastern portions of the MSPA, with the exception of a few coastal locations in MU 6. For 28 extant or presumed extant San Diego thornmint populations, all modeled scenarios predict no habitat suitability by 2050 (Table C-5). The modeling approach to assessing the distribution of future suitable habitat for San Diego thornmint indicates that both invasive plants and fire frequency are threats that impact thornmint population viability; thus, reducing the impact of these threats would benefit the species under all climate change scenarios (Conlisk et al. 2012).

The California Invasive Plant Council (Cal-IPC) developed a climate change model for the invasive grass, *Brachypodium distachyon*, which has been identified as a threat to San Diego thornmint. Model results for 2050 predict that the range of this species in San Diego County will remain stable or expand to the east, with some range reductions in coastal and central areas (Cal-IPC 2012).

In addition to managing climate change-related threats to San Diego thornmint, it will be important to ensure linkages to facilitate movement to future suitable habitat. Edaphic species may have an increased risk from the effects of climate change because of the patchy nature of suitable habitat, which may present limited opportunities for colonization (see Damschen et al. 2012), particularly where dispersal capabilities are limited.

Table C-5

San Diego Thornmint and Potential Climate Change Scenarios

Management Unit	EO #[1]	Potential Climate Change Scenarios[2,3]			
		RF_PCM_2050	RF_GFDL_2050	Max_PCM_2050	Max_GFDL_2050
2	34	0.713	0.724	0.697	0.632
2	79	0.000	0.000	0.000	0.000
3	Bonita Meadows	0.000	0.000	0.000	0.000
3	McGinty Mountain	0.669	0.646	0.751	0.545
3	15	0.000	0.000	0.000	0.000
3	21	0.580	0.572	0.687	0.512
3	22	0.306	0.294	0.474	0.379
3	45	0.553	0.571	0.667	0.000
3	55	0.691	0.703	0.000	0.000
3	56	0.000	0.000	0.000	0.000
3	63	0.000	0.000	0.000	0.000
3	66	0.000	0.000	0.000	0.000
3	71	0.000	0.000	0.000	0.000
3	72	0.156	0.150	0.468	0.000
3	81	0.050	0.069	0.000	0.000
3	83	0.077	0.117	0.652	0.370
3	84	0.430	0.412	0.000	0.000
3	85	0.558	0.580	0.546	0.508
3	86	0.362	0.329	0.000	0.000
3	87	0.204	0.190	0.582	0.000
3	88	0.100	0.113	0.000	0.000
3	89	0.000	0.000	0.000	0.000
3	90	0.000	0.000	0.000	0.000
3	96	0.100	0.118	0.000	0.000
4	Simon Preserve	0.000	0.000	0.000	0.000
4	El Capitan	0.064	0.062	0.000	0.000

Table C-5

San Diego Thornmint and Potential Climate Change Scenarios

Management Unit	EO #[1]	Potential Climate Change Scenarios[2,3]			
		RF_PCM_2050	RF_GFDL_2050	Max_PCM_2050	Max_GFDL_2050
4	Viejas Hills	0.104	0.109	0.566	0.490
4	11	0.000	0.000	0.000	0.000
4	26	0.000	0.000	0.000	0.000
4	32	0.392	0.379	0.551	0.000
4	33	0.557	0.562	0.653	0.581
4	35	0.794	0.777	0.629	0.596
4	36	0.000	0.000	0.000	0.000
4	51	0.104	0.109	0.566	0.490
4	64	0.775	0.746	0.805	0.592
4	69	0.580	0.593	0.000	0.000
4	73	0.310	0.316	0.569	0.532
4	75	0.601	0.517	0.723	0.608
4	77	0.000	0.000	0.000	0.000
4	78	0.689	0.621	0.747	0.531
4	80	0.272	0.208	0.482	0.000
5	92	0.580	0.562	0.617	0.506
6	17	0.000	0.000	0.000	0.000
6	19	0.657	0.625	0.870	0.865
6	25	0.647	0.642	0.720	0.000
6	28	0.000	0.000	0.000	0.000
6	31	0.381	0.396	0.761	0.728
6	38	0.000	0.000	0.000	0.000
6	39	0.000	0.000	0.000	0.000
6	41	0.000	0.000	0.000	0.000
6	42	0.000	0.000	0.000	0.000
6	46	0.657	0.670	0.911	0.897
6	47	0.000	0.000	0.000	0.000
6	48	0.000	0.000	0.000	0.000
6	49	0.566	0.551	0.000	0.000
6	53	0.000	0.000	0.000	0.000
6	57	0.000	0.000	0.000	0.000
6	58	0.000	0.000	0.000	0.000

Table C-5

San Diego Thornmint and Potential Climate Change Scenarios

Management Unit	EO #[1]	Potential Climate Change Scenarios[2,3]			
		RF_PCM_2050	RF_GFDL_2050	Max_PCM_2050	Max_GFDL_2050
6	59	0.000	0.000	0.000	0.000
6	60	0.672	0.672	0.912	0.900
6	70	0.098	0.092	0.753	0.542
6	82	0.663	0.623	0.919	0.895
6	91	0.246	0.227	0.704	0.698
6	94	0.686	0.672	0.921	0.900
6	97	0.000	0.000	0.000	0.000
8	61	0.000	0.000	0.000	0.000
8	93	0.106	0.121	0.000	0.000

1 EO = Element occurrence number (per CNDDB); populations with no EO # are identified by population name.

2 Four potential climate change scenarios were reviewed: RF_PCM_2050 = Random Forest Species Distribution Model + PCM climate model (from the Department of Energy's Parallel Climate Model); RF_GFDL_2050 = Random Forest Species Distribution Model + GFDL climate model (from the National Oceanic and Atmospheric Association's Geophysical Fluid Dynamic Laboratory's CM.2 model); Max_PCM_2050 = Maxent Species Distribution Model + PCM climate model; Max_GFDL_2050 = Maxent Species Distribution Model + GFDL climate model. Data provided by Syphard pers. comm. 2013. 2050 indicates the year.

3 In all models, a higher value indicates higher predicted habitat suitability in 2050.

C-2 Habitat Suitability

Spatially explicit models identifying suitable habitat can be important tools for conserving, monitoring, and managing rare species (Guisan et al. 2013, Marcer et al. 2013). Niche models use environmental variables calculated with Geographic Information Systems (GIS) and species occurrences to delineate potentially suitable habitat. These models can be used to increase our understanding of a species' habitat requirements, prioritize areas to survey for new populations, and identify potential sites for population enhancement and translocation. SDMMP prepared a habitat suitability model for San Diego thornmint. This model was developed to evaluate connectivity between populations, identify opportunity areas with suitable habitat to survey for new populations, and assess prospective sites for population enhancement and translocation. We also developed a habitat suitability model for *Brachypodium* to identify locations where this nonnative grass has high potential for invasion and could pose a threat to San Diego thornmint populations.

Methods

CBI compiled species location data for San Diego thornmint and *Brachypodium* in San Diego County. Sources of records included field surveys conducted by CBI and TNC, land managers, environmental consultants, and botanists, as well as databases such as the California Natural Diversity Database (CNDDB), the San Diego Natural History Museum (SDNHM) Plant Atlas, the California Consortium of Herbaria (CCH), and the Invasive Strategic Plan database for western San Diego County (CBI et al. 2012). For each species, we randomly selected 60% of records to use as a calibration dataset for constructing the models, and the remaining 30% of observations were included in a validation dataset for assessing model performance.

We characterized environmental conditions across San Diego County using GIS and digital spatial layers to compute topographic, climatic, and edaphic variables. We created a grid of points spaced 200 m apart for San Diego County and calculated values for various environmental variables at each point in the grid (Table C-6). Using ArcGIS, we spatially joined each species location to the closest grid point to characterize the environment occupied by the species. If two records for a species fell in the same grid cell, one was excluded from the modeling datasets.

Partitioned Mahalanobis D^2 Models

We developed partitioned Mahalanobis D^2 models for San Diego thornmint and *Brachypodium* in San Diego County. This modeling approach is based upon the premise that environmental attributes with consistent values where a species occurs are likely to be associated with limiting factors, whereas environmental attributes that vary widely are not as informative in predicting suitable habitat (Dunn and Duncan 2000, Rotenberry et al. 2002, 2006). Mahalanobis D^2 is a standardized distance between the multivariate mean for environmental variables calculated at locations occupied by a species and values for the same set of environmental attributes at any point in the landscape being modeled. The more similar environmental characteristics at a point in the landscape are to the species' multivariate mean, the more suitable the habitat is for the species. The D^2 distance is scaled following a chi-squared distribution and ranges from 0 to 1.0. These rescaled values form a Habitat Similarity Index (HSI), with 1.0 indicating environmental conditions identical to the species' multivariate mean (i.e., most suitable) and 0 indicating conditions that are highly dissimilar (i.e., unsuitable).

