A CONSERVATION PLAN FOR AGAVE SHAWII SUBSP. SHAWII (SHAW’S AGAVE, AGAVACEAE)

SULA E. VANDERPLANK
RANCHO SANTA ANA BOTANIC GARDEN
OCCASIONAL PUBLICATIONS

NUMBER 14

A CONSERVATION PLAN FOR AGAVE SHAWII
SUBSP. SHAWII (SHAW’S AGAVE, AGAVACEAE)

SULA E. VANDERPLANK

This publication was printed with support from the California Native Plant Society (CNPS). Founded in 1965, CNPS is a science-based non-profit organization dedicated to increasing understanding and appreciation of California’s native plants, and to conserving them and their natural habitats. Learn more at http://CNPS.org.

Current address for Sula Vanderplank: Botanical Research Institute of Texas, 1700 University Dr., Fort Worth, TX 76107-3400; and Terra Peninsular, A.C. Calle 1era y Castillo No. 1090-5, Ensenada, Baja California 22880, Mexico
# TABLE OF CONTENTS

LIST OF FIGURES .................................................................................................................... vi
LIST OF TABLES ....................................................................................................................... vi

1.0 EXECUTIVE SUMMARY .................................................................................................... 1
2.0 SCOPE AND PURPOSE ..................................................................................................... 1
3.0 METHODS .......................................................................................................................... 1

4.0 BACKGROUND ................................................................................................................. 1
4.1 Taxonomic Description ..................................................................................................... 1
4.2 Taxonomic History ........................................................................................................... 2

5.0 BIOLOGY, ECOLOGY, HABITAT, AND HUMAN USES .................................................... 4
5.1 Biology and Ecology ......................................................................................................... 4
5.2 Habitat ............................................................................................................................ 6
5.3 Human Uses .................................................................................................................... 6

6.0 DISTRIBUTION, ABUNDANCE, AND POPULATION TRENDS ........................................... 7
6.1 Distribution and Abundance ............................................................................................ 7
6.2 Population Trends ........................................................................................................... 8
6.3 Threats and Limiting Factors .......................................................................................... 10
6.4 Threats with Regard to Listing Requirements ............................................................... 10
6.5 Conservation Status ....................................................................................................... 14

7.0 CONSERVATION ............................................................................................................ 14
7.1 Conservation Objectives ................................................................................................ 14
7.2 Conservation Criteria ..................................................................................................... 14
7.3 General Conservation Actions ....................................................................................... 15
7.4 Site-Specific Actions ....................................................................................................... 16
7.5 Conservation Tasks ....................................................................................................... 18
7.6 Out-Of-State Considerations ......................................................................................... 18
7.7 List of Likely Participants in Conservation Efforts ............................................................ 19

8.0 IMPLEMENTATION ....................................................................................................... 19
8.1 Action Assessment ......................................................................................................... 19
8.2 Federal Listings .............................................................................................................. 19
8.3 Other Actions ................................................................................................................. 19
8.4 Implementation Schedule .............................................................................................. 19
8.5 Potential Difficulties in Implementation ....................................................................... 19

ACKNOWLEDGMENTS ......................................................................................................... 20
REFERENCES CITED .......................................................................................................... 20
LIST OF FIGURES

Fig. 1. Inflorescence of *Agave shawii* subsp. *shawii* ................................................................. 3
Fig. 2. Variations in the habit of *Agave shawii* subsp. *shawii* ......................................................... 4
Fig. 3. Habitat of *Agave shawii* subsp. *shawii* ................................................................................. 5
Fig. 4. CNDDDB occurrences of *Agave shawii* subsp. *shawii* in San Diego County ......................... 8
Fig. 5. Distribution of “the shawii complex,” adapted from Gentry (1978) ............................................. 9
Fig. 6. Stereocard of *Agave shawii* subsp. *shawii* from the San Diego History Center ...................... 9
Fig. 7. Predation of *Agave shawii* subsp. *shawii* seeds ................................................................. 11
Fig. 8. Threats to *Agave shawii* subsp. *shawii* ................................................................................. 12
Fig. 9. Lichty Mesa before, during, and after clearance for the construction of the international triple border fence ......................................................................................................................... 16
Fig. 10. Rosettes sorted by size at RECON Native Plants, Inc., San Diego .............................................. 17

LIST OF TABLES

Table 1. Summary of known element occurrences (EOs) of *Agave shawii* subsp. *shawii* from CNDDB RareFind Database (CNDDB 2014) ........................................................................................................ 7
Table 2. Summary of potential threats for *Agave shawii* subsp. *shawii* in the USA ....................... 10
Table 3. Summary of recommended conservation tasks and proposed implementation schedule ....... 18
A Conservation Plan for *Agave shawii* subsp. *shawii* (Shaw’s Agave, Agavaceae), by Sula E. Vanderplank
© 2014, Rancho Santa Ana Botanic Garden

### 1.0 EXECUTIVE SUMMARY

*Agave shawii* Engel. subsp. *shawii* (Shaw’s agave) is a large perennial plant in Agavaceae. Its native range in the United States is now restricted to a single wholly natural occurrence in San Diego County, California, which was recently reduced to just one genetic individual during construction of the new border fence. A second occurrence of partially native origin is found on the Naval Base Point Loma. The taxon is considered seriously endangered in California by the California Native Plant Society (CNPS); it has a global rank between G2 and G3, and a State Rank of S1.2, meaning that there are fewer than six occurrences or fewer than 1000 individuals, or that there are less than 3000 acres of occupied habitat in the state of California. However, *A. shawii* subsp. *shawii* is not listed as threatened or endangered by the U.S. Fish and Wildlife Service at this time.

*Agave shawii* subsp. *shawii* inhabits maritime coastal scrub from San Diego County, California, USA, south to approximately the 30th parallel in coastal Baja California, Mexico (near El Rosario). Plants may take decades to flower. Flowering occurs between February and May in California (as early as November in Baja California), and the rosette dies thereafter. Although capable of reproducing by suckering, occurrences vary considerably in this respect, with some consisting entirely of individual unbranched rosettes whereas others are of plants that form clumps or colonies of clones.

There are six occurrences of *A. shawii* subsp. *shawii* in San Diego County, four of which are wholly transplanted. The two at least partially native occurrences are found within 25 km (15 miles) of the USA/Mexico border. Nearest occurrences in Baja California, Mexico, are not fully documented but appear to be at least 25 kilometers to the south. Sexual reproduction and seedling recruitment are low throughout its range. Recommendations for conserving this taxon include: development of a long-term, bi-national conservation plan (and consideration of listing as an endangered species in both nations); implementing a monitoring program with standardized protocols; maintaining an ex situ conservation seed collection; engaging in research into the causes of limited seed set and low seedling recruitment in the context of reproductive and population dynamics; a laboratory study on genetic variation among all occurrences in California and throughout its range in Baja California; an assessment of the genetic distance between subsp. *shawii* and *goldmaniana* to the south, including a survey of zones of potential inter-subspecific hybridization; and assessing occurrences in northern Baja California for long-term conservation.

### 2.0 SCOPE AND PURPOSE

*Agave shawii* subsp. *shawii* was selected as the focus of a conservation plan due to its restricted range in the United States and concern for its future in the United States and Mexico. Discussion and recommendations in this plan emphasize occurrences in the United States, as well as some of those in Baja California, Mexico. The purpose of this conservation plan is to compile and review available information about *A. shawii* subsp. *shawii* in a single document that will be useful to land managers, conservation organizations, state and federal agencies, researchers, consultants, plant enthusiasts, and groups that have historically utilized this taxon. This document should also serve to determine current conservation needs and to identify areas where more information is necessary to effectively protect this taxon and its genetic diversity to ensure its long-term survival.

### 3.0 METHODS

Historical locality data were extracted from the California Natural Diversity Database [CNDDB], and field surveys were undertaken in 2008 to locate these populations and update the CNDDB. Rosettes and individuals (clumps) were counted at each site. Phenological status, floral visitors, associated species, habitat, and potential threats were recorded at each locality, and CNDDB records were updated following field surveys. Herbarium data from the Consortium of California Herbaria [CCH] 2012 were also considered and pertinent specimens examined. Several Mexican populations were also visited to identify the Mexican population closest to the border and the population furthest south, as well as to examine prime habitat in the center of the range. Population-level DNA samples were taken from the populations at Border Fields State Park and Naval Base Point Loma for future research. Herbarium specimens were deposited at Rancho Santa Ana Botanic Garden (RSA).

### 4.0 BACKGROUND

#### 4.1 Taxonomic Description

The description presented below is drawn from the author’s personal observations as well as data from Gentry (1978), Reveal (2012), Reveal and Hodgson (2002), and Trelease (1911).

*Agave shawii* subsp. *shawii* is a rosette-forming, perennial monocot in the family Agavaceae. Rosettes are short-trunked, budding and branching from the rootstocks, and individuals may consist of single rosettes or several connected rosettes. The trunks are erect to decumbent, rosettes 0.8–20 dm wide × 10–25 dm tall.
The leaves are generally broad, ascending, 20–50 cm long × 8–20 cm wide; blades are glossy, light to dark green, narrowly ovate, thick, fleshy, and rigid (Fig. 1). Individual leaves often have their adaxial surface slightly hollowed (at least toward the apex) and are abaxially convex; leaf margins are armed with a row of single spines that are often colorful and well defined, mostly 5–6 mm (rarely >20 mm) long, 1–2+ cm apart. The distinct apical spine is dark reddish brown to gray, acicular, 2–4 cm long. The flowering scape reaches 2–4 m in height. Inflorescences are paniculate and the peduncle is stout; bracts are persistent, lanceolate to triangular, 10–25 cm long, and succulent. There are 8–14 horizontal to ascending lateral inflorescence branches along the distal ¼–½ of the inflorescence, each longer than 10 cm, oval in cross-section. Each inflorescence branch holds 35–75 sessile flowers in tight erect clusters (Fig. 1). Floral buds are usually red-purple in color and open from the base of the inflorescence. Each flower is 6–10 cm long, with a yellow perianth turning reddish (especially upon withering), and the tube is erect, yellow, and broadly funnelform, 12–19 × 15–22 mm; the lobes are erect, unequal, 17–40 mm long, the outer tepal longest. The stamens are 4.3–7 cm long and attached near the middle of the perianth tube; anthers are yellow, 20–35 mm long. The ovary is inferior, 30–50 mm long, 6–15 mm across. The fruits are short-pedicellate, obovoid to oblong capsules, 5.5–7 cm long, apically short- to long-beaked. The seeds are flat, black at maturity, 4–7 mm long. The chromosome number is 2n = 60 (Lenz 1959). Diagnostic characters for this taxon in its native range include rosette size, leaf size and color, large red spines along the leaf margins, usually clumping habit, and presence of large bracts on the inflorescence scape.

4.2 Taxonomic History

Taxonomic classification of genus Agave has long presented special difficulties. There is considerable morphological variation within taxa and a paucity of herbarium specimens of adequate quality available for study. In addition, a number of named Agave species in cultivation are of unknown origin and may be artificially selected variants of original wild species. Agave has been popular in Europe ever since plants were brought back from the Americas by the Spanish and Portuguese in the 17th century. During the 19th century collectors imported many forms, and some have been continuously propagated since. Many cultivated taxa cannot be linked to any species known in the wild, although this may simply be due to differences in growing conditions. Agaves have also been cultivated for centuries by Native Americans for fiber, food, and drink. Five extant species that were cultivated by pre-Columbian people occur in Arizona alone (Hodgson 1995, 2001, 2002). Taxonomic confusion is reflected in discrepancies between recent taxonomic treatments. The estimated number of species has been given as 200 (Reveal 2012; Reveal and Hodgson 2002) or 166 (Good-Avila et al. 2006). The Agave treatment in Flora of North America (Reveal and Hodgson 2002) recognizes 27 species occurring in the flora of North America, north of Mexico. Reveal and Hodgson (2002) identify the taxon at varietal rank as Agave shawii var. shawii, a treatment also followed in a checklist of plants of San Diego County (Rebman and Simpson 2006).

Genus Agave is naturally distributed throughout the warmer regions of the world and is divided into two subgenera: Agave and Littaea. Gentry (1978), in his work on the agaves of Baja California, recognized four alliances in Agave, equivalent to sections but not ranked as such: Deserticolae, Campanilflorae, Datyliones, and Umbelliflorae. Alliance Umbelliflorae is also known as “the shawii complex” and consists of desert-restricted species that require a Mediterranean climate of winter-spring rain and dry summers. Gentry (1978) included three taxa in the shawii complex: A. shawii subsp. shawii (syn. A. orcuttiana Trel., A. pachyacantha Trel.); A. shawii subsp. goldmaniana (Trel.) Gentry (syn. A. goldmaniana Trel.); and A. sebastianiana Greene (syn. A. shawii subsp. sebastianiana (Greene) Gentry, A. disjuncta Trel.). Agave shawii subsp. shawii is the only representative of the Umbelliflorae alliance (the shawii complex) in the USA.

Agave orcuttiana and A. pachyacantha were first described by Trelease (1911) among 21 other species from "Lower California." The two Agave species cannot be readily distinguished using Trelease’s key, and both were described as having the "aspect of A. shawii." Gentry (1978) recognized 16 Agave taxa in Baja California, including three species, eight subspecies, and one variety new to science. He synonymized many taxa and treated A. orcuttiana and A. pachyacantha as synonyms of A. shawii subsp. shawii. Castetter et al. (1938) were the first to suggest that A. orcuttiana and A. shawii subsp. shawii are not distinct (contra Trelease).

Agave shawii was described by Engelmann (1875). Gentry (1978) recognized A. goldmaniana as A. shawii subsp. goldmaniana, thus creating the autonym A. shawii subsp. shawii. Gentry (1978, 1982) recognized subsp. goldmaniana as a subspecies of A. shawii, rather than a separate species because of a small range overlap with subsp. shawii at the northern end of its range (near El Rosario, Baja California, Mexico) where plants of both taxa show some plasticity in appearance, making them difficult to distinguish in areas of sympathy.
Fig. 1. Inflorescence of Agave shawii subsp. shawii: (A) whole inflorescence, (B) flowers, (C) single rosette from above, (D) lateral view of single rosette and bud, and (E) inflorescence stalk and bud.
Both the *Jepson Flora Project* (Reveal 2012) and *Flora of North America* (Reveal and Hodgson 2002) recognize five infraspecific taxa for California: two varieties each for *A. utahensis* and *A. deserti*, and *A. shawii* var. *shawii* as the only taxon of *A. shawii*. Three taxa are included in the *California Native Plant Society Inventory* (CNPS 2010): *A. shawii* (Shaw’s agave), *A. utahensis* var. *eborispina* (Hester) Breitung (ivory-spined agave), and *A. utahensis* var. *nevadensis* Greenm. & Roush (Clark Mountain agave). *Agave shawii* is treated at the species level by CNPS and listed as rare in California but more common elsewhere (CNPS list 2.1). It is important to note that since subsp. *shawii* is the only subordinate taxon of *A. shawii* in the USA, a great deal of the literature references the species without specifying a subspecies or variety, and it cannot be assumed that authors are always referring strictly to the typical subspecies. This Conservation Plan follows the subspecific taxonomy of Gentry, which has been adopted in the regional *Checklist of the Vascular Plants of San Diego County* (Rebman and Simpson 2006). Two agave taxa occur in San Diego County: *A. deserti* subsp. *deserti* and *A. shawii* subsp. *shawii*. *Agave shawii* is distinct from *A. deserti* in having green ovate leaves, rather than gray lanceolate leaves, and in having large (versus small) bracts on the peduncle.

5.0 **Biology, Ecology, Habitat, and Human Uses**

5.1 **Biology and Ecology**

Occurrences of *A. shawii* subsp. *shawii* differ considerably in plant growth form, with some consisting entirely of single rosettes (Fig. 2C), whereas in others, individuals form clumps of multiple rosettes (Fig. 2B).

![Fig. 2. Variations in the habit of *Agave shawii* subsp. *shawii*, including (A) budding from the roots, (B) clumping, (C) individual rosettes, and (D) horizontal growth.](image)
Agave shawii subsp. shawii does well in cultivation and is easily propagated clonally, with many rosettes surviving transplanting at reintroduction sites (MSCP 2006). Plants of Agave shawii subsp. shawii (Fig. 3A,B), like other Agave taxa, have monocarpic rosettes that flower just once and then die. A published letter from Dr. Reid Moran questioned the time to flowering in A. shawii subsp. shawii, and suggested that it takes much longer than commonly supposed, citing one plant that grew from seed and flowered in the wild after 31 years (Roof 1971b). Gentry (1978) suggested an average time to flowering of 20–40 years. The flowering season of A. shawii subsp. shawii in the USA is reported to be winter to late spring (Reveal and Hodgson 2002). Herbarium specimens with flowers cite collection months of December through April (CCH 2010). However, flowering of plants in Baja California and in cultivation at Rancho Santa Ana Botanic Garden, Claremont, California, has been observed as early as November and as late as June (Sula Vanderplank, pers. obs. 2008, 2010–2012).

The flowers of A. shawii subsp. shawii are large and open widely, in contrast to those of sympatric Agave taxa. They show many characteristics associated with chiropterophily (bat pollination), including large tubular to bowl-shaped flowers held upright and away from the stem in tight clusters, and abundant pollen and nectar production. Long, thick filaments bear large anthers that produce abundant pollen. The pollen-to-ovule ratio in this taxon is particularly high in comparison to other agaves, averaging 1327 pollen grains per ovule, which indicates likely outcrossing (Hogue 1981). Nectar and sugar production averaged 819.5 µl/day and 85 µg/day per flower, respectively (Hogue 1981). In contrast to the
strong signal of chiropterophily, about 2/3 of nectar production was diurnal, with peak production between 2 and 6 p.m., and dropping off rapidly after 6 p.m., suggesting that the flowers are attracting diurnal pollinators. Hogue (1981) suggested that A. shawii subsp. shawii may be shifting from ancestral chiropterophily toward pollination by bees or other diurnal pollinators due to selection pressures. Large bees and hummingbirds have been suggested as pollinators of A. shawii subsp. shawii and are often seen visiting flowers (Phil Rouillard, pers. comm. 2007); empirical data that these visitors are pollinators are lacking. Documenting pollination biology would be valuable to future conservation efforts, given concern for the low production of viable seed in this taxon: Previous studies in related species have indicated that some flowers are self-incompatible whereas others are not (Hogue 1981). If successful outcrossing is achieved, fruits developing from the self-compatible flowers may abort (Wendy Hodgson, pers. comm. 2010). It is not known whether A. shawii subsp. shawii shares these traits. Inflorescence stalks and fruits are persistent, and seeds are shaken from the tall dry inflorescences by wind and other forces. Often a few seeds remain inside the capsule until the inflorescence falls (Sula Vanderplank, pers. obs. 2009). The percentage of viable seed within a capsule is often very low: a few hundred seeds from several thousand ovules is not unusual; recent collections have averaged 13% viable seed (Michael Wall, pers. comm. 2007). Seed germination requirements and rates in nature are not known; however, A. shawii subsp. shawii is frequently grown from seed in cultivation without the need for any special treatment. Seed germination trials under standardized conditions at Rancho Santa Ana Botanic Garden have shown 100% germination rates without any special treatment.

5.2 Habitat

Agave shawii subsp. shawii has a restricted distribution, occurring only in a vegetation type known as maritime succulent scrub that is found in Baja California, Mexico, and southern San Diego County, California, USA. This vegetation type has been recognized under similar names, including succulent coastal scrub, maritime cactus scrub, matorral costero rosetófilo (rosettophilous coastal scrub), Diegan sage scrub, and Baja California scrub. Maritime succulent scrub is a diverse and globally rare habitat type occurring on coastal terraces and foothills; it is the most xeric of the coastal sage vegetation types recognized by Axelrod (1978). Maritime succulent scrub has the greatest species diversity and endemism of any of the coastal and inland scrub communities, which is thought to be related to the low fire frequency (Barbour et al. 2007). The vegetation series that supports A. shawii subsp. shawii has been termed Coast prickly-pear series (Sawyer et al. 2009).

Maritime succulent scrub vegetation extends only a few kilometers into the USA in southern San Diego County, occurring in narrow vegetation bands on seaside bluffs where dominant plants are often dwarfed by almost constant exposure to coastal winds with high salt content (Anteon 2006). Agave shawii subsp. shawii is one of the distinctive and conspicuous species that characterize this vegetation type. Cacti and other succulents are abundant, including Bergerocactus emoryi (Engelm.) Britt. & Rose (golden-spined cereus), Cylindropuntia prolifera (Engelm.) F.M.Knuth (cholla), Dudleya Britt. & Rose spp. (live forever), Opuntia Mill. spp. (cholla and prickly pear), and Stenocereus gumnosus (Engelm.) A.C.Gibson & K.E.Horak (pitaya cactus). Commonly occurring shrubs include Aesculus parryi A.Gray (Parry’s buckeye), Artemisia californica Less. (California sagebrush), Cylindropuntia californica (Torr. & A.Gray) F.M.Knuth var. californica (snake cholla), Encelia californica Nutt. (coast sunflower), Euphorbia misera Benth. (cliff spurge), Lycium californicum Nutt. (boothorn), Rhus integrifolia (Nutt.) Benth. & Hook.f. ex Brewer & S.Watson (lemonade berry), Rosa minutifolia Engelm. (the small-leaved rose), and Simmondsia chinensis (Link) C.K.Schneid. (jojoba) (Gentry 1978; USFWS 2003; Anteon 2006).

Mean annual rainfall in A. shawii subsp. shawii habitat in California is 423 mm, with rains falling mostly between October and April. Mean annual maximum and minimum temperatures are 68°F and 55°F, respectively (NOAA 2007).

5.3 Human Uses

Various agaves have a long history of use by native peoples of the USA and Mexico (Gentry 1982; Hodgson 2001). Agaves concentrate liquid carbohydrates and fiber in their tissues and, as a result, have been an important food and fiber source for humans since prehistoric times (Dobyns 1988; Bye 1993). The main food sources are the meristem and leaf bases, which are often baked in pits (Gentry 1982). Agave shawii subsp. shawii is not among the taxa most frequently used in this way (Gentry 1982), but there are detailed historical accounts of A. shawii being baked for food in Baja California (Gentry 1978). Agave shawii was historically used in trials as a crop for fiber production (Gentry 1978). Plants of this taxon are easily propagated, and it was recently listed among the top ten agaves, yuccas, and cacti recommended for native landscaping (Ingram 2008). It is, however, somewhat cold sensitive, with damage starting at 23°F and becoming extensive at 18°F (Turner et al. 1995).
6.0 DISTRIBUTION, ABUNDANCE, AND POPULATION TRENDS

6.1 Distribution and Abundance

*Agave shawii* subsp. *shawii* is considered to be extremely scarce in San Diego County, with particular risk from altered fire frequency (MSCP 2006). Six element occurrences are documented in the California Department of Fish and Game’s California Natural Diversity Database (CNDDDB 2014; the CNDDDB identifies locations of target taxa as element occurrences or EOs) and in Table 1. All EOs were visited by the author or otherwise surveyed for plants as part of this study (2008–2009). Based upon findings, all CNDDDB records have been updated. A population at Cabrillo National Monument reported as part of this study was added to EO5.

As described below, four of the six EOs are composed entirely of transplants and a third partially so. The source of the out-planted individuals is generally not known, and transplants in EO2 and EO3 may have been made a considerable time ago date (CNDDDB 2014).

EO1: The population on Lichty Mesa at Border Field State Park is the only occurrence known to have been made up entirely of indigenous plants. Plants were abundant there until construction of the border fence in 2008 almost completely extirpated them. A single clump of rosettes (one genetic individual) occurs there now. RECON Native Plants nursery has some salvaged rosettes from this site that are to be transplanted back onto this EO.

EO2: This occurrence has the most individuals at present. Some individuals are thought to be native. Others are known to have been transplanted in 1991–1992 to a location near Woodward Road (Vince Scheidt, pers. comm. 2009); yet others may have been transplanted over 100 years ago (CNDDDB 2014). The occurrence is within the historic native range of *Agave shawii* subsp. *shawii*. Included within EO2 is former EO4 (extirpated) that fell within 0.25 miles of EO2 and is therefore not considered a separate occurrence. EO4 was located near the property of Nazarene University at Point Loma. Students of Point Nazarene University surveyed the area in spring of 2008 but observed rosettes only in cultivation nearby (Sunamita Sanabria, pers comm. 2008). Staff at Naval Base Point Loma surveyed that area again without finding any individuals of natural origin (Kimberley O’Connor, pers. comm. 2008). If plants reoccur in this area they should be considered for planting within EO2, to which they are almost immediately adjacent (<0.3 km distant).

### Table 1. Summary of known element occurrences (EOs) of *Agave shawii* subsp. *shawii* from CNDDDB RareFind Database (CNDDDB 2014).

<table>
<thead>
<tr>
<th>EO</th>
<th>Location</th>
<th>Management authority</th>
<th>Elev. (ft)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E of border monument #258, E of Border Field Naval Reservation (Lichty Mesa)</td>
<td>Department of Homeland Security-Border Field State Park</td>
<td>40</td>
<td>32.53551</td>
<td>-117.11853</td>
<td>Native, recently almost extirpated on USA side of border. One individual remains</td>
</tr>
<tr>
<td>2</td>
<td>Point Loma Peninsula (NW end): Fleet Combat Training Center, West of Woodward Road; includes former EO4 in area south of Nazarene University campus</td>
<td>Department of Defense-Fleet Combat Training Center</td>
<td>60</td>
<td>32.71004</td>
<td>-117.25548</td>
<td>Partially transplanted; populations self-sustaining</td>
</tr>
<tr>
<td>3</td>
<td>Torrey Pines State Reserve, on Guy Fleming Trail, San Diego</td>
<td>Torrey Pines State Reserve</td>
<td>240</td>
<td>32.92357</td>
<td>-117.25868</td>
<td>Transplanted</td>
</tr>
<tr>
<td>4</td>
<td>Point Loma Peninsula (S end): 5 polygons around Cabrillo National Monument and Old Point Loma Lighthouse</td>
<td>Department of Defense–Naval Ocean Systems Center; National Parks Service</td>
<td>200</td>
<td>32.67109</td>
<td>-117.24090</td>
<td>Transplanted</td>
</tr>
<tr>
<td>5</td>
<td>Point Loma Peninsula: ca. 0.9 air miles N of the Old Lighthouse, E side of Cabrillo Memorial Drive</td>
<td>Department of Defense-Navy</td>
<td>300</td>
<td>32.67735</td>
<td>-117.24332</td>
<td>Transplanted</td>
</tr>
<tr>
<td>6</td>
<td>Point Loma Peninsula: E side of Gatchell Road</td>
<td>Department of Defense-Navy</td>
<td>175</td>
<td>32.68388</td>
<td>-117.24794</td>
<td>Transplanted</td>
</tr>
</tbody>
</table>

*EO4 (extirpated) is included in EO2 as it falls within 0.25 miles of EO2.
EO3: Shaw’s agave has been introduced at Torrey Pines State Reserve (CNDDB 2014), although it is not known exactly when this took place. The occurrence at Torrey Pines State Reserve represents a 25 km (15 mile) range extension beyond EO2 at Naval Base Point Loma. It is possible that the taxon occurred farther north historically.

EO5: Located just south of Cabrillo National Monument Visitor Center and Old Point Loma Lighthouse, this occurrence is the farthest south on the peninsula. It has been mapped by CNDDB (2014) as five polygons, four tracing to a survey in 2000 and the fifth to a 2008 survey by the author (middle polygon, just south of the Old Lighthouse). In 1976 plants from within Naval Base Point Loma (EO2) were introduced at Cabrillo National Monument (Beauchamp 1976): nine plants were planted on the bay side, two at the Visitor Center, and the remainder on the west side.

EO6: This occurrence is located ca. 0.9 air miles north of Old Point Loma Lighthouse on the east side of Cabrillo Memorial Drive.

EO7: This occurrence is located ca. 0.45 air miles southwest of Bennington Monument (Fort Rosecrans National Cemetery) just east of Gatchell Road.

There is also a historical account of A. shawii from San Bernardino County, with a specimen at the Jepson Herbarium collected by Samuel B. Parish in 1895 (CCH 2010); however, the identification of this specimen cannot be confirmed as it is sterile and the plant may have been introduced.

Plants of A. shawii subsp. shawii in the USA occupy a combined area of less than five square kilometers (two square miles). All five occurrences fall within a range of 50 linear kilometers (30 miles) along the Pacific coast (Fig. 4).

The only occurrence harboring indigenous plants was reduced to a single plant at this writing. The remaining occurrences are understood to consist wholly of transplants. Agave shawii subsp. shawii has been reportedly planted also at the San Diego National Wildlife Refuge headquarters in Imperial Beach (Reiser 1994) and is widely planted horticulturally. Plants of this taxon also occur in northern Baja California (Mexico), from the international border with the USA to ca. 275 kilometers (170 miles) south at the southern tip of the California Floristic Province near El Rosario. Rapid expansion of industry and agriculture along the northwestern coast of Baja California means that population sizes and numbers are in considerable decline there. The entire range of this taxon lies along 325 kilometers (200 miles) of coastline.

Fig. 4. CNDDB occurrences of Agave shawii subsp. shawii in San Diego County; squares = populations with at least some specimens of native origin, pentagons = wholly transplanted populations.

6.2 Population Trends

The available data on population trends in this taxon are limited, and are difficult to obtain, given the longevity of monocarpic rosettes and the fact that the only sizable occurrence in the USA is located on Naval Base Point Loma where access is restricted. Long-term monitoring will be necessary to accurately assess reproductive and population trends at each occurrence; however, the overall population trend for this taxon is towards decreasing numbers, both within the USA and in Mexico. There are still some large occurrences in Mexico, but the taxon’s range is being rapidly diminished. Gentry (1978) indicated that A. shawii was more abundant at the beginning of the twentieth century than in the 1970s when he studied them. Unrestricted collecting and habitat alteration have apparently reduced both occurrences and numbers of plants significantly in intervening years (Reveal and Hodgson 2002).

Recruitment from seeds is critical as an indicator of population viability (MSCP 2006). Seedling recruitment in California is visibly low, and viable seed production on both sides of the border appears to have been very low in recent years (Sula Vanderplank, pers. obs. 2009), which may impact both recruitment and genetic diversity. The only occurrence in the USA that is visibly
reproducing from seed is one of transplanted origin (EO5: middle polygon; Sula Vanderplank, pers. obs. 2009; CNDDDB 2014). “Budding” or clonal reproduction appears to be more frequent in California occurrences than in Baja California (Sula Vanderplank, pers. obs. 2008). Historical data are mostly lacking regarding the former extent of occurrences in southern California. At one time *Agave shawii* was considered extirpated in California, but Roof (1971a) retracted his earlier statement that “*A. shawii* was no longer found in the wild in California” and cited two then-extant locations: (1) Naval Base Point Loma and (2) the type locality on the USA/Mexico border near the Initial Boundary Monument (Lichy Mesa) where he indicated that only a few individuals remained. In 1978, Gentry included a map that indicated three occurrences in San Diego County (see Fig. 5). The two southern occurrences are those cited by Roof (1971a); the northernmost might refer to the Torrey Pines State Reserve occurrence. The occurrences on Point Loma were certainly more extensive in the past: an image (Fig. 6) on a stereocard housed in the San Diego History Center Archives and probably taken in the late 19th century clearly shows several rosettes of *A. shawii* subsp. *shawii* growing in an area that appears to be where Catalina Boulevard

Fig. 5. Distribution of “the shawii complex,” adapted from Gentry (1978).

Fig. 6. Stereocard of *Agave shawii* subsp. *shawii* from the San Diego History Center (http://www.sandiegohistory.org/collections/stereocards/images/agave.jpg). Exact date unknown, but probably taken in the late 1800s; believed to be northern Point Loma Peninsula where Catalina Boulevard and Narragansett Avenue intersect today (John Martin, pers. comm. 2008).
intersects Narragansett Avenue at present (John Martin, USFWS, pers. comm. 2008). There is currently no native vegetation at this site. The introduction of plants at Cabrillo National Monument (Beauchamp 1976) may have increased the numbers of individuals in the USA considerably as EO5 covers the largest area (3 acres) of any EO in the USA.

6.3 Threats and Limiting Factors

The major threat to *Agave shawii* subsp. *shawii* globally is physical loss of plants and habitat through human interference (CNDDB 2014; Jon Rebman 2007, pers. comm.). The fact that there are few individuals in the USA means that very few individuals flower in any given year, which in turn limits the potential for outcrossing and production of viable seed. Lack of successful sexual reproduction is a considerable concern on both sides of the border. Collecting has historically been a problem; however, occurrences in San Diego County seem to have been less threatened by this in recent years (MSCP 2006).

6.4 Threats with Regard to Listing Requirements

The threats to *Agave shawii* subsp. *shawii* are classified and assessed here according to the five factors identified in section 4(a)(1) of the Endangered Species Act for consideration in listing, delisting, and reclassification decisions.

---

### Table 2. Summary of potential threats for *Agave shawii* subsp. *shawii* in the USA.

<table>
<thead>
<tr>
<th>EO#</th>
<th>Locality</th>
<th>Nativity</th>
<th>Size estimates</th>
<th>Potential threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO1</td>
<td>Border Field State Park</td>
<td>Native</td>
<td>1 individual, ca. 50 rosettes</td>
<td>Careless planting of rescued rosettes, plant and habitat loss, genetic isolation, low recruitment, disturbance</td>
</tr>
<tr>
<td>EO2</td>
<td>Point Loma Peninsula (northwest side): Fleet Combat Training Center</td>
<td>Partially planted</td>
<td>ca. 60 individuals, ca. 1500 rosettes</td>
<td>Stability of ocean bluffs, low recruitment, genetic dilution of natives by introduced plants of unknown origin, trampling, crowding</td>
</tr>
<tr>
<td>EO3</td>
<td>Torrey Pines State Reserve</td>
<td>Planted; some transplants may be old</td>
<td>4–5 individuals, ca. 100 rosettes in 2008</td>
<td>Limited seed production, genetic isolation</td>
</tr>
<tr>
<td>EO5</td>
<td>Point Loma Peninsula (southernmost occurrence)</td>
<td>Planted; 28 transplants came from EO2 (Beauchamp 1976)</td>
<td>ca. 30 individuals, ca. 100 rosettes in 2008 in eastern polygon</td>
<td>Habitat loss and disturbance, trampling</td>
</tr>
<tr>
<td>EO6</td>
<td>Point Loma Peninsula</td>
<td>Planted</td>
<td>Fewer than 20 rosettes</td>
<td>Habitat loss and disturbance, trampling</td>
</tr>
<tr>
<td>EO7</td>
<td>Point Loma Peninsula</td>
<td>Planted</td>
<td>3 clumps of ca. 11 rosettes</td>
<td>Habitat loss and disturbance, trampling</td>
</tr>
</tbody>
</table>

---

1. The present or threatened destruction, modification, or curtailment of its habitat or range (Factor A)

The native range of *Agave shawii* subsp. *shawii* in the USA (San Diego County, California) includes only one occurrence of entirely natural origin that is highly threatened by habitat loss and disturbance: the occurrence at Lichty Mesa (EO1) on land acquired by the Department of Homeland Security was reduced to a single individual in August of 2008 when the area was cleared for the construction of the new international triple border fence. There are efforts underway to reintroduce a number of the salvaged rosettes inside the adjacent property of Border Field State Park, but it is likely that only 10% of rosettes will be returned to the area with the rest being sold for cultivation (Ryan West, pers. comm. 2009). A portion of the occurrence at Point Loma (EO2) is considered native and includes close to 1500 rosettes; these plants occur on a steep coastal bluff and may be threatened by erosion that might cause the rosettes to plummet into the sea (CNDDB 2014). All occurrences are threatened by habitat disturbance, and encroachment by non-native species is a significant problem at Naval Base Point Loma (EO2).

Non-native plant species may be negatively impacting recruitment by *Agave* seedlings (Jon Rebman, pers. comm. 2007). This may be due to the impact of non-native species on the local environment or direct competition for resources.
Fig. 7. Predation of *Agave shawii* subsp. *shawii* seeds. (A) Seeds in capsule: note that most seeds are white (non-viable) and very few are black (viable); (B) seed predation by caterpillars; (C) pseudoscorpions found inside capsules. Images taken in Baja California.
Fig. 8. Threats to *Agave shawii* subsp. *shawii*: (A) rosettes crowded by native vegetation (lemonade berry [*Rhus integrifolia]*) at Naval Base Point Loma; (B) results of inflorescence harvesting in Baja California (Mexico); (C) fire survival in northern Baja California—a large number of rosettes continuing to grow; (D) bare inflorescence after flower harvesting; (E) slash and burn agriculture on Colonet Mesa, Baja California.
2. Over-utilization for commercial, scientific, or educational purposes (Factor B)

Historically, collecting of plants of this taxon has been a problem (Gentry 1978; Reveal and Hodgson 2002; MSCP 2006). Collecting probably still occurs in light of its ease of propagation, ornamental properties, and other uses, but it is doubtful whether collecting of rosettes is a real cause of decline in population numbers today. However, in Baja California flowering panicles of both subspecies of *A. shawii* are cut and trucked to cattle (Gentry 1982) for fodder on a large scale, which is likely to be negatively impacting reproduction via seeds (Sula Vanderplank, pers. obs. 2008–2012). Given the monocarpic nature of the rosettes, use of the inflorescences in this way signifies death without reproduction of the rosette thus impacted.

3. Disease or predation (Factor C)

Aborted axillary inflorescences have been observed; causes are unknown but should be further investigated to assess whether its origin is genetic or environmentally induced and to what degree it threatens reproduction. Livestock and wildlife are known to eat emerging flower stalks, and rodents occasionally eat the rosettes. Seed and seedling predation may be a factor affecting seedling recruitment (Jon Rebman, pers. comm. 2007; Sula Vanderplank, pers. obs. 2008–2012). Capsules examined at Arroyo Hondo (near the southern end of the range of *A. shawii* subsp. *shawii*) were heavily preyed by caterpillars, which were in turn preyed on by pseudoscorpions living inside the fruit capsules (Fig. 7).

4. Inadequacy of existing regulatory mechanisms (Factor D)

*A. shawii* subsp. *shawii* does not have any regulatory protection at the state or national level in the US or Mexico. The taxon does not currently have federal listing under the Endangered Species Act nor is it state listed.

5. Other natural or man-made factors affecting its continued existence (Factor E)

In the USA this taxon occurs on the edge of its range where it is limited by a lack of suitable habitat and ongoing human impact. Of six occurrences, four (EO3, EO5, EO6, EO7) are wholly introduced and a fourth (EO2) is at least partially introduced (CNDDDB 2014). Occurrences in San Diego County may have reduced reproductive vigor and a limited gene pool, perhaps as a result of being near the edge of their range. However the genotypes present at these EO's may also be significant for the conservation of this subspecies. A single environmental disturbance could easily destroy a large proportion of remaining individuals, as occurred during construction of the border fence on Lichty Mesa (EO1). The fate of the individuals salvaged from Lichty Mesa merits careful consideration in light of the ethics of assisted migrations (introducing new plant populations), habitat disturbance, and genetic conservation.

The unknown origin of the plants now at Torrey Pines State Reserve and of the introduced rosettes at Naval Base Point Loma is a cause of concern from a genetic standpoint. To conserve the genotypes native to the USA, it is critical to know if neighboring occurrences are natural or introduced. Similarly, re-introduction efforts need to take into account distance to other occurrences, particularly if they are not native. The genetic identity of individuals from the native USA occurrence needs to be assessed and all genotypes conserved.

It is my assessment that the greatest threat to *A. shawii* subsp. *shawii* in the USA is a low rate of recruitment of new individuals. Open ground is a likely necessity for seedling recruitment. The only area where seedling recruitment was observed within the USA was in disturbed open areas at Cabrillo National Monument where it seems to be naturally occurring (Andrea Compton, pers. comm. 2008). At Naval Base Point Loma, dense undergrowth crowds young rosettes (Fig. 8A) and may be affecting seedling recruitment. Torrey Pines State Reserve also offers open ground in places, but seedling recruitment was not observed; however, there are few individuals present and none were reproductive in 2008 (Sula Vanderplank, pers. obs.).

Low rates of seedling establishment may also stem from low seed set which has been observed throughout the range of *A. shawii* subsp. *shawii* in recent years (Sula Vanderplank, pers. obs. 2007–2009: plants were examined at occurrences in California and in Rosarito, San Quintin, Arroyo Hondo, and El Rosario, Baja California; Fig. 8). In contrast, plants of the conspecific taxon *A. shawii* subsp. *goldmaniana* had high percentages (ca. 90%) of viable seed set at two occurrences visited in 2009 (Sula Vanderplank, pers. obs.).

It is important to note that effective population size for this taxon is much lower than the number of extant individuals owing to the very long lag-time to flowering and because rosettes are monocarpic. The fact that few individuals in the USA are reproductive in any given year is likely the primary cause of low seed set and a paucity of recruitment by seedlings. Moreover, non-synchronous flowering is especially problematic if plants are self-incompatible (the compatibility system is unknown for these plants). The distances between occurrences are considerable in the northern portion of the range and may well be impacting cross-pollination, especially given the loss of nectarivorous bats from coastal southern California and northern Baja California. In 2008, only one individual was observed flowering outside cultivation in the USA (Sula Vanderplank, pers. obs.). This single individual (at Naval Base Point Loma)
had fruits with an average of 2–3 fertile seeds per capsule (Sula Vanderplank, pers. obs. 2008). Further, if most pollen transfer is within a clone, as was likely the case here, then inbreeding depression is expected to result in low seed set (Barrett 2002) and in seeds and seedlings of low fitness. Reduced genetic diversity may threaten the long-term survival of this taxon. The ease of propagation and relatively large numbers of plants already in cultivation means that these plants may play a role in outcrossing and in conservation of the taxon. More generally, the longevity of individual plants of this taxon may be obscuring population trends, and it is essential to monitor for recruitment of new plants.

Other threats include natural events/catastrophes (e.g., landslide, fire) (Beauchamp 1976; MSCP 2006). Fire is often cited as a serious concern for this taxon (MSCP 2006; CNDBB 2014); however, plants of *A. shawii* subsp. *shawii* often survive fire and resprout, especially larger rosettes (John Rebman, pers. comm. 2007; Sula Vanderplank, pers. obs.; Fig. 8C), and fire may be of limited concern in occurrences of many individuals. However, fire suppression regimes may result in hotter and longer-burning fires than were natural in this habitat, ultimately causing higher mortality (Turner et al. 1995).

### 6.5 Conservation Status

*Agave shawii* subsp. *shawii* is not listed by either the state or federal governments and does not have any regulatory protection at the state or federal level. *Agave shawii* is currently listed by the California Native Plant Society as 2.1: Rare, Threatened or Endangered in California, but more common elsewhere (in this case in Baja California, Mexico); Seriously Endangered in California (CNPS 2010; because *A. shawii* subsp. *shawii* is the only subspecies to occur in the USA, it is referred to at the species level by CNPS). *Agave shawii* has a Global Rank between G2 and G3, meaning that it has between 6–80 known element occurrences or 1000–10,000 individuals or is known from 2000–50,000 acres. *Agave shawii* subsp. *shawii* has a state rank of S1.2: S1 meaning fewer than six element occurrences or fewer than 1000 individuals or occurs on less than 2000 acres; the suffix of .2 indicates that it is threatened in the state of California.

### 7.0 Conservation

#### 7.1 Conservation Objectives

The primary objectives for conserving *A. shawii* subsp. *shawii* in the USA are as follows:

1. To maintain all existing occurrences, with priority given to natural occurrences
2. To preserve existing suitable habitat with attention to habitat quality, especially with regard to invasive species
3. To limit and minimize impacts from disturbance and development
4. To assess genetic diversity in the USA of plants in natural occurrences to establish the origin of transplanted individuals and potentially verify the origin of the different sub-occurrences at Naval Base Point Loma. Results should be used to assess appropriate locations for transplanting individuals to augment known populations or to introduce plants to new sites with reference to genetic diversity. This taxon benefits from being easy to cultivate, but the ethics and genetic impacts of transplanting individuals into new areas must be assessed
5. To establish ex-situ maternal line seed collection(s) to be housed in a long-term seed storage facility. These collections are to ensure survival of the taxon and to be used for future research and recovery efforts (given low seed set, this may require hand-pollinations)
6. To investigate factors affecting reproductive output and recruitment success:
   - Conduct a pollination study to investigate self-pollination between cloned rosettes
   - Identify pollinators
   - Assess seed production based on pollination type, and quantify seed predation
   - Assess seedling recruitment
   - Determine why this is only observed at Cabrillo National Monument in the USA
   - Investigate the causes of axillary inflorescence production and their subsequent abortion as observed at Naval Base Point Loma and Cabrillo National Monument
   - Assess the threat of disrupted gene-flow caused by construction of the new border fence
7. To identify specific research and monitoring needs at each occurrence in the USA. Monitor and update information on each occurrence regularly and report with more detail on occurrences along the border region and throughout the range of this taxon.

#### 7.2 Conservation Criteria

The criteria for successful conservation of *A. shawii* subsp. *shawii* in the USA are as follows:

**Criterion 1:** Every three years occurrences are revisited and monitored. There should be no decline in occurrence size (number of individuals) and extent, nor in obvious health or fitness of plants.

**Criterion 2:** Invasive and native plants are managed to allow seedling recruitment by *A. shawii* subsp. *shawii*, especially in years of good rainfall when seed set is
more likely and invasive plant species are more abundant.

Criterion 3: Occurrences are not impacted by new disturbance or development. Existing occurrences are protected at the state level and, ideally, listed under the Federal Endangered Species Act.

Criterion 4: A genetic study has been undertaken to assess genetic variability within and among USA occurrences, as well as for occurrences from northern and southern Baja California. This will help identify appropriate genotypes for reintroduction stock. The incidence and impact of hybridization between Agave taxa should be assessed.

Criterion 5: A seed bank accession has been deposited, consisting of many maternal lines from plants of natural origin; this should include seeds of plants at the edges of the species’ range which may be of genotypes that are important to preserve. The receiving facility must ensure long-term storage for out-planting, viability trials, and other curatorial best practices.

Criterion 6: A field study must be established to evaluate recruitment and population dynamics within the USA and for comparison to large occurrences in northern Baja California. Factors affecting successful pollination, seed-set, and germination should be investigated.

Criterion 7: Adjacent occurrences in northern Baja California should be assessed for future protection and conservation to ensure the long-term survival of this taxon. A cross-border initiative should be established to develop a long-term recovery plan and assess the need for assisted cross-pollination (e.g., via pollinator corridors or hand transfer of pollen) between the international occurrences.

7.3 General Conservation Actions

Landowners within the USA are largely state and federal agencies that offer some protection, except at Lichty Mesa where plants occur on land owned by the Department of Homeland Security. Land managers should be contacted regarding the occurrences they manage and should be encouraged to take an active role in conservation actions. The long-term viability of documented occurrences has not been established, and CENDB records should be updated every 3–5 years. Seed viability tests and germination trials should be conducted to assess reproductive potential. The lack of information on seed predation, pollinators, seed dispersal, and population trends indicates a need for monitoring.

Listing under state statutes and/or the federal Endangered Species Act should be considered. Long-term survival of this taxon will likely rely heavily on conservation of Mexican occurrences, and preserving genetic diversity among the USA occurrences will benefit from preserving northern stands of this taxon in Baja California, perhaps even as patches within the most heavily developed areas. As such, a more comprehensive conservation plan for this taxon should be developed as part of a bi-national partnership with Mexico. Pollination studies may help in assessing proximity requirements for gene flow.

Recommendations for habitat preservation: avoid large-scale disturbance, in particular to occurrences and individual rosettes. Control invasive species to permit seedling establishment and avoid hot fire. Reduce biomass of native plants if they are crowding existing occurrences. Identify areas of potential habitat for future efforts in the conservation of this taxon.

Recommendations for field monitoring: due to the visual prominence of this plant, it is feasible to walk around the occurrences to record perimeters with a sub-meter accuracy GPS unit in order to create polygons for GIS use. Attributes documented for each occurrence should include number of plants (individuals and rosettes), plant size, number of individuals and rosettes flowering, number of flowers and fruits per scape, number of seeds/fruit, number of aborted inflorescences, potential causes of abortion, habitat, slope, aspect, vegetation type, associated species, percent cover of natives and non-natives, and density of ground cover. When seedling recruitment appears to be occurring, micro-habitat should be recorded. Local disturbances, including animal activity, should be noted. If pollinators are observed, they should be collected and sent to an expert for identification or photographed.

Recommendations for study of genetic variation and nativity of USA populations: sample (5 mm × 5 mm surface leaf material) from up to 32 individuals for each USA occurrence and occurrences in adjacent regions of northern Baja California for DNA extraction; a more southerly occurrence should also be sampled for comparison. Tissues have already been sampled from two of the USA occurrences, Lichty Mesa (EO1) and Naval Base Point Loma (EO2). Agave-specific primers for microsatellite loci are available (Navarro-Quezada et al. 2003) and should be used to assess genetic variation and the nativity of USA occurrences. These data may reveal sources of planted individuals at Naval Base Point Loma (EO2) and Torrey Pines State Reserve (EO3), will inform efforts to transplant, reintroduce and actively conserve this taxon, and will give biological context to the occurrences we see today. Before transplanting rosettes, a habitat assessment should be conducted, and relevant examples of transplantation experience from adjacent areas should be reviewed to inform the process.

Recommendations for seed banking: seeds should be collected from each occurrence in May–June to establish a conservation seed bank collection. Population size permitting, seed should be collected from more than 50 maternal lines without impacting more than 10% of
plants every ten years, in accordance with standards set out in Guerrant et al. (2004). In smaller occurrences all individuals should be sampled. Because of the life history of this plant, it is likely that this will be a multi-year effort.

Recommendations for study of reproductive biology: a pollination study should include diurnal observations and nocturnal imagery, the latter specifically focused on bat visitation to assess the possibility of pollinator loss from developed coastal regions. Hand pollinations should be conducted to determine whether plants are self-compatible, whether cloned rosettes from the same parent plant are inter-fertile, and whether lack of pollen delivery is the main factor limiting seed set. Pollinations should include flowers at different positions along the inflorescence (i.e., distal, mid, proximal). Reproductive biology of the conspecific taxon *A. shawii* subsp. *goldmaniana* should be assessed and compared, particularly in the hybrid zone, to ascertain whether seed set is a direct function of pollinator effectiveness or differing pollen compatibilities. Seed production, seed predation, and seedling recruitment should be evaluated at each of the USA occurrences, in northern Mexico, and also on the edge of its range near El Rosario farther south on the Baja California peninsula.

7.4 Site-Specific Actions

EO1 Border Field State Park (previously 13 individuals totaling some 1000 rosettes, currently one individual, ca. 50 rosettes). Because this is the only occurrence in the USA known to be wholly native, its preservation has highest priority; all actions taken should be conducted with extreme caution as these plants may be genetically unique, perhaps representing a genotype adapted to the northern margin of the taxon’s natural range. Most of this occurrence is on land managed by the USA Customs and Border Patrol (CBP), Department of Homeland Security. Most of the 13 individual clumps, totaling more than 1,000 rosettes that were documented in 2008 were removed by staff of the RECON Native Plants nursery, San Diego, and the adjacent Border Field State Park as part of a salvage operation during construction of the new border fence in August 2008. Only one clump of rosettes remained within the jurisdiction of the adjacent Border Field State Park. Figure 9 shows images of the occurrence (a) prior to vegetation clearing, (b) after vegetation clearing, and (c) after complete grading. It is hoped that some of these rosettes will be reintroduced on the adjacent park property in the near future. Figure 10 shows plants sorted by size at RECON Native Plants. It is likely that 10% of the rosettes will be replanted on adjacent property close to the original occurrence. (Note that it was not possible to keep track of parental origin or genotype during the rescue process.) Great care should be taken if moving individuals over a greater distance because proximity to other plants of *A. shawii* subsp. *shawii* (both in the USA and Mexico) may have major implications for pollination, cross-fertilization, and seed-set.

EO2 (ca. 1500 rosettes, 50+ individuals, with two sub-occurrences, one of which is thought to have been
transplanted). This occurrence is along the Point Loma peninsula within the Naval Base Point Loma. Some of the plants at the occurrence are known to have been transplanted here, and others are likely indigenous. Genetic data should be gathered to determine the origin of the transplants and assess genetic diversity of the putatively indigenous plants. New rosettes should not be introduced in this area until the genetic identity of existing rosettes has been documented. The plants inside the naval base are subject to direct impact from trespassing, and measures should be taken to protect them there. Measures should also be implemented to ensure protection of individuals on eroding coastal bluffs or to salvage these as necessary. This site is home to the largest occurrence in the USA and would be ideal for life history studies, given the numerous plants and natural origin of at least the larger patch. No seedling recruitment has been observed here and reducing the thick cover of perennial plants (e.g., *Rhus integrifolia*) might create open space for germination. Several non-native species are very abundant on land adjacent to this occurrence, primarily where disturbance has occurred. Care should be taken to ensure that these species do not invade the *A. shawii* subsp. *shawii* occurrence.

EO3 (65 rosettes, 4–5 individuals). This occurrence lies within Torrey Pines State Reserve. It is thought to be wholly introduced and may represent a mix of planted and naturalized individuals. This site should be maintained; a study to assess whether any of the plants are native would guide future efforts for this occurrence. No additional plants should be introduced to this area until the origin of existing rosettes has been investigated and conservation measures assessed. Data regarding pollinators and modes of recruitment (i.e., vegetative vs. seedlings) would be useful to aid in conservation planning.

EO5 (ca. 100 rosettes, 30 individuals). Vicinity of Cabrillo National Monument Several patches of rosettes occur within Cabrillo National Monument and are thus federally protected. However, they are all documented to have been transplanted to this area from a cliff-side occurrence at EO2 within Point Loma Naval Base (Beauchamp 1976). This occurrence would benefit from a study of reproductive biology as it is the only one in the USA that appears to have active seedling recruitment. Trespassing by the public should be prevented, and habitat quality should be maintained.

EO6 (<20 rosettes). Located on E side of Cabrillo Memorial Drive, at entrance to Cabrillo National Monument on the property of the Department of Defense (Navy). A 1993 report mentioned that the plants were planted along the City of San Diego’s sludge line. Nothing is noted on the number of rosettes seen at that time.
EO7 (three clumps of ca. 11 rosettes). Located on the E side of Gatchell Road ca. 0.45 air miles SW of Bennington Monument on Department of Defense (Navy) land.

7.5 Conservation Tasks

A summary of recommended conservation tasks and a proposed implementation schedule are provided in Table 3.

7.6 Out-Of-State Considerations

Many more plants of *A. shawii* subsp. *shawii* occur in the neighboring state of Baja California, Mexico, than in the USA. The range of the taxon in Baja California covers approximately 275 kilometers (170 miles) on a north-south gradient along the Pacific coast. South of the international border, natural occurrences are first seen in Rosarito (Sula Vanderplank, pers. obs. 2008), about 20 km from the occurrence at Lichty Mesa (EO1) just north of the border and 40 km from the occurrences on Point Loma Peninsula (EO2, EO5–EO7). The southernmost individuals of *A. shawii* subsp. *shawii* that can be easily distinguished from those of *A. shawii* subsp. *goldmaniana* are found just south of San Quintín, Mexico; farther south, near El Rosario, it becomes difficult to distinguish the two subspecies (Gentry 1978). *Agave shawii* subsp. *shawii* is increasingly seen in cultivation in Baja California, including some rosettes planted in central dividers along the freeway.

The long-term viability of this taxon can only be achieved through cross-border collaborations with Mexico to preserve some large occurrences of this taxon. The rapid rate at which plant numbers and habitat are declining in Baja California is also a cause for concern, especially when considering the genetic diversity of this taxon. Once highly abundant in the California Floristic Province in Baja California, *A. shawii* subsp. *shawii* is certainly in decline (Sula Vanderplank, pers. obs 2007–2012). The boom in coastal development in Baja California that continues to expand from Ensenada south to El Rosario (Dedina 2007) is threatening this subspecies since it favors coastal lands that are generally considered prime real estate. The Baja California Rare Plant Working Group (unpublished) produced a shortlist of 81 plants that are becoming rare north of 28° latitude in Baja California and for which habitat should be protected; *A. shawii* subsp. *shawii* is on this list. The *Rare, Endangered, and Endemic Plants of the California Floristic Province Portion of Baja California, Mexico* (O'Brien et al., in press) lists *A. shawii* subsp. *shawii* as a watch-list taxon with a note that its habitat is rapidly diminishing. In this context, it is vital that large natural occurrences throughout the range of this taxon in Mexico be identified as soon as possible and their habitat conserved to ensure a broad base of genetic diversity for the future survival of this taxon. The population on the mesa near Colonet seems to be the largest natural stand of this taxon.

The research questions and proposed seed-banking in California should also be considered in Mexico, and data from Mexico should be included for comparison with any studies conducted in the USA. Contraction of the range of this taxon in Mexico will have genetic

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Priority</th>
<th>Timeframe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor and map</td>
<td>Update CNDDB records; monitor reintroduction effort at Lichty Mesa</td>
<td>High</td>
<td>Ongoing every 3–5 years; Lichty Mesa every 6 months for first 3 years</td>
</tr>
<tr>
<td>occurrences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat conservation</td>
<td>Avoid disturbance, reduce crowding, control competition from other plant species, provide open ground for seed germination, suppress fire</td>
<td>Medium</td>
<td>Assess every 2 years and take action as needed</td>
</tr>
<tr>
<td>Genetic study</td>
<td>Assess origin of EO2 and EO3, and variation between subspecific taