

Review of the Purple Amole *Chlorogalum purpureum* (Agavaceae): a Threatened Plant in the Coast Ranges of Central California

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Abstract.—The purple amole *Chlorogalum purpureum* (Agavaceae) is a bulbous, perennial soap plant endemic to central California and listed as threatened under the U.S. Endangered Species Act since 2000. *Chlorogalum p. purpureum* occurs in the rain shadow of the Santa Lucia Range on Fort Hunter Liggett, south Monterey Co., and on Camp Roberts, north San Luis Obispo Co. *Chlorogalum p. reductum* occurs in the rain shadow of the La Panza Range in central San Luis Obispo Co., mostly on Los Padres National Forest and with potential for a substantially larger occupied area on private land. We review and enhance the existing knowledge of *C. purpureum*, in particular its life history and ecology, distribution, population sizes, threats, current management and conservation status. In 2012, invasive plants are the primary threat to *C. purpureum*.

Introduction

The genus *Chlorogalum* (Agavaceae, Bolger et al. 2006) comprises five plant species inhabiting western North America from southern Oregon, USA, to Baja California, Mexico (Jernstedt 2012). One species, purple amole *Chlorogalum purpureum*, is listed as threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service [USFWS] 2000). *Chlorogalum purpureum* is a bulbous, perennial soap plant and the only member of the genus with purple or blue flowers, the other species having white or pink flowers (Hoover 1940, Jernstedt 2012). It is endemic to central California (Figure 1), with two varieties recognized (Hoover 1964): purple amole *C. purpureum purpureum* (25 to 40 cm tall), and Camatta Canyon amole *C. purpureum reductum* (10 to 20 cm tall, Jernstedt 2012).

At Federal listing in 2000, *C. p. purpureum* was known from three occurrences on Fort Hunter Liggett (a training installation of the U.S. Army; 35°54'4.37"N, 121°10'40.33"W), Monterey Co., with an estimated population of ≈ 13,450 plants (USFWS 2000). Primary threats were loss of plants and habitat by military activities, and displacement by invasive grasses. In 2000 after listing, a population estimated at 10,000 plants was discovered on

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Camp Roberts (a training installation of the California Army National Guard; 35°45'35.29"N, 120°50'3.91"W), San Luis Obispo Co. (USFWS 2001), which was estimated in 2001 to comprise > 200,000 plants (California Army National Guard in USFWS 2002). *Chlorogalum p. reductum* was known from three occurrences in the La Panza region in central San Luis Obispo Co. at listing: on Los Padres National Forest (35°24'2.69"N, 120°16'49.01"W), and two nearby private properties. Population estimates ranged from \approx 1,300 to 300,000 plants on \approx 4 ha. Primary threats were illegal vehicle trespass on national forest land, road maintenance, displacement by invasive grasses, and cattle grazing (USFWS 2000). The State of California had previously listed *C. purpureum reductum* as rare under the California Endangered Species Act in 1978 (California Department of Fish and Game 2012b). Our purpose is to review and enhance the existing knowledge of *C. purpureum*, in particular its life history and ecology, distribution, population sizes, threats, current management and conservation status.

Methods

In the literature, the common name purple amole has been used for the species *C. purpureum* and also for the nominate variety. To avoid confusion, hereafter we use purple amole only for *C. p. purpureum*. Throughout this paper, “we” refers to all or any one of the authors. We summarize the knowledge of the species, including current threats and management, and analyze the conservation status in 2012. The expressed views are solely ours and not the official position of any agency.

We managed purple amole on Fort Hunter Liggett (66,773 ha) from 1998 to 2012 and on Camp Roberts (17,314 ha) from 2001 to 2012. At Fort Hunter Liggett, we have maintained a database since 2000 with attributes of the population that we update as new information is obtained by annual monitoring of life history parameters and by additional analyses. We mapped 880 patches from 1997 to 2012, established transects in some patches, mapped and numbered (marked) some individual plants, and estimated the number of plants in most patches: 1 to 10, 11 to 50, 51 to 100, 101 to 200, 201 to 500, 501 to 1,000, 1,001 to 2,000, 2,001 to 5,000 or > 5,000. At Camp Roberts, we censused the population during May to June 2001 by demarcating the occupied area into quadrats (each 25 \times 100 m) and then counting (using a clicker counter) the number of plants in each quadrat, stopping at 5,001 (> 5,000). Our counts are only for plants with above-ground structures, which excludes the bulbous stage. For Camatta Canyon amole, we conducted three site visits (2010, 2011, 2012), communicated with relevant persons and examined soil maps. In addition, we reviewed the literature. We consider a location as a separate occurrence only if it is > 0.4 km from the nearest occurrence (California Department of Fish and Game 2012a).

Review of the Species

The species inhabits a semiarid environment with hot dry summers and cool wet winters. Both varieties grow in gravelly clay soil in open areas with a light cover of native plants in grassland, blue oak savanna (*Quercus douglasii*) and blue oak woodland. Records for purple amole account for 97% (\approx 429 ha) of the known occupied area, and for Camatta Canyon amole 3% (\approx 12 ha, our current estimate). Both varieties sometimes grow in association with cryptogamic crusts (cyanobacteria, lichens, mosses and fungi on the soil surface; E.L. Painter in USFWS 2000, Guretzky et al. 2005, pers. obs.). Cryptogamic crusts are important elements of arid and semiarid ecosystems (Beymer and

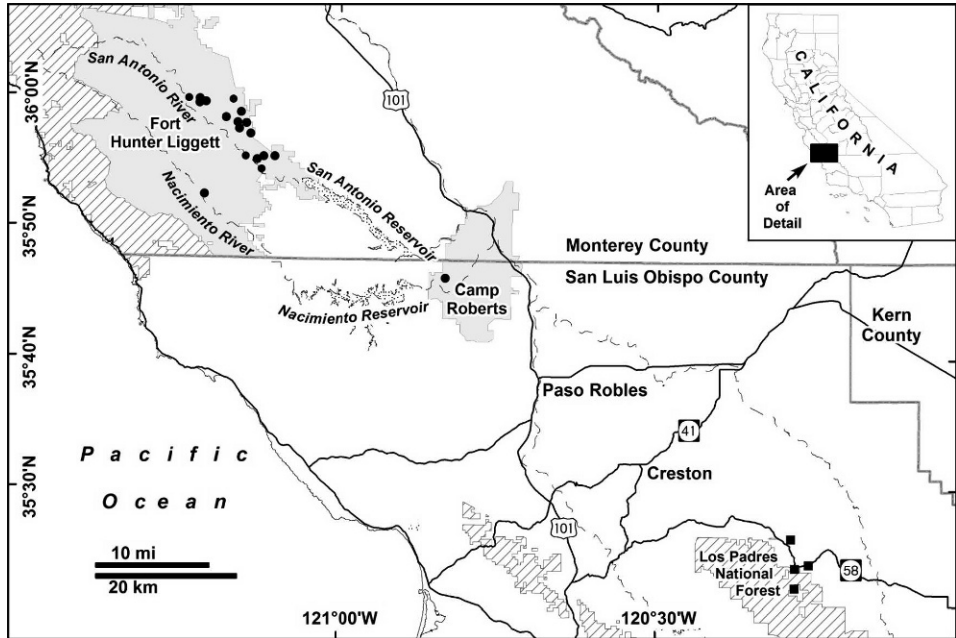


Fig. 1. Distribution of the threatened *Chlorogalum purpureum* (Agavaceae) in central California. Black dots, purple amole *C. p. purpureum*; black squares, Camatta Canyon amole *C. purpureum reductum*.

Klopatek 1992) because they stabilize soil against erosion, fix atmospheric nitrogen, form organic matter (Eldridge and Greene 1994), retain soil moisture, discourage weed growth (Belnap et al. 2001) and provide favorable sites for growth of native plants (e.g., Lesica and Shelly 1992). New *C. purpureum* become established almost entirely by seed (Hoover 1940). Purple amole in a screen house flowered 3 to 4 y after planting as seed, and most died 5 to 7 y after germination (D. Wilken, Santa Barbara Botanic Garden, California, pers. comm.). Camatta Canyon amole planted on site as seed required at least 12 y to flower (Koch and Hillyard 2009). Purple amole emerge above ground Nov. to Dec., with inflorescences developing during early spring, and flower and fruit during May to June. Camatta Canyon amole flower and fruit during Apr. to June. As fruits mature, the leaves wither and inflorescences dry and turn brown. We observed purple amole bulbs entering dormancy during summer, and some marked plants remained dormant for multiple years.

Purple Amole

Purple amole is now known to occur on two properties: 17 occurrences on Fort Hunter Liggett, and one occurrence on Camp Roberts (Figure 1). It is endemic to the Santa Lucia Range in south Monterey Co. and north San Luis Obispo Co., occurring in the rain shadow at lower elevations (213 to 390 m) on the east side. The Coast Ridge rises to 1,000 m west of Fort Hunter Liggett, and Pine Mountain rises to 1,095 m west of Camp Roberts. Mean annual rainfall is 485 mm at Fort Hunter Liggett (Cantonment, primarily Nov. to Apr.; National Park Service 2007) and 285 mm at Camp Roberts (primarily Oct. to May, White et al. 2000). All known occurrences are in the San Antonio and Nacimiento River valleys. Construction of Lake Nacimiento and Lake San Antonio in 1961 and 1965, respectively, may have submerged some occupied areas.

The land comprising Fort Hunter Liggett has been settled and used by EuroAmericans since 1771, which has affected current distribution. Purple amole is nearly absent from areas previously ripped/disked for cultivation, and most abundant in areas not previously ripped/disked including some used for intensive military training since 1941. The taxon occupies ≈ 341 ha on Fort Hunter Liggett, occurring in hundreds of discontinuous patches at mean density up to 11 plants/m² in grassland, blue oak savanna and open areas of blue oak woodland. Using our cumulative data since 1997, we estimate the population comprises 315,000 to 700,000 plants. Records on Fort Hunter Liggett are at 270 to 390 m elevation. Surveys along the east boundary suggest it likely occurs also on adjacent private land (Wilken in USFWS 2002), for which the USFWS (2002, 2003) designated critical habitat (620 ha; an area with essential characteristics).

Purple amole on Fort Hunter Liggett occurs on both deep and thin soils, most of which are loamy and underlain by clay with fine gravel (generally < 0.5 cm diameter) on the surface. Most occupied areas (78%) are level or near-level (slope < 10%), including a few on ridge top terraces (Wilken in USFWS 2001). It generally grows where other vegetation is sparse (Guretzky et al. 2005) and in association with low-growing annual plants, including: natives—rusty popcornflower *Plagiobothrys nothofulvus*, miniature lupine *Lupinus bicolor* and California goldfields *Lasthenia californica*; and invasives—soft brome *Bromus hordeaceus* and stork's bill *Erodium* sp. Purple amole and cryptogamic crusts co-occur in 50% of the survey plots, and density of purple amole is positively correlated ($P < 0.05$) with cryptogamic crusts ($r = 0.271$) and other native plants ($r = 0.199$, Guretzky et al. 2005). Niceswanger (2002) reported Botta's pocket gophers *Thomomys bottae* eating purple amole (stems, leaves, flowers) on Fort Hunter Liggett. We observed Botta's pocket gophers displacing bulbs and causing extensive disturbance to the habitat. Since 2010, feral pigs *Sus scrofa* are also disturbing the habitat.

In 2003, the U.S. Army used a ball and chain to clear chaparral (Kucera and Mayer 1999) at several sites presumably not occupied by purple amole. However, one of these sites (≈ 78 ha) now likely has the highest density on Fort Hunter Liggett. At another site, fire burned a study plot before seed maturation, with apparent loss of all seeds (Niceswanger 2002). The following year, the number of plants at the burned site increased by 175%. These observations suggest purple amole may respond favorably to removal of potentially competitive species (invasives and natives) and to fire at certain times of the year. We are testing the potential of prescribed fire to remove invasive plants and benefit purple amole, with several areas already burned in 2011.

Over 7 y at Fort Hunter Liggett, we observed 26% of monitored plants (range 13 to 63% per y) attempting reproduction (produced stalks, flowers, capsules or seeds), with 12% (range 5 to 26% per y) actually producing seeds. Flowering was correlated with total rainfall in the preceding few months (Guretzky et al. 2005). Numbers of seeds ranged up to 386 per plant (mean = 28, Niceswanger 2002). We observed many marked plants in dormancy as bulbs for 1 to 3 y, and one marked plant remained dormant for 6 y and another 5 y. Guretzky et al. (2005) estimated the dormancy rate as 23% of the population per y and the mortality rate as 10% of the population per y.

Since Federal listing, the U.S. Army has included purple amole in its natural resources management plan at Fort Hunter Liggett and annually monitors life history parameters. In 2005, 2007 and 2010, the U.S. Army consulted with the USFWS regarding its ongoing activities and effects on purple amole. In accordance with biological opinions issued under the U.S. Endangered Species Act, cumulative loss of occupied areas by ground disturbance does not exceed 0.4 ha/y. The U.S. Army terminated cattle grazing on Fort

Hunter Liggett in 1991 because of adverse effects to natural resources, and it is not likely to resume in the occupied areas. Although the population appears stable on Fort Hunter Liggett, we identify invasive plants, Botta's pocket gophers, feral pigs and possibly lack of fire as threats in 2012 (Table 1).

Purple amole on Camp Roberts occupies ≈ 88 ha north of the Nacimiento River on the west side of the installation (213 to 274 m elevation), which is ≈ 31 km from the nearest occurrence on Fort Hunter Liggett. The most-recent census in 2001 recorded $> 250,000$ plants (our refined analysis). In June 2005, a hot wildfire burned $\approx 90\%$ of the occupied area with loss of the seed crop. A dense layer of thatch (10 to 20 cm) had accumulated since cessation of sheep grazing. In 2006, we observed 10.4 plants/m² in survey plots during Mar. and 5.6 plants/m² during May. The decrease likely represented some plants entering dormancy without flowering. Although not tested and anecdotal, plants in the burned area appeared taller and with increased reproductive vigor (more flowers, fruits or seeds) than plants in the non-burned area, which suggests purple amole may respond favorably to fire at certain times of the year.

On Camp Roberts, purple amole occurs predominately in soil with a high concentration of gravel underlain by hard-packed clay, growing across the flat surface of an old alluvial fan primarily on northeast exposures with slope $< 10\%$. The vegetation is predominantly grassland, with blue oak woodland on surrounding slopes. Here purple amole grows where there is sparse plant cover, seldom under oak canopies, and usually among low-growing native grasses (especially small fescue *Vulpia microstachys*) and herbaceous native plants. In particular, yellowflower tarweed *Holocarpha virgata* co-occurred in 95% of survey plots, annual agoseris *Agoseris heterophylla* in 82%, and bigflower agoseris *Agoseris grandiflora* in 79%. Together, yellowflower tarweed and bigflower agoseris comprised 75% of total plant cover in survey plots with purple amole. Invasive plants in the habitat include wild oat *Avena fatua*, soft brome and redstem stork's bill *Erodium cicutarium*. Feral pigs eat the bulbs of purple amole on Camp Roberts and previously caused extensive disturbance to the habitat. This threat has been reduced by controlled hunting elsewhere on the installation.

The California Army National Guard ceased training activities in areas occupied by purple amole in 2000 (except occasional road use), along with sheep grazing and hunting. The agency included the taxon in its natural resources management plan for Camp Roberts and annually monitors life history parameters. The California Army National Guard consults with the USFWS regarding its activities and effects on purple amole. Consequently, limited military activities resumed in occupied areas in 2011. We identify the following threats on Camp Roberts in 2012: invasive plants, feral pigs and possibly lack of fire (Table 1). We are considering several actions that may benefit purple amole, including prescribed fire and controlled sheep grazing to remove invasive plants.

Camatta Canyon Amole

Camatta Canyon amole is now known from four occurrences on four properties (Figure 1), ≈ 61 km southeast of purple amole on Camp Roberts and ≈ 92 km southeast of purple amole on Fort Hunter Liggett. It is endemic to the La Panza Range in central San Luis Obispo Co., occurring in the rain shadow at intermediate elevations (570 to 633 m) on the east side. Black Mountain rises to 1,104 m immediately to the west. Based on data for La Panza Ranch (≈ 10 km eastward and therefore drier), mean annual rainfall at the occupied area is > 156 mm (likely by several cm), along with rain primarily from Oct. to Apr. (<http://www.worldclimate.com> 2011).

Table 1. Status of the threatened *Chlorogalum purpureum* (Agavaceae) at listing in 2000 and since listing to 2012. Invasive plants are now the primary threat. CR denotes Camp Roberts. FHL denotes Fort Hunter Liggett. LPNF denotes Los Padres National Forest. USFWS denotes U.S. Fish and Wildlife Service.

Attribute	Purple amole <i>C. p. purpureum</i>		Camatta Canyon amole <i>C. purpureum reductum</i>	
	At listing in 2000	Since listing to 2012	At listing in 2000	Since listing to 2012
Occupied area (≈ number of ha)	Unknown FHL	429 (341 FHL, 88 CR)	4	12
Mean density (≈ number of plants/m ²)	Not known	11 FHL, 10.4 CR	10.7 (1988)	up to 5.3 (2012)
Population estimate (≈ number of plants)	13,450 FHL	315,000 to 700,000 FHL; > 250,000 CR	1,300 to 300,000	20,000 to 500,000
Number of populations	1 FHL	2 (1 FHL, 1 CR)	1	1
Number of occurrences	3 FHL	18 (17 FHL, 1 CR)	3	4
Threat	At listing in 2000	Since listing to 2012	At listing in 2000	Since listing to 2012
Loss of plants and habitat by military activities	Ongoing FHL	Reduced by consultation with USFWS FHL CR	Ongoing	Ongoing
Invasive plants	Ongoing FHL	Reduced by management FHL, ongoing CR	Not a threat	Suspected
Alteration of fire cycle	Suspected FHL	Reduced by management FHL, suspected CR	Ongoing	Ongoing
Cattle grazing	Potential FHL	Removed FHL	Not a threat	Suspected
Sheep grazing	Not a threat FHL	Removed CR	Not a threat	New LPNF (2010)
Habitat conversion to chaparral	Not a threat FHL	Ongoing FHL	Ongoing LPNF	Removed LPNF
Predation/disturbance by gophers	Not a threat FHL	Ongoing FHL	Ongoing LPNF	Ongoing LPNF
Predation/disturbance by feral pigs		New FHL (2010), reduced by management CR		
Off-highway vehicle recreation				
Road maintenance				

The primary occupied area is on a ridge top ≈ 200 m east of the south end of Camatta Canyon, which is immediately south of the junction of State Highway 58 and Red Hill Road. The population as currently known is mostly on Los Padres National Forest, extending also onto both sides of State Highway 58 in the right-of-way (1.2 m beyond each shoulder), north onto private property (also likely east), and 3.3 km south of State Highway 58 on private property. The right-of-way of State Highway 58 is managed by the California Department of Transportation, which designated the right-of-way as a botanical management area. This agency gives greater environmental review when planning work here (T. Edell, California Department of Transportation, pers. comm.). The private property immediately north of State Highway 58 is a cattle ranch. The private property south of State Highway 58 appears to be a residential property, and it was registered with The Nature Conservancy in a land protection program (California Department of Fish and Game 2007). The extent of the population across the four properties is not precisely known. However, the occupied area was estimated to comprise 3.2 ha on national forest land, 0.1 ha on the private land south of State Highway 58 (USFWS 2000, 2002), and 0.5 ha on the right-of-way of State Highway 58 (California Department of Fish and Game 2007). Records of the California Department of Fish and Game (2007) state the occupied area comprises 51 ha.

Abundance estimates for Camatta Canyon amole on national forest land have ranged from tens of thousands to $\approx 500,000$ plants (California Department of Fish and Game 2007). The private property south of State Highway 58 contained an estimated several hundred plants (A. Koch in USFWS 2002). In the right-of-way of State Highway 58, 213 and 306 plants were observed in 2000 (J. Luchetta in USFWS 2001) and 2005 (T. Edell, California Department of Transportation, pers. comm.), respectively. On the private property north of State Highway 58, we were able to observe Camatta Canyon amole only from the right-of-way in May 2011. We counted ≈ 60 plants from one strategic point, observing predominantly tall grasses in the habitat and an absence of grazing. Mean densities in 10 random plots on national forest land in 1987 and 1988 were 6.5 plants/m² and 10.7 plants/m², respectively (Magney 1988). During May 2011, we observed a general absence of Camatta Canyon amole among taller invasive plants (≈ 30 to 46 cm height) that were especially dense in vicinity of blue oak trees. In contrast, a previous staging area for off-highway vehicles (≈ 929 m²) with relatively few invasive plants contained 3.2 Camatta Canyon amole/m². In addition, we observed Botta's pocket gophers causing extensive disturbance to the habitat in 2011 and 2012, especially where invasive plants were abundant. In May 2012, the mean density of Camatta Canyon amole in the most densely populated part of the occupied habitat (18 quadrats, each 0.5×50 m) was 5.3 plants/m² (L. Simpson, U.S. Forest Service, pers. comm.).

Some authors reported Camatta Canyon amole on serpentine soil (e.g., Hoover 1964), with Safford et al. (2005) reporting it as a strict endemic. We correct and clarify by stating that Camatta Canyon amole on Los Padres National Forest occurs on an alluvial terrace in soil with a red sandy matrix dominated by gravel, all derived from sandstone and shale with no serpentine (D. Chipping, California Polytechnic State University, pers. comm.; Natural Resources Conservation Service 2003). In the vicinity of Red Hill Road, this particular soil type (Arbuckle sandy loam with slope $< 10\%$) comprises ≈ 11 ha on Los Padres National Forest and ≈ 96 ha on private land immediately north of State Highway 58 (<http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>, 2010). Potential exists for the occupied area on private land immediately north to be substantially larger than on

national forest land. The USFWS (2002, 2003) designated critical habitat for Camatta Canyon amole on 1,324 ha of private land immediately north.

On Los Padres National Forest, Camatta Canyon amole grows in open areas predominantly in annual grassland and blue oak savanna, and often co-occurring with cryptogamic crusts. Native plant associates include crown brodiaea *Brodiaea coronaria*, winecup clarkia *Clarkia purpurea*, sand pygmyweed *Crassula erecta*, bluedicks *Dichelostemma capitatum*, sanicle *Sanicula* spp., California goldfields, sky lupine *Lupinus nanus* and gilia *Gilia* sp. (Magney 1988, Service 2002). Along State Highway 58, it typically grows in hard-packed soil and away from dense grasses, either among low-growing plants or in open areas around chamise *Adenostoma fasciculatum* (T. Edell, California Department of Transportation, pers. comm.).

The occupied area on national forest land is in the Pozo-La Panza Unit, which is best known for off-highway vehicle recreation, and it is bisected by a dirt road. In 2010, 2011 and 2012, we observed that the occupied area was effectively protected from off-highway vehicles by fencing, signs and ranger patrols. The adverse effects of road maintenance (in particular grading) appeared to be ongoing, but which we consider a lesser threat. It is also in the Navajo Allotment where a permittee usually grazes cattle from Feb. to May, which overlaps in time with flowering and fruiting of Camatta Canyon amole (Apr. to June). Cattle can cause physical damage by trampling, along with soil compaction and erosion, damage to cryptogamic crusts, reducing presence of native plants and increasing presence of invasives (Fleischner 1994, DiTomaso 2000, Belnap and Eldridge 2001). In 2010, we observed the relatively flat soil surface to be imprinted with hoof depressions where cattle had been when the soil was soft and wet. In 2011 and 2012, the allotment had not been grazed. In each year we observed potential competition with invasive plants (e.g., red brome *Bromus rubens*, slender oat *Avena barbata*, soft brome) and also possibly native chamise, along with buildup of thatch. Germano et al. (2001) previously recommended grazing as a tool for managing invasive grasses and helping to conserve declining native species in California. In consideration of all factors, controlled cattle grazing at the right density and timing may benefit Camatta Canyon amole by reducing the presence of invasive plants and thatch. In summary, we identify the following threats to Camatta Canyon amole in 2012: invasive plants, Botta's pocket gophers, uncontrolled cattle grazing, road maintenance, and possibly lack of fire (Table 1). The USFWS and U.S. Forest Service are discussing management of Camatta Canyon amole on national forest land.

Conservation Status

The USFWS (2008) reviewed the status of the species in 2008 and recommended no change in its listing status of threatened. Although more information is now available, a five-factor analysis using USFWS criteria is beyond the scope of this paper. Nonetheless, using the best available information and international standards (IUCN 2001, 2010), *C. purpureum* in 2011 does not meet IUCN criteria for placement on its red list as critically endangered, endangered or vulnerable: extent of occurrence, 931 km²; area of occupancy, 4.41 km²; quality of the habitat, declining; and number of occurrences, 22. Nor does *C. p. purpureum* meet IUCN criteria for listing: extent of occurrence, 310 km²; area of occupancy, 4.29 km²; quality of the habitat, declining; and number of occurrences, 18. However, *C. purpureum reductum* meets IUCN criteria for placement on its red list as endangered: extent of occurrence, 2.3 km²; area of occupancy, 0.12 km²; quality of the habitat, declining; and number of occurrences, 4. With these attributes, *C. purpureum reductum* faces a very high risk of extinction.

Conclusions

Since Federal listing in 2000, purple amole is now known to occur in substantially greater numbers, occupy a substantially greater area and occur on two properties, which are managed as separate populations: 17 occurrences on Fort Hunter Liggett, and one on Camp Roberts (Table 1). Unknown occupied areas may possibly occur in the San Antonio and Nacimiento river valleys between the two populations, especially in designated critical habitat (USFWS 2002, 2003). Camatta Canyon amole is known from only four occurrences within a small area: mostly on Los Padres National Forest, two private properties, and the right-of-way of State Highway 58 at Red Hill Road. Based on landscape characteristics (Arbuckle sandy loam and slope < 10%), potential exists for a substantially larger occupied area on private land north of State Highway 58, especially in designated critical habitat (USFWS 2002, 2003).

The U.S. Endangered Species Act is the primary Federal law protecting the species, although it has limited ability to protect listed plants on private land. Camatta Canyon amole is also listed under the California Endangered Species Act (California Department of Fish and Game 2007); however, grazing and other agricultural activities on private land are exempt. Invasive plants are now the primary threat to *C. purpureum*. Invasives may be able to displace it by outcompeting and monopolizing limited resources (e.g., space, sunlight, nutrients, water; Stephenson and Calcarone 1999), and by producing thatch, which can prevent growth and recruitment and also alter the natural fire regime (Brooks et al. 2004). In addition, based on our observations on Fort Hunter Liggett and Los Padres National Forest, some native plants (climax chaparral) may be able to displace *C. purpureum*, possibly in the absence of fire.

We are considering several management actions that may benefit purple amole on Fort Hunter Liggett (prescribed fire) and Camp Roberts (prescribed fire, controlled sheep grazing) by removing invasive plants and thatch. Also, the species may respond favorably to fire in ways not yet known. For example, the wavyleaf soap plant *C. pomeridianum* exhibits fire-stimulated flowering and produces seeds only in the first year after fire (Borchert and Tyler 2009). However, caution must be exercised because fire can destroy the flowers and seeds of purple amole and also benefit some invasive plants (Klinger et al. 2006). We encourage controlled cattle grazing on Los Padres National Forest and the relevant private land to remove invasive plants and reduce thatch, so long as consideration is given to stock density, the life cycle of Camatta Canyon amole and soil conditions. The effects of the grazing regime should be thoroughly considered.

Acknowledgements

We acknowledge Dieter Wilken and JoAnn Froland for leading the census at Camp Roberts in 2001. We thank the following for various contributions: Angela Chapman, David Chipping, Douglass Cooper, Kevin Cooper, Nancy Hill Cunha, Thomas Edell, Gary Houston, Tamara Kleeman, Fletcher Linton, Justin Maciulis, Jenness McBride, Gary Montgomery, David Pereksta, Roger Root, Lloyd Simpson and Kirk Waln. Without the assistance of all these persons, this project could not have been accomplished.

Literature Cited

- Belnap, J. and D. Eldridge. 2001. Disturbance and recovery of biological soil crusts. Pp. 363–383 *In*: Biological Soil Crusts: Structure, Function, and Management. (Belnap, J. and O.L. Lange, eds.) Springer-Verlag, Berlin. 503 pp.

- , J.H. Kaltenecker, R. Rosentreter, J. Williams, S. Leonard, and D. Eldridge. 2001. Biological Soil Crusts: Ecology and Management. Technical Reference 1730–2. Bureau of Land Management, Denver. 110 pp.
- Beymer, R.J. and J.M. Klopatek. 1992. Effects of grazing on cryptogamic crusts in pinyon-juniper woodlands in Grand Canyon National Park. *Am. Midl. Nat.*, 127:139–148.
- Bolger, D.J., J.C. Pires, and J. Francisco-Ortega. 2006. Phylogeny of Agavaceae based on *ndhF*, *rbcL*, and its sequences: implications of molecular data for classification. *Aliso*, 22:313–328.
- Borchert, M. and C.M. Tyler. 2009. Patterns of post-fire flowering and fruiting in *Chlorogalum pomeridianum* var. *pomeridianum* (DC.) Kunth in southern California chaparral. *Int. J. Wildland Fire*, 18:623–630.
- Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. *BioScience*, 54: 677–688.
- California Department of Fish and Game. 2007. California Natural Diversity Database. Calif. Dept. Fish Game, Sacramento.
- . 2012a. Special vascular plants, bryophytes, and lichens list. Calif. Dept. Fish Game, Sacramento. 72 pp.
- . 2012b. State and federally listed endangered, threatened, and rare plants of California. Calif. Dept. Fish Game, Sacramento. 16 pp.
- DiTomaso, J.M. 2000. Invasive weeds in rangelands: species, impacts, and management. *Weed Sci*, 48: 255–265.
- Eldridge, D.J. and R.S.B. Greene. 1994. Microbiotic soil crusts: a review of their roles in soil and ecological processes in the rangelands of Australia. *Aust. J. Soil Res.*, 32:389–415.
- Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. *Conserv. Biol.*, 8: 629–644.
- Germano, D.J., G.B. Rathbun, and L.R. Saslaw. 2001. Managing exotic grasses and conserving declining species. *Wildl. Soc. Bull.*, 29:551–559.
- Guretzy, J.A., E.R. Clark, and D. Woodbury. 2005. Life history traits of the threatened purple amole (*Chlorogalum purpureum* var. *purpureum*): Fort Hunter Liggett, California. ERDC/CERL Tech. Rep.–05–32. U.S. Army Corps Eng., Champaign, Illinois. 77 pp.
- Hoover, R.F. 1940. A monograph of the genus *Chlorogalum*. *Madroño*, 5:137–147.
- . 1964. Some noteworthy Californian Liliaceae. *Leaflets West. Bot.*, 10:121–128.
- IUCN. 2001. IUCN Red List Categories and Criteria. Version 3.1. IUCN, Gland, Switzerland. 30 pp.
- . 2010. Guidelines for Using the IUCN Red List Categories and Criteria. Version 8.1 (August 2010). IUCN, Gland, Switzerland. 85 pp.
- Jernstedt, J.A. 2012. *Chlorogalum* soap plant, amole. Pp. 1284–1285 *In: The Jepson Manual: Vascular Plants of California* (2nd ed.). (Baldwin, B.G., D.H. Goldman, D.J. Keil, R. Patterson, T.J. Rosatti, and D.H. Wilken, eds.) Univ. Calif. Press, Berkeley. 1,600 pp.
- Klinger, R.C., M.L. Brooks, and J.M. Randall. 2006. Fire and invasive plant species. Chapter 22, Pp. 499–519 *In: Fire in California's Ecosystems*. (Sugihara, N.G., J.W. Van Wagtenonk, K.E. Shaffer, J. Fites-Kaufman, and A.E. Thode, eds.) Univ. Calif. Press, Berkeley. 612 pp.
- Koch, A. and D. Hillyard. 2009. Camatta Canyon amole (*Chlorogalum purpureum* var. *reductum*) experimental restoration. P. 86 *In: Abstracts for Oral and Poster Presentations: CNPS 2009 Conservation Conference—Strategies and Solutions*. Calif. Native Plant Soc., Sacramento. 197 pp.
- Kucera, T.E. and K.E. Mayer. 1999. A Sportsman's Guide to Improving Deer Habitat in California. Calif. Dept. Fish Game, Sacramento. 95 pp.
- Lesica, P. and J.S. Shelly. 1992. Effects of cryptogamic soil crust on the population dynamics of *Arabis fecunda* (Brassicaceae). *Am. Midl. Nat.*, 128:53–60.
- Magney, D. 1988. Results of second year population dynamics of the state-listed rare Camatta amole (*Chlorogalum purpureum* var. *reductum*). Report to Los Padres National Forest, Goleta, Calif. 23 pp.
- National Park Service. 2007. Final Fort Hunter Liggett Special Resource Study. *Natl. Park Ser.*, Oakland, Calif. 188 pp.
- Natural Resources Conservation Service. 2003. Soil Survey of San Luis Obispo County, California, Carrizo Plain Area. *Nat. Resour. Conserv. Ser.*, Sacramento, Calif. 608 pp.
- Niceswanger, J. 2002. Purple amole (*Chlorogalum purpureum* var. *purpureum*) monitoring report: results summarized for monitoring 1998, 1999 and 2000. Report to Fort Hunter Liggett, Monterey County, Calif. 28 pp.

- Safford, H.D., J.H. Viers, and S.P. Harrison. 2005. Serpentine endemism in the California flora: a database of serpentine affinity. *Madroño*, 52:222–257.
- Stephenson, J.R. and G.M. Calcarone. 1999. Potentially vulnerable species: plants. Chapter 5, Pp. 223–316. *In* Southern California Mountains and Foothills Assessment: Habitat and Species Conservation Issues. USDA For. Ser. Pac. Southwest Res. Stn., Albany, Calif. 402 pp.
- U.S. Fish and Wildlife Service [USFWS]. 2000. Endangered and threatened wildlife and plants; determination of threatened status for *Chlorogalum purpureum* (purple amole), a plant from the south coast ranges of California. *Fed. Register*, 65:14878–14888.
- . 2001. Endangered and threatened wildlife and plants; proposed designation of critical habitat for *Chlorogalum purpureum*, a plant from the south coast ranges of California. *Fed. Register*, 66: 56508–56531.
- . 2002. Endangered and threatened wildlife and plants; final designation of critical habitat for *Chlorogalum purpureum*, a plant from the south coast ranges of California. *Fed. Register*, 67: 65414–65445.
- . 2003. Endangered and threatened wildlife and plants; final designation of critical habitat for *Chlorogalum purpureum*, a plant from the south coast ranges of California; correction. *Fed. Register*, 68:20083 pp.
- . 2008. Purple amole (*Chlorogalum purpureum*) five-year review: summary and evaluation. U.S. Fish Wildl. Ser., Ventura, Calif. 31 pp.
- White, P.J., W.H. Berry, J.J. Eliason, and M.T. Hanson. 2000. Catastrophic decrease in an isolated population of kit foxes. *Southwest. Nat.*, 45:204–211.