Using principle components analysis, D^2 can be divided into independent components or partitions (Rotenberry et al. 2002, 2006). Each partition represents an independent environmental relationship. The last partition with the smallest eigenvalue (measure of variance) represents the linear combination of environmental variables that vary the least. A larger eigenvalue indicates an increase in the amount of variance in environmental relationships

Table C-6

Environmental Variables for San Diego Thornmint and *Brachypodium* Models

Variable(s)	Scale(s)	Description
DemPt, Dem200m	At point & 200m median	Computed elevation (m) using ArcGIS to extract values from a 9.9m elevation raster at each point and calculate median values for a 200m neighborhood centered on each point. The elevation raster was downloaded from SanGIS Regional Data Warehouse (http://www.sangis.org/download/index.html).
TopoPt, Topo200m	At point & 200m median	Computed topographic heterogeneity, a measure of topographic ruggedness (Sappington et al. 2007), using ArcGIS and the elevation raster to calculate a value at each point and a median value for a 200m neighborhood centered on each point.
SlopePt, Slope200m	At point & 200m median	Computed slope (%) using ArcGIS to extract values from the elevation raster at each point and to calculate a median value for a 200m neighborhood centered on each point.
CosPt, Cos200m	At point & 200m median	Northness is a measure of northerly aspect. Used the "Aspect" tool in ArcGIS to calculate the cosine of aspect from the elevation raster using the "Raster Calculator" at each point and to calculate a median value for a 200m neighborhood centered on each point.
SinPt, Sin200m	At point & 200m median	Eastness is a measure of easterly aspect. Used the "Aspect" tool in ArcGIS to calculate the sine of aspect from the elevation raster using the "Raster Calculator" at each point and to calculate a median value for a 200m neighborhood centered on each point.
Prec01-12, PrecAnn, PrecJanApr, PrecNovDec, PrecNovFeb	At point	Computed precipitation variables (mm) for monthly, seasonal and annual time periods at each point using ArcGIS and a raster with 1981-2010 precipitation averages downloaded from the PRISM Climate Group (http://www.prism.oregonstate.edu)
TMax01-12, TMin01-12	At point	Computed monthly minimum and maximum temperature (°C) for each point using ArcGIS and rasters with 1981-2010 minimum and maximum monthly temperature averages downloaded from the PRISM Climate Group.
Clay, Sand, Silt	At point	Extracted percent clay, sand, and silt at each point using ArcGIS and soil shapefiles from the USDA Soil Viewer ArcMap Extension (http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/home)
AWC	At point	Extracted available water capacity (cm of water per cm of soil) at each point using ArcGIS and a soils shapefile from the USDA Soil Viewer ArcMap Extension.
Desp2ResLyr	At point	Extracted rock depth (depth in cm to restrictive soils layer) at each point using ArcGIS and a soils shapefile from the USDA Soil Viewer ArcMap Extension.

represented by that partition. Partitions are additive and together add up to the original D^2. Partitions are added by starting with the last partition with the smallest variance and adding that to the next higher partition with the next lowest variance and so on. The more partitions retained, the greater the variability in environmental conditions specified by the model. Combinations of partitions with low variance represent ecological minimums for a species, while combinations that retain more partitions and higher variability represent habitat relationships that are not as limiting for a species distribution. Determining the number of partitions to retain in a model depends on the modeling objectives, an analysis of eigenvalues, and an evaluation of model performance using calibration and validation datasets. Median HSI values are calculated for calibration and validation datasets and used to assess the number of partitions to retain and to evaluate overall model performance. Alternative models with different combinations of environmental variables and selected partitions are compared based on performance of the calibration and validation datasets. Once a model and partitions are selected, an HSI value can be calculated for every point in the landscape being modeled, resulting in a habitat suitability map.

San Diego Thornmint Habitat Suitability Model

We randomly selected 45 spatially distinct San Diego thornmint location records for the calibration dataset and retained the remaining 30 records for the validation dataset. Over 40 partitioned Mahalanobis D^2 models with different combinations of climatic, topographic, and edaphic variables were constructed and evaluated for San Diego thornmint. Model performance was satisfactory for several models, but not particularly high. The highest performing model (partition 5) had a median validation HSI of 0.697 and a median calibration HSI of 0.535. The best performing model included average April minimum/maximum temperatures, April precipitation, percent sand, and median elevation, slope, and topographical heterogeneity within a 200 m neighborhood. The habitat suitability map, without urban and agricultural development (Figure C-18), shows that historically there were large amounts of potentially suitable habitat in western San Diego County. Figure C-19 shows the current level of land use with remaining potential habitat on private and Conserved Lands. Conserved sites with high suitability (darker orange and brown grid cells) can be surveyed for new populations and to identify candidate sites for improving connectivity through population enhancement and translocation.

The San Diego thornmint habitat model is a preliminary model and is likely to be improved as we conduct surveys in potential habitat and use the results to evaluate and refine the model. One difficulty in modeling San Diego thornmint is that the number of location records is not large, given the wide range in environmental conditions over which this species occurs. Thornmint populations occur along an elevation gradient from 40 m near the coast to 3,108 m in the foothills. Along this gradient there are large differences in climate, with some populations

Figure C-18

Predicted Suitable Habitat for San Diego Thornmint in the Absence of Development in San Diego County

White areas were not modeled due to a lack of soil data.

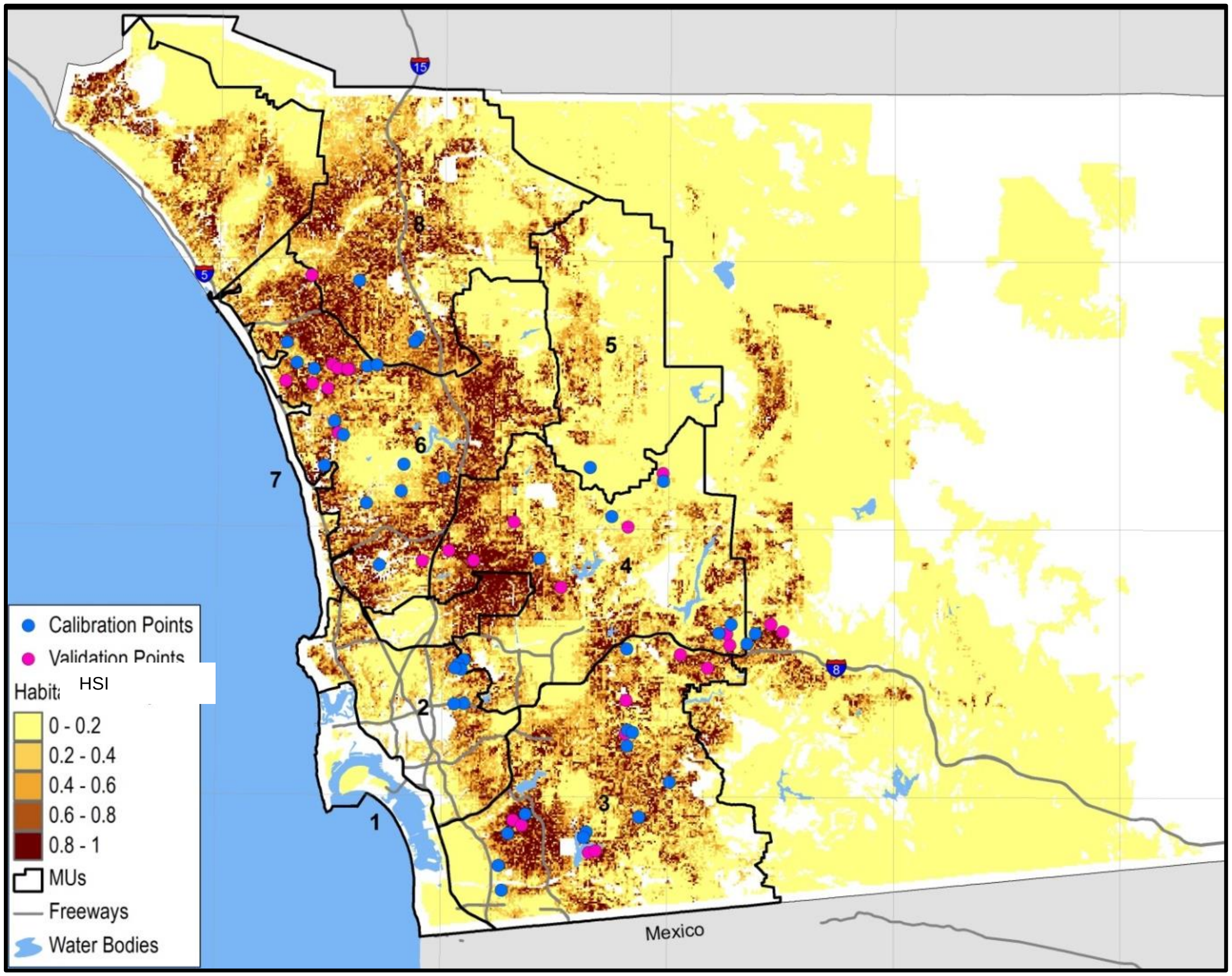
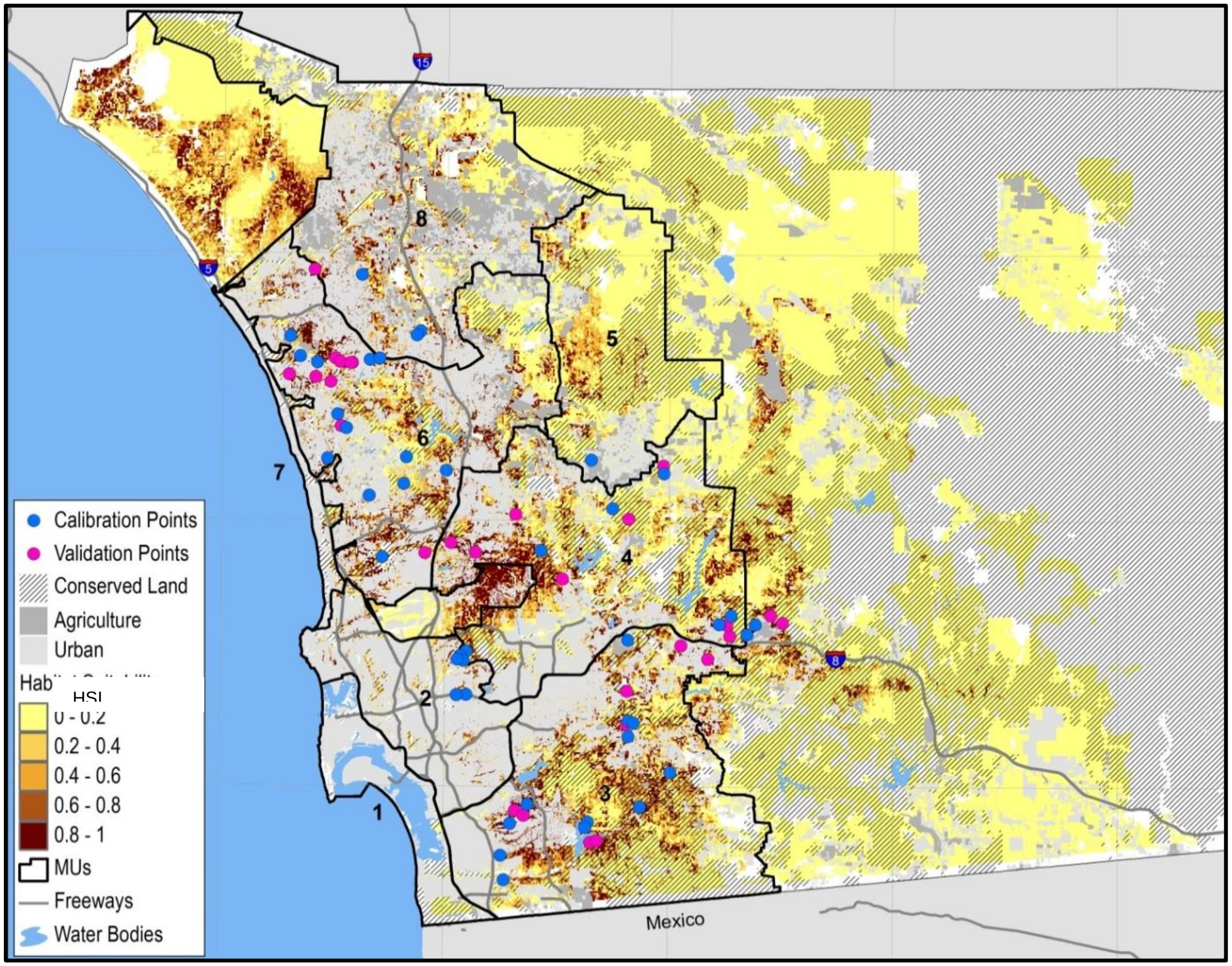


Figure C-19

Land Use, Conserved Lands, and Predicted Suitable Habitat for San Diego Thornmint in San Diego County.

White areas were not modeled due to a lack of soil data.



receiving an average of only 27 cm of annual precipitation, whereas others receive an average of 52 cm. Similarly, average minimum and maximum temperatures in the growing season can vary by two-fold. This level of variation is difficult to model without a large number of location records that can be subsampled spatially over multiple iterations to improve model predictions (Knick et al. 2013).

San Diego thornmint is also associated with small clay lenses within a matrix of other soil types (Section C.1). The USDA digital soil layer is coarse in scale and does not delineate many small areas with clay lenses. Models that included percent clay did not perform as well as models that included other soil attributes, such as percent sand and extracted rock depth. A digital soils map for western San Diego County that captures small clay lenses would substantially improve model performance.

The habitat model likely over-predicts where San Diego thornmint might occur for several reasons. Plants may have failed to colonize suitable habitat isolated from existing populations or may be excluded from suitable habitat by competition for space with invasive plants and native shrubs. The model is useful in prioritizing areas to survey so that more detailed on-the-ground data can be collected regarding thornmint population status and for assessing habitat and threats to inform management recommendations.

Brachypodium Habitat Suitability Model

We compiled 112 spatially distinct locations for *Brachypodium* modeling; 66 for calibration and 46 for validation. We constructed and evaluated over 20 partitioned Mahalanobis D^2 models. Overall, model performance was relatively high, with the best performing moderate model (partition 1) having a median validation HSI of 0.805 and median calibration HSI of 0.636. This model included average minimum December/maximum November temperatures and November to December precipitation, percent slope in a 200 m neighborhood, and percent clay. As with San Diego thornmint, suitable habitat based upon the current species location data is primarily in western San Diego County, particularly in the foothills (Figure C-20). A large portion of potentially suitable habitat has been lost to urban and agricultural development (Figure C-21). There is considerable overlap in predicted suitable habitat for *Brachypodium* and San Diego thornmint (Figures C-18, C-20). Environmental variables associated with *Brachypodium* occurrence are those related to winter climate conditions and clay soils.

The model for *Brachypodium* over-predicts suitable habitat, as this is an invasive, nonnative plant species that recently has expanded its range in western San Diego County. There are likely areas that it has not yet dispersed to where it could establish in the future.

Figure C-20

Predicted Suitable Habitat for *Brachypodium* in the Absence of Development in San Diego County.

White areas were not modeled due to a lack of soil data.

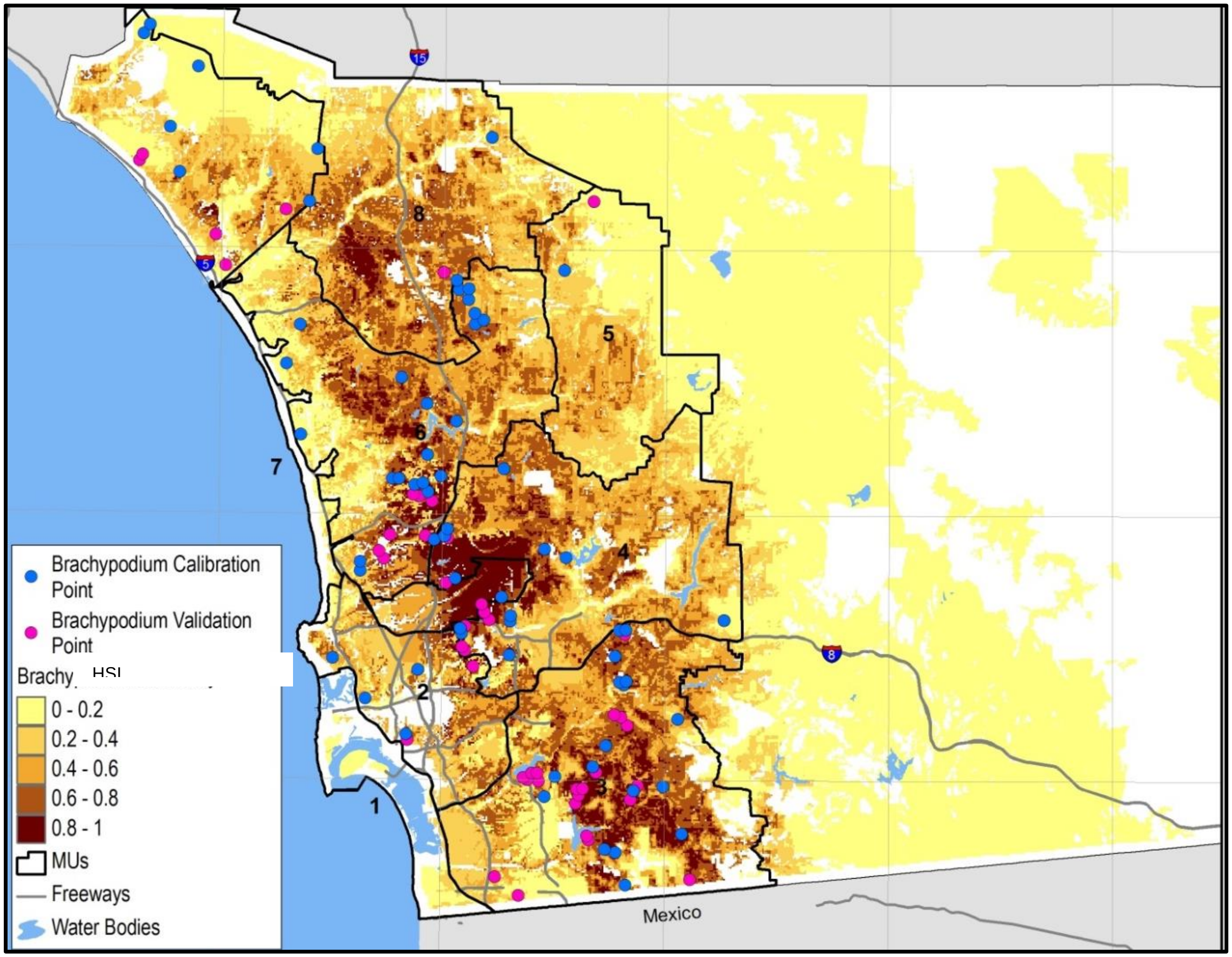
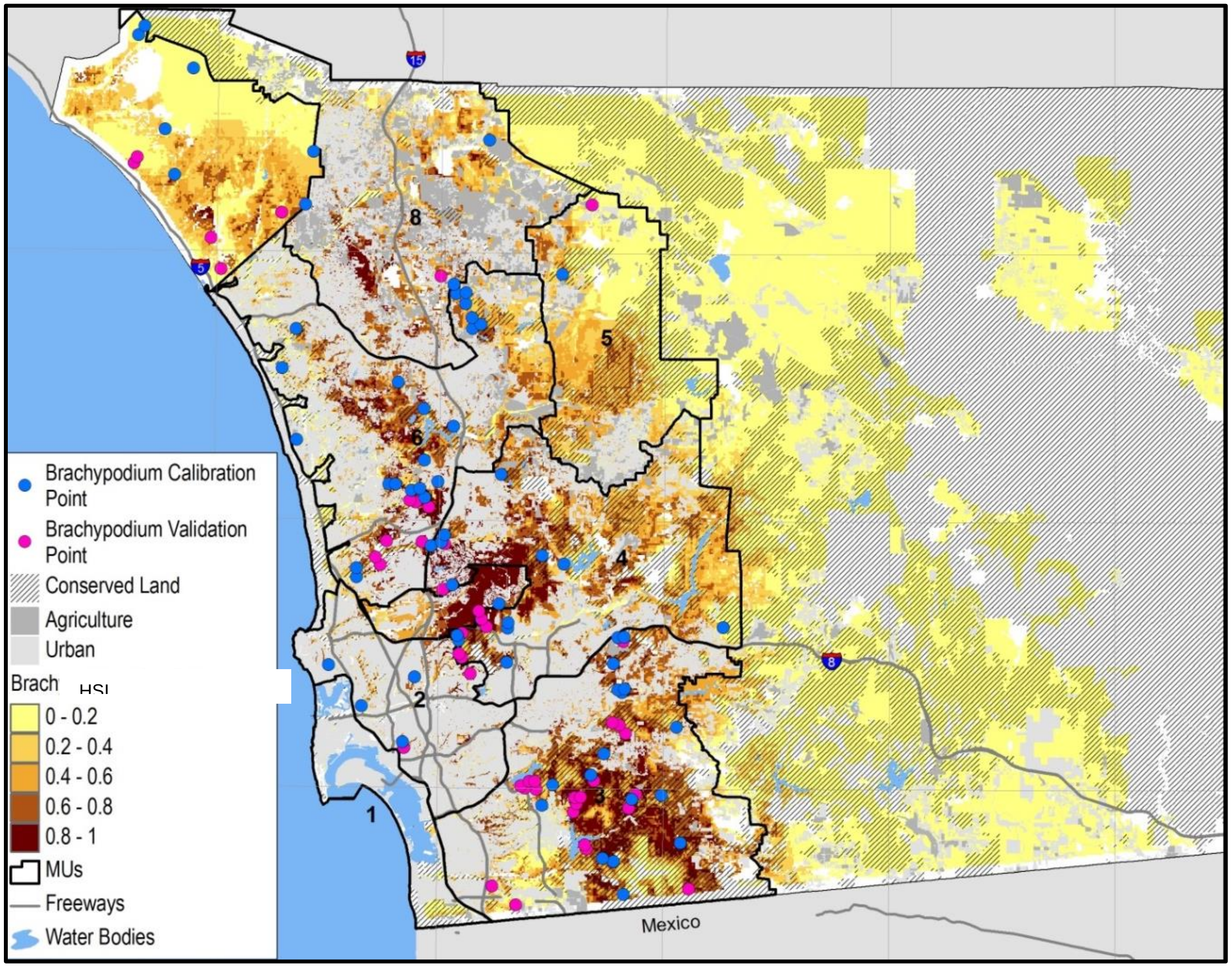


Figure C-21

Land Use, Conserved Lands, and Predicted Suitable Habitat for *Brachypodium* in San Diego County

White areas were not modeled due to a lack of soil data.



C.3 Climatic Influences

San Diego thornmint populations can vary by orders of magnitude in annual abundance, depending on weather patterns. Other annual plant species such as invasive, nonnative grasses and forbs can also vary dramatically in abundance depending on climate conditions. Understanding interactions between thornmint and invasive plant population dynamics may be important in controlling the distribution and abundance of invasive plants and enhancing thornmint populations. By identifying those climate correlates associated with years of high versus low thornmint abundance, we may be able to design targeted management strategies that are more efficient and effective.

Methods

We compiled available data on the number of plants observed each year at thornmint populations in western San Diego County. For most of the populations, we did not have precise abundance estimates covering multiple years. Population numbers often were rounded to orders of magnitude in years of high abundance, whereas complete counts of individual plants were often available in years of low abundance. The lack of precise estimates meant that we categorized extreme "high" and "low" abundance years for each population. For each thornmint population with sufficient data, we selected the smallest and largest annual abundance estimates to use as paired samples in conditional logistic regression modeling. For some populations there were multiple years with comparable population estimates categorized as high abundance years. Similarly, there may be more than one year with very small abundances for a population. In these cases, we used randomly generated numbers to select a single high abundance year and a single low abundance year for each population.

For every year of San Diego thornmint population abundance data, we calculated an array of climate variables characterizing weather conditions in that year. Climate data were obtained from the closest weather station to each population (http://www.raws.dri.edu/). These stations included National Oceanic Atmospheric Administration Cooperative Stations (NOAA) and Regional Automated Weather Stations (RAWS). We had an initial list of 44 climate variables including monthly, seasonal, and bioyear (August to July) precipitation totals and average monthly and seasonal minimum and maximum temperatures. We also calculated precipitation totals for the previous bioyear rainfall and for different time periods within that previous rainfall year.

We constructed conditional logistic regression models, using the paired samples as strata and compared how well different combinations of climate variables distinguished between high abundance years and low abundance years. We started by constructing single variable models with each of the 44 climate variables. Based on model performance we selected one or two variables that represented each of our hypotheses about how climate might be related to population fluctuations. This decreases redundancy among variables measuring similar climate conditions. Using this subset of climate variables, we developed a set of models representing different hypotheses about climate and San Diego thornmint population fluctuations.

Our hypotheses included:

H1. Growing season (late winter through spring) precipitation is positively associated with San Diego thornmint abundance. This hypothesis is based on the positive association of rainfall with annual plant abundance in arid southern California.

H2. Late fall and early winter rains are positively associated with the abundance of invasive, nonnative grasses and forbs, which then crowd out thornmint, resulting in lower abundance. Winter annual grasses (e.g., *Brachypodium distachyon*) can take advantage of early rains to germinate and grow before many native annual forbs have germinated.

H3. Total bioyear precipitation is positively associated with San Diego thornmint abundance, regardless of the seasonal timing of the rainfall. The bioyear is defined as rainfall occurring from August 1 of the year prior to the growing season being measured through July 31 of the year being measured.

H4. High amounts of rainfall in the previous year could increase nonnative annual plant seed banks and thatch and adversely affect thornmint populations measured in the following year. In contrast, low amounts of rainfall in the previous year could limit nonnative annual plant thatch and seed banks, resulting in large thornmint populations measured in the following year.

H5. Higher maximum and minimum temperatures in winter could adversely affect growth and reproduction of winter annual plants, particularly grasses. This would reduce competition for thornmint and result in larger thornmint populations.

H6. Unusually high growing season temperatures could reduce soil moisture and lead to lower thornmint population abundance. If the soil dries out too rapidly, then germination could be inhibited and mortality increased, resulting in small population size.

We evaluated models using Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002). We selected the model with the lowest AIC_c and calculated the difference in AIC_c (Δ_i) for each model. Akaike's weights (ω_i) indicate the probability that the model with the highest weight is the best approximating model for the dataset. Evidence ratios (ω_i/ω_i) represent the probability that the model with the highest ω_i was likely to be correct compared to another model. When there was no single best approximating model, we identified a 95% confidence subset of models based on cumulative Akaike weights.

We calculated model average parameter estimates for the variables consistently represented in the subset of top performing models. We calculated model-averaged parameter coefficients with unconditional standard errors, cumulative variable weights (CVW), and 90% and 95% confidence intervals.

Results

We assembled a paired dataset with paired extreme high and low abundance years for 37 San Diego thornmint occurrences in western San Diego County that spanned the period of 1978 to 2013. We ran 44 single variable models and selected 11 higher performing variables that reflect the various hypotheses we developed about climate influences on annual thornmint population abundance (Table C-7).

Eight models were included in a 97% subset of top performing models (Table C-8). The top model included growing season precipitation (JanMayPrecip) and sustained maximum winter temperature (MaxNovJanTemp) and all eight models included current growing season precipitation. Other parameters included in the subset of models were sustained minimum winter temperature (MinNovDecTemp), previous growing season precipitation (PrevFebAprPrecip), and an interaction between current and previous growing season precipitation.

Model averaged parameter estimates indicate only current growing season precipitation and sustained maximum winter temperature were positively associated with thornmint abundance based upon 90% confidence intervals (Table C-9, Figure C-22 a-d). Only current growing season precipitation showed a positive trend at the 95% confidence interval. The CVWs show the strength of association of current growing season (0.967) and sustained maximum average temperature (0.787) to thornmint population fluctuations. The other two variables and interaction term did not improve model performance, showed no trend at 90% or 95% confidence intervals, and had CVWs <0.500.

Discussion

The models support the hypotheses that growing season precipitation and winter temperatures are associated with fluctuations in San Diego thornmint abundance. The most important variables in distinguishing between low and high population abundance were growing season precipitation and sustained average maximum temperature─both show positive associations with abundance. Sustained minimum winter temperature and previous year growing season rainfall are included in the subset of top performing models, but did not show any trends in relation to

Table C-7

Climate Variables Used in Modeling San Diego Thornmint Population Fluctuations

Seasonal Climate Condition	Variable Name	Variable Description
Growing season precipitation	JanMayPrecip	January 1 to May 31 growing season rainfall total
Bioyear precipitation	AnnPrecip	Rainfall total from August 31 of previous year to July 31 of the following year
Winter precipitation	NovJanPrecip	Rainfall total from November 1 of previous year to January 31 of the following year
Previous year's bioyear precipitation	PrevAnnPrecip	Rainfall total starting two years previously on August 31 and ending one year previously on July 31
Previous year's growing season precipitation	PrevFebAprPrecip	Rainfall total starting one year previously from February 1 to April 30
Previous year's winter precipitation	PrevNovJanPrecip	Rainfall total starting two years previously on November 1 and ending one year previously on January 31
Minimum winter temperature	MinNovTemp	Average minimum November temperature in the previous year
Sustained minimum winter temperature	MinNovDecTemp	Average minimum November and December temperature in the previous year
Maximum growing season temperature	MaxAprTemp	Average maximum April temperature
Sustained maximum growing season temperature	MaxMarAprTemp	Average maximum March and April temperature
Sustained maximum winter temperature	MaxNovJanTemp	Average maximum temperature from November 1 of previous year to January 31 of current year

Table C-8

Top Performing (97% Confidence Interval) Subset of Conditional Logistic Regression Models Distinguishing Between High and Low Abundance Years for San Diego Thornmint Populations Relative to Various Climate Variables.

Model Type	Model Parameters	K	Δ_i	ω_i	Evidence Ratio ω_i/ω_1
Growing Season Precipitation & Maximum Winter Temperature	JanMayPrecip, MaxNovJanTemp	4	0.000	0.438	
Growing Season Precipitation & Minimum/Maximum Winter Temperatures	JanMayPrecip, MinNovDecTemp, MaxNovJanTemp	5	1.284	0.230	1.901
Current & Previous Growing Season Precipitation & Minimum/Maximum Winter Temperatures	JanMayPrecip, PrevFebAprPrecip, MinNovDecTemp, MaxNovJanTemp	6	3.493	0.076	5.735
Growing Season Precipitation & Minimum Winter Temperature	JanMayPrecip, MinNovDecTemp	4	3.813	0.065	6.730
Growing Season Precipitation	JanMayPrecip	3	3.830	0.065	6.789
Current & Previous Growing Season Precipitation & Minimum/Maximum Winter Temperatures & Interaction Between Current & Previous Precipitation	JanMayPrecip, PrevFebAprPrecip, MinNovDecTemp, MaxNovJanTemp, JanMayPrecip*PrevFebAprPrecip	7	5.150	0.033	13.133
Current & Previous Growing Season Precipitation, Minimum Winter Temperature & Maximum Growing Season Temperature	JanMayPrecip, PrevFebAprPrec, MinNovTemp, MaxAprTemp	6	5.226	0.032	13.641
Current & Previous Growing Season Precipitation	JanMayPrecip, PrevFebAprPrecip	4	5.552	0.027	16.056

K represents the number of model parameters, Δ_i is the difference in AIC_c values for each model relative to the model with the lowest AIC_c, ω_i is the model weight, and ω_i/ ω_i is the evidence ratio.

Table C-9

Model Averaged Parameter Estimates, 90% Confidence Intervals, Trends, and CVWs for Climate Variables Associated with High and Low San Diego Thornmint Abundances.

Variable Type	Variable	Parameter Estimate	90% Lower CI	90% Upper CI	Trend	CVW
Growing season precipitation	**JanMayPrecip**	**0.282**	**0.100**	**0.463**	+	**0.967**
Sustained maximum winter temperature	**MaxNovJanTemp**	**0.264**	**0.023**	**0.506**	+	**0.787**
Previous growing season precipitation	PrevFebAprPrecip	-0.008	-0.051	0.035	None	0.173
Sustained minimum winter temperature	MinNovDecTemp	-0.089	-0.252	0.075	None	0.415

thornmint abundance and are of less importance based on CVWs. Other hypotheses relating fluctuations in abundance to winter rainfall, total bioyear precipitation, and growing season temperatures were not supported with the current dataset.

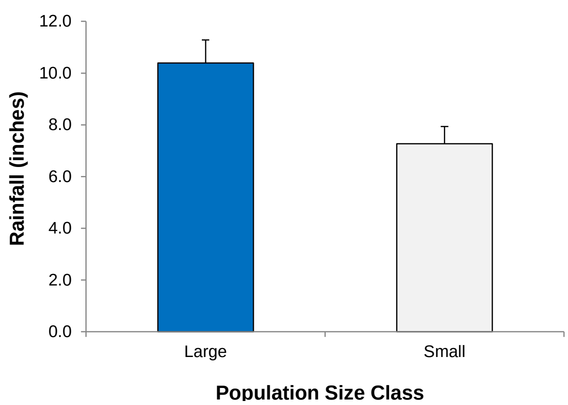
The importance of sustained maximum winter temperatures could be related to population dynamics of winter grasses, such as *Brachypodium*, that lead to competition with San Diego thornmint during the spring growing season. For example, winter climate variables were important in predicting suitable habitat for *Brachypodium* (see previous section). Under high temperatures (27°C or 80°F), accessions of this species from the Middle East exhibit reduced grain production, but no reduction in vegetative growth (Boden et al. 2013). Warm maximum temperatures in winter (November to January) may reduce grain production and, with continuing high temperatures and low rainfall through the spring, limit the number of cohorts producing seed. After several seasons of this type of weather pattern, the abundance of *Brachypodium* could be reduced through seed bank depletion. It is not known if this relationship between elevated temperatures and decreased grain yield is found in other winter annual nonnative grass species (e.g., *Avena* spp., *Bromus* spp.). The amount of rainfall during the November to January period is not correlated with average maximum temperatures during the same period (r=-0.108). What is not clear is how elevated winter maximum temperatures in the same bioyear would cause immediate declines in *Brachypodium*, as the effects on the seed bank are likely to be manifested in future years. However, there is some observational data to indicate that if *Brachypodium* germinates with early rains and temperatures are high, many seedlings can die and the current year cover will be sparse (P. Gordon-Reedy, pers. comm.).

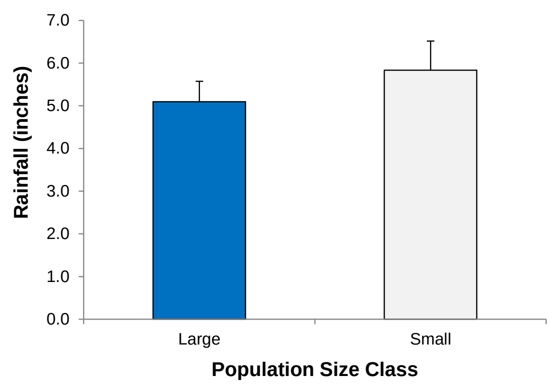
Alternative explanations could be that warm winter maximum temperatures promote earlier germination and growth of San Diego thornmint. Higher rainfall during the growing season may increase germination and growth of San Diego thornmint and be independent of effects on annual grasses. These are preliminary explanations that need further investigation, with experimental studies addressing San Diego thornmint abundance and competition with winter annual nonnative grasses under different climate conditions.

It is important to better understand the mechanisms that underlie phenology and abundance patterns of San Diego thornmint and invasive nonnative plants that may be a competitive risk. By understanding such mechanisms, or at least the environmental correlates associated with fluctuating abundance in both thornmint and the invasive annuals, we may be able to develop management strategies that are more targeted, efficient, and effective.

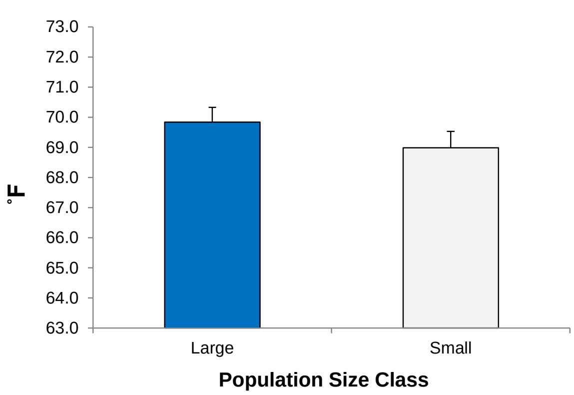
Figure C-22

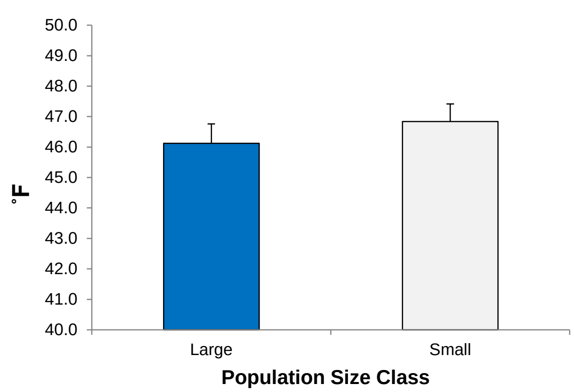
Mean (±SE) Model Parameters in the 97% Top Performing Subset of Models Distinguishing Low from High San Diego Thornmint Abundances





a. Growing season precipitation b. Previous growing season precipitation





c. Sustained maximum winter temperature d. Sustained minimum winter temperature

C.4 References

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Appendix D
Best Management Practices

Appendix D provides a compendium of Best Management Practices (BMPs) to be incorporated into San Diego thornmint management, as outlined in Appendix A (Table A-9). Existing BMPs developed by other sources are referenced below, while BMPs developed specifically for thornmint are described in more detail. For some management actions, BMPs will be developed or refined based on results of research studies or experimental management programs. Thornmint BMPs included in this appendix fall into the following categories:

- Seed Banking
- Soil Testing
- Invasive Plant Control

D.1 Seed Banking

Establishment and maintenance of a regional seed bank has been identified as a priority management action that would benefit conservation, restoration, and research activities for San Diego thornmint (Appendix A). Seed banking includes seed collection and storage (including testing), as well as development of seed bulking guidelines and establishment of appropriate seed transfer zones for population augmentation, establishment, or translocation.

Seed bulking guidelines and establishment of seed transfer zones are contingent upon results of genetic (and possibly garden) studies, and are not discussed in this document. In this context, guidelines for seed bulking refer to identifying appropriate seed sources or provenance for bulking based on genetic studies, rather than the actual process of bulking. Seed transfer zones are geographic regions within which seeds of a given species can be moved with minimal risk of either the plant's ability to thrive or harm the genetic integrity of other local populations of the same species (Bower et al. 2010, Kramer and Havens 2009). Seed transfer zones are widely used in forest management (Rehfeldt 1991, Sorensen 1992, Sorensen and Weber 1994, Campbell 1991, Bower and Aitken 2008, and others) and more recently, have been established for selected herbaceous and shrub species used in restoration (Bower et al. 2010, Bussell et al. 2006, Doede 2005, Johnson et al. 2004). Seed transfer zones for San Diego thornmint may be identifiable based on genetic, garden, and modeling studies; these zones would maximize short- and long-term restoration success by using genetic material that is locally adapted to site conditions or possesses phenotypes that may promote survival and adaptation to changing conditions (Kramer and Havens 2009). In the absence of seed transfer zones, San Diego County ecology subregions (SANDAG 2003) may function as surrogates for seed transfer zones (e.g., Miller et al. 2011), with the following qualifiers (Vander Mijnsbrugge et al. 2010, McKay et al. 2005, Montalvo and Ellstrand 2000):

- Match donor and receptor habitats as closely as possible with respect to climatic and environmental conditions.
- Use seed from the closest source population.
- Use seed collected from the same habitat type.

Seed Collection and Seed Storage

San Diego thornmint seed will be required for propagation, conservation, and possibly research purposes. With those objectives in mind, systematically collect seed to enhance out-planting success and maximize genetic diversity for long-term conservation. A number of seed collection protocols are available, including:

- Seed collection guidelines for California native plant species (Wall 2009)
- Assessing a potential seed collection. Millennium seed bank project, Kew (Way and Gold 2008a)
- Seed collecting techniques. Millennium seed bank project, Kew (Way and Gold 2008b)
- Field manual for seed collectors: seed collecting for the Millennium seed bank project, Kew (RBGK 2001)

Refer to SDMMP (2013, Volume 3, Section 3) for annotated descriptions and links to these documents. Wall (2009), in particular, provides information most relevant to developing a comprehensive seed collection strategy for San Diego thornmint, including discussions of (1) seed source or provenance, (2) seed collection size, (3) field assessments of viability, (4) seed sampling considerations and techniques, (5) seed collection methods, (6) post-harvest seed care, (7) seed collection data, and (8) permitting issues. BMPs for seed collection and seed storage are summarized below.

Sampling Strategy

- Develop and implement a seed collection strategy that maximizes genetic variability by collecting in multiple years and from multiple ecotypes within each San Diego thornmint population. In addition, collect throughout the seed production period in a given season to capture seed from early- and late-germinating plants. For some species, seed produced at different times may exhibit differences in viability.

- Establish minimum targets for seed collection on a regional, preserve, or population-level. A minimum target of 2,500 seeds per population or accession (subject to availability) provides adequate seed for propagation or conservation, and for short- and long-term seed viability testing. In some cases, an accession may include seeds from fragmented populations that were formerly connected.

- Collect seed from 30-50 plants per population;[1] select samples randomly and evenly from throughout the population. Collect no more than 5% of seed from the population or on a per-plant basis.

- Obtain applicable collecting and research permits prior to seed and voucher collection.

- Collect seed at the appropriate time of year and throughout the seed production period. This may necessitate multiple scouting and collecting trips to assess ripeness and capture the range of seed variability, respectively. Document each collection, using a standard seed collection documentation form; map Geographic Positioning System [GPS] coordinates; and package and deliver to an appropriate institution for cleaning, testing, and storing.

- Maintain seed from each population as a separate accession. Where donor populations are small (e.g., ≤1,000 individuals), store collected seed along maternal lines (e.g., seed from each parent plant is kept separate) to maximize genetic diversity for propagation or out-planting. Where donor populations are large (e.g., >1,000 individuals), seed can be collected along maternal lines or as bulk collections (e.g., all seed from a site can be packaged and stored as a single accession). Bulk collections are most appropriate where number of plants sampled (and thus, genetic diversity) is large. For these populations, the decision to collect along maternal lines or in bulk should consider cost-effectiveness, population genetics (if known), and specific collection objective.

Data Collection

- Maintain detailed records to document donor and receptor sites, collection dates, and amounts collected. Submit seed collection data to the SC-MTX website portal and a regional seed bank database (if established). Refer to Attachment D-1 for a sample seed collection form (Wall 2009).

Seed Collection Method and Interim Storage

- Hand-pluck or cut inflorescences and place into a paper bag. Pulling an entire plant may result in soil impacts, while collecting only seed or inflorescences will minimize soil damage and expedite the seed cleaning process by reducing excess plant material.

[1] Guidelines on minimum number of plants necessary for an adequate seed collection vary. Wall (2009) indicates that 30 plants would capture 95% of the genetic diversity in a population. Meyer (pers. comm. 2014) recommends minimum targets of 40-50 plants, based on studies at Rancho Santa Ana Botanic Garden (RSA) that suggest this number would capture about 90% of the alleles in a population. CPC guidelines (1991) recommend sampling 10-50 individuals per population. Within the suggested range, minimum sampling size should be dependent on population size and history, life history, and intended use.

- Place collected material in the bag loosely (as opposed to packing material densely) to allow for air circulation and inhibit mold growth.

- Deliver seed to the designated seed repository as soon as possible after collecting to reduce seed degradation as a result of improper storage.

Seed Storage

- Store seed to international standards at a recognized seed storage facility to maintain seed viability and genetic integrity. Store seed as either a short-term (≤5 years) propagation collection or long-term (>5 years) conservation collection.

- Test seed upon accession into the seed bank and on a regular basis (yearly) thereafter to ensure it retains viability; where tests indicate a decline in viability below a species-specific acceptable level (as determined by existing information or research, or results of initial testing of the accession), augment the seed bank with additional collections.

- Structure initial seed testing to obtain data on viability, germination rates, and dormancy factors, where feasible. In some cases, these tests may require additional funding beyond the cost of storage.

- Utilize seed from the collections for propagation (bulking) or direct seeding into existing or new (establishment/translocation) San Diego thornmint sites. Ideally, seed from the propagation collection will provide stock material for bulking and will be replaced periodically by additional collections.

D.2 Soil Testing

Soil testing within San Diego thornmint populations is recommended to better understand soil correlates (and ultimately, refine habitat suitability models) and select appropriate sites for establishment or translocation. Although San Diego thornmint is a soil endemic, it is not known precisely which soil properties influence species presence or whether fine-scaled soil characteristics can be used to predict thornmint habitat. To date, the species is most often described as occurring on clay soils or clay lenses within other soil types. We recommend a structured approach to obtaining additional soils data. The initial step includes a field assessment of soil type and texture, per the CNPS vegetation rapid assessment methodology (Brewer and McCann 1982 *in* CNPS 2007, Table D-1). This assessment can be conducted by land managers or others with little experience in soil sampling. Sampling should be conducted at all San Diego thornmint populations and results submitted to the SC-MTX website. SDMMP (or another entity) should analyze soils data for predictive patterns or correlations. A soils data collection form is included as Attachment D-2.

Table D-1

Simplified Key to Soil Texture[2]

Place about a tablespoon of soil in the palm of your hand, add water, and use the key below to figure out soil texture (e.g. loamy sand). Then, excessively wet a small pinch of soil, rub with forefinger, and determine the general texture subclass (e.g., *coarse*, *fine*) using the table below. Finer levels of subclass differentiation may require lab analysis.

A1	Soil does not remain in a ball when squeezed………………………………	sand
A2	Soil remains in a ball when squeezed	B
B1	Add a small amount of water. Squeeze the ball between your thumb and forefinger, attempting to make a ribbon that you push up over your finger. Soil makes no ribbon…………………………………………………….	loamy sand
B2	Soil makes a ribbon; may be very short…………………………………….	C
C1	Ribbon extends less than 1 inch before breaking…………………………..	D
C2	Ribbon extends 1 inch or more before breaking……………………………	E
D1	Add excess water to small amount of soil; soil feels gritty or at least slightly gritty (not smooth……………………………………………	sandy loam or loam
D2	Soil feels very smooth..…......................	silt loam
E1	Soil makes a ribbon that breaks when 1-2 inches long; cracks if bent into a ring.....	F
E2	Soil makes a ribbon 2+ inches long; does not crack when bent into a ring...............	G
F1	Add excess water to small amount of soil; soil feels gritty or at least slightly gritty (not smooth)..	sandy clay loam or clay loam
F2	Soil feels very smooth..	silty clay loam or silt
G1	Add excess water to a small amount of soil; soil feels gritty or not smooth..	sandy clay or clay
G2	Soil feels very smooth...	silty clay

General Soil Type	Texture Subclass		
	Very Gritty	Very Smooth	Neither Grittiness nor Smoothness Predominates
Sand, loamy sand	Coarse		
Sandy loam, sandy clay loam, sandy clay	Moderately coarse		
Silt, silt loam		Medium	
Silty clay loam, silty clay		Fine	
Loam			Medium
Clay loam, clay			Fine

[2] From Brewer and McCann 1982 *in* CNPS 2007, Thien 1979.

Based on results of the initial soils assessment, it may be necessary to investigate additional soils factors that may influence thornmint presence, such as nutrients or chemical properties. These types of studies will require more intensive sampling, including collection of soil samples for laboratory analysis, as well as input from a professional soil scientist.

D.3 Invasive Plant Control

Invasive plants[3] have been identified as a primary threat to San Diego thornmint (Appendix C). Several sources assess invasive plants that potentially impact thornmint (CBI et al. 2012, Cal-IPC plant assessment forms), as well as species-specific invasive plant control methods (Tu et al. 2001, Bossard et al. 2000, DiTomaso and Healy 2007). Refer to SDMMP (2013) for a link to Tu et al. (2001). DiTomaso et al. (2013) provide an expanded discussion of chemical (herbicide) and non-chemical (mechanical, cultural, biological) control techniques for approximately 340 invasive species that impact natural areas. These sources may be referenced when determining (1) which invasive species to control and (2) appropriate control methods (including rates and timing of herbicide application).

San Diego thornmint-specific invasive plant control methods discussed below are based on the experience of land managers and biologists involved in managing thornmint populations and habitat in San Diego County, and represent the current state of management knowledge for this species. These methods may be refined or replaced with alternative methods based on results of adaptive management or experimental programs. All invasive plant control actions should be tailored to the specific thornmint population and its unique complement of invasive plants and habitat conditions. In addition, not all invasive plants will necessarily require management; priority management actions should be directed at those invasive species known or strongly suspected to result in thornmint population declines and habitat degradation.

Invasive plant control methods described below have the potential to cause soil disturbance and, in some cases, thornmint mortality, particularly in large, dense populations. However, the net benefit to the population is expected to outweigh any adverse consequences, and potential impacts can be avoided or minimized with care.

Management Boundary Delineation

Prior to implementing invasive plant control actions, delineate the thornmint management boundary, which may include all or part of the population. Boundary delineation will allow relocation of the treatment area and an assessment of management effectiveness.

[3] For the purpose of this discussion, invasive plants are primarily non-native species, but may include a few native species that out-compete San Diego thornmint for resources.

Delineating Populations with a Small Spatial Extent (≤10 m^2)

Locate the thornmint population and determine the population extent. Demarcate a plot around the population or sub-population using permanent markers (rebar, pvc pipe) at corners and string or a tape measure to form a rectangle or square wherein management actions will take place (Figure D-1). Permanently marking corners will ensure the plot can be relocated and managed annually, or as often as necessary.

Figure D-1

San Diego Thornmint Management Plot

Delineating Populations with a Large Spatial Extent (>10 m^2)

The method for delineating populations over a large spatial extent is similar to that described above for populations in smaller areas. However, the shape of the management boundary should match the actual population boundary. Mark the management boundary permanently with rebar and/or pvc pipe and map it using a hand-held GPS device to facilitate relocation and management.

Data Collection

At a minimum, collect or record the following information to assess management effectiveness.

- Photograph the thornmint management plot(s) before and after management actions from an established photo point.
- Record thornmint management plot compass bearings.
- Develop thornmint management plot plant species list.
- Assess percent cover (obtained visually) for all species in the thornmint management plot.
- Count or estimate number of thornmint plants in the management plot.
- Record amount of time to conduct management actions.

Invasive Control Protocols

Invasive control protocols differ depending on thornmint population spatial extent and density. Figure D-2 provides a flow chart, or decision matrix, for determining which protocol to follow.

Populations with a Small Spatial Extent (≤10 m^2)

1. No more than two people should work on a small thornmint plot at one time to avoid excessive impacts to the clay lens. Minimize impacts by conducting management actions from outside the plot (e.g., plot edge), restricting foot placement within the clay lens, and using the same (preferably, disturbed) areas for foot placement on repeat visits.

2. Hand clipping and hand pulling are effective methods for controlling invasive plants and reducing thatch in small areas. Using this protocol, one or two individuals can hand clip/hand pull all invasive plants and thatch within the designated plot in one day or less. Several types of scissors/snips (Figure D-3) can be used for clipping, including small snips for small plants growing close to the soil surface and large scissors for thatch and tall non-native grasses and forbs. Place all hand clipped/hand pulled biomass in bags and remove from the site or place in a designated compost area onsite and away from the thornmint plot.

3. Where thornmint plants grow close together (i.e., ≤1 foot between individuals), hand clip/hand pull all invasive plants and grass thatch within the thornmint plot. Carefully clip plants at the base of the stem where the root meets the soil. In many cases, pushing the clippers into the soil will be necessary to remove plants whose leaves grow close to the soil surface (e.g., *Centaurea melitensis, Plantago virginica*). Care should be taken when hand pulling invasive plants to avoid disrupting the soil surface or pulling out large clumps of soil. Soil disturbance can be minimized by placing fingers at the base of the invasive plant and holding soil in place while pulling.

Figure D-2

San Diego Thornmint Invasive Plant Management Flow Chart

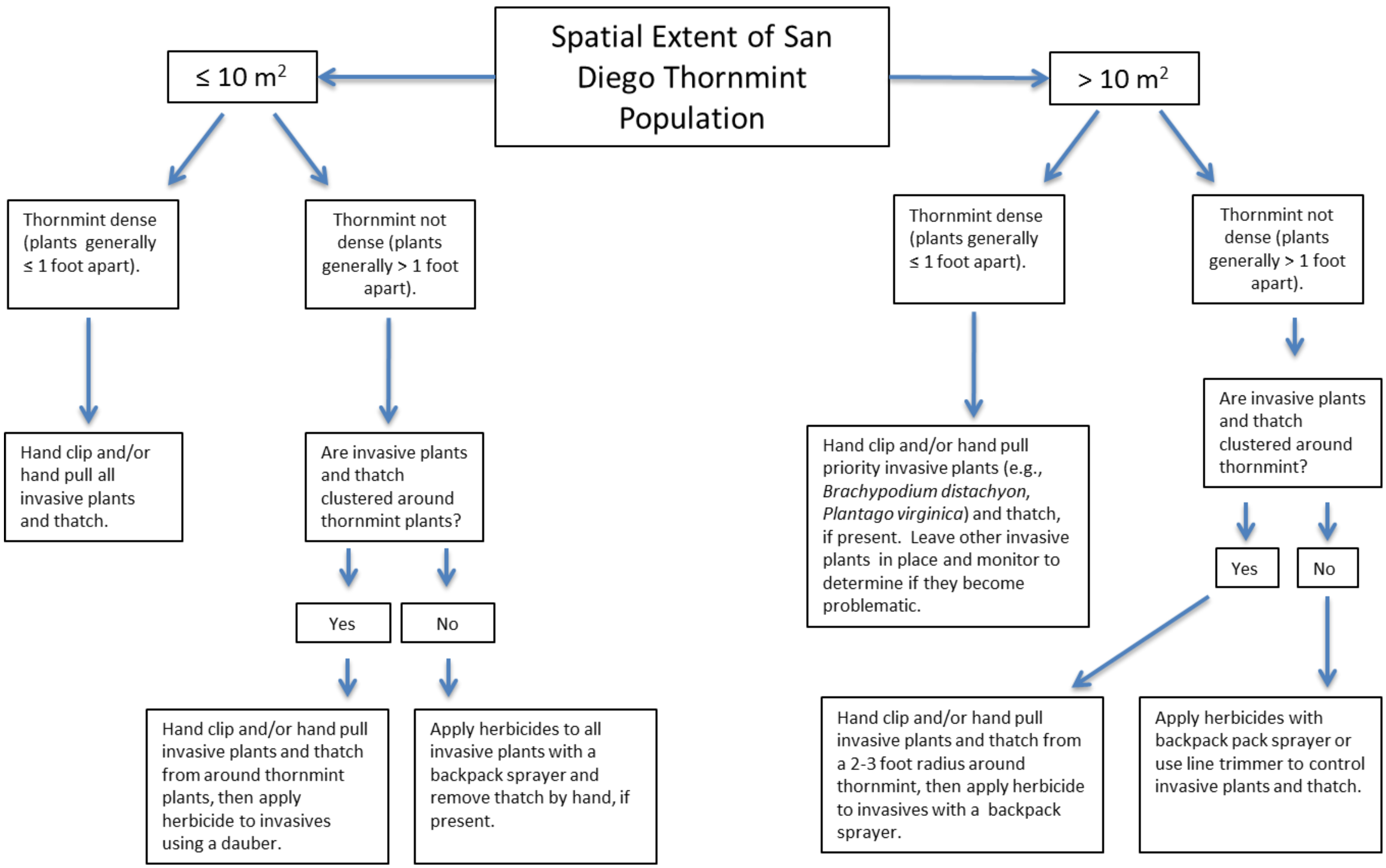

Figure D-3
Tools for Clipping

4. Where thornmint plants are not growing close together (>1 foot apart), but invasive plants and thatch are clustered around thornmint, hand clip/hand pull invasive plants around each thornmint individual(s). Apply appropriate herbicide(s) to other invasive plants in the plot using a backpack sprayer or herbicide wand applicator (herbicide dauber).

5. Where thornmint plants are not growing close together (>1 foot apart) and invasive plants are not clustered around thornmint, apply appropriate herbicide(s) to invasive plants with a backpack sprayer or herbicide dauber, taking care to avoid thornmint plants, to the degree feasible. Herbicides should be mixed according to label recommendations and used with a surfactant (if necessary).

6. Apply herbicides prior to invasive plant fruit formation, to the extent possible. Note that invasive plant phenology will vary by species, geographic location, and weather conditions. Some invasive species will be flowering or fruiting while others are just beginning to germinate. Thus, two visits may be necessary for effective herbicide control of invasive plants.

7. Apply herbicide in a 3-foot wide buffer strip outside and adjacent to the thornmint plot to inhibit invasive plant growth and production of seeds that could disperse into thornmint management plots.

Populations with a Large Spatial Extent (>10 m^2)

1. Minimize impacts within the thornmint population by restricting foot placement within the clay lens, to the degree feasible, and using the same areas for foot placement on repeat visits.

2. Place all hand clipped/hand pulled biomass in bags and remove from the site or place in a designated compost area onsite and away from the thornmint plot.

3. Where thornmint plants grow close together (i.e., ≤1 foot between individuals), hand clip/hand pull all invasive plants of concern for that population (e.g., *Brachypodium distachyon, Hedypnois cretica, Plantago virginica*), following the methodology described for populations in small areas, above. Do not treat other invasive plants unless monitoring detects increases in spatial extent or cover that threaten thornmint persistence.

4. Where thornmint plants are not growing close together (>1 foot apart), but invasive plants are clustered around thornmint plants, hand clip/hand pull invasive plants in a 2-3 foot radius around each thornmint individual. Apply herbicide(s) to other invasive plants in the treatment area using a backpack sprayer.

5. Where thornmint plants are not growing close together (>1 foot apart) and invasive plants are not clustered around thornmint plants, control invasives by applying herbicide with a backpack sprayer or using a line trimmer, taking care to avoid thornmint plants, to the degree feasible. Remove all cut biomass as described in no. 2 above and in the previous section.

6. Apply herbicides prior to invasive plant fruit formation, to the extent possible. Note that invasive plant phenology varies by species, geographic location, and weather conditions. In many cases, some invasive species flower or fruit while others are just beginning to germinate. Thus, two visits may be necessary for effective control of invasive plants using herbicide.

Other Considerations and Requirements

- Use botanists and/or land managers over contractors and volunteers for invasive plant management in thornmint plots unless contractors or volunteers are trained on species identification and control methods.
- Apply only herbicides approved for use in wildland environments.
- Herbicide applicators should possess a Qualified Applicator's License (QAL) or be trained by someone that possesses a QAL.
- Obtain land owner permission prior to application of herbicides.

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Seed Collection Data Form

Collection Date: Accession Date:

Species Name

Collector Name: Collection #: ____________

Property or Preserve Name:

Preserve Owner/Land Manager:

Voucher? No _____ Yes _____ Location of voucher:

Country: ________________ State: __________________________ County: ____________________________

SD County ecoregion: _______________________________ Elevation: FT _____ M ____

General Locality:

CNDDB EO#: Landowner/Land Manager:

Latitude: N Longitude: W | NAD83 ___ NAD27 _____WGS84 ____

Map Quad: T,. R., SEC, 1/4 SEC:

Sampled population size: ____

Number of individuals sampled: ____

Local abundance (common, scattered, rare): ____

Phenology: % veg _____ % flw _____ % fruit _____

Associated species:

Habitat:	Slope:	Exposure:	Moisture:
Group[2]: ______________________________	Flat _____	Full sun _____	Dry ____
Alliance[2]: ____________________________	Gentle _____	Semi shade _____	Moist ____
Association[2]: _________________________	Steep _____	Shade _____	Wet ____
Holland: _______________________________	Cliff _____		Seasonally ____
Other: _________________________________	Aspect _____		Moist ____

Geology:	Soils:	
Gabbro _____	Sand _____	Clay _____
Granite _____	Gravel _____	Alluvium _____
Sandstone _____	Rock _____	Other _____
Shale _____	Loam _____	
Volcanic _____		
Metavolcanic _____	Soil Series: ______________________________	

Notes and observations:

[1]Wall 2009

[2]San Diego Vegetation Classification

Soil Data Collection Form

Scientific Name (target species):	*MSP Occurrence ID:*
Common Name:	*CNDDB EO#:*
Preserve:	*Management Unit:*
Land Owner	*Land Manager:*
Surveryors & Affiliation:	*Sample Point #:*
	Date:

OCCURRENCE STATUS - *Document historic and current presence of target species within soil sampling area.*

Target Species Known from Site? □ Yes □ No

Target Species Present at Time of Sampling? □ Yes □ No

SAMPLING AREA LOCATION - *record precise soil sampling location.*

GPS Accuracy: ± _____ □ meters □ feet Datum: ____

Coordinates: E:____ N: ____

□ State Plane (feet) □ UTM (meters) □ Lat-Long (dec deg): ____

SOIL DATA - *collect/record soils data; refer to Attachment A for instructions on field testing soil texture.*

Soil Series (SSURGO):

Soil Texture (field-tested):

Soil Sample in Occupied Habitat? □ Yes □ No

Sample Collected for Lab Analysis? □ Yes □ No Lab Name: ____

ASSOCIATED SPECIES IN SAMPLING AREA - *record all plant species within soil sampling area.*

Invasive?	Species	% Cover

Total % Cover: __________ % Herb Cover:__________ % Shrub Cover: __________ % Tree Cover __________

Vegetation Alliance/Association (SDVC map): ____

Vegetation Alliance/Association (Field assessment): ____

Appendix E
Monitoring Metrics

Appendix E provides references to applicable monitoring metrics to be incorporated into San Diego thornmint management, as outlined in Appendix A (Table A-9).

E.1 Baseline and Annual Monitoring

The San Diego Management and Monitoring Program (SDMMP) has prepared rare plant monitoring protocols and data forms designed to obtain data on status and threats to rare plant occurrences (populations) and ensure consistency in data collection across the Management Specific Planning Area (MSPA) (SDMMP 2014). The SDMMP methodology is based on a number of sources including:

- San Diego Multiple Species Conservation Program (MSCP) rare plant monitoring review and revision (McEachern et al. 2007)
- Assessment of 11 years of rare plant monitoring data from the San Diego Multiple Species Conservation Plan (McEachern and Sutter 2010a)
- San Diego MSCP Rare plant monitoring data review presentation (McEachern and Sutter 2010b)
- San Diego rare plant monitoring plan: fiscal year 2011 (Tracey et al. 2011)
- City of San Diego Plant survey form and field form instructions (Miller 2013)
- Habitat monitoring form, South County grasslands
- South County Grasslands Habitat Monitoring data form (CBI and TNC 2012)
- Crestridge Ecological Reserve qualitative monitoring data sheet (CBI 2013)
- Input and review from local biologists

The SDMMP monitoring protocol is appropriate for baseline and inventory data. Data are primarily qualitative and will be used to assess population status and general threats, and recommend appropriate management actions.

The San Diego Thornmint Working Group compiled methods for obtaining more precise population counts, as well as estimates of cover and species diversity in occupied thornmint habitat. These methods are based on work conducted by biologists at the Center for Natural Lands Management:

- San Diego thornmint direct population count methodology (Vinje 2009)
- San Diego thornmint percent cover and diversity estimate procedures (McConnell and Vinje 2009)

Where additional types of monitoring are required (e.g., trend monitoring, targeted monitoring to assess management effectiveness), refer to the following documents for guidance on sampling design, methodologies, data analyses, and monitoring targets:

- Draft framework/template for implementing adaptive management (Lewison and Deutschman 2013)
- San Diego rare plant monitoring plan: fiscal year 2011 (Tracey et al. 2011)
- Measuring and monitoring plant populations (Elzinga et al. 1998)

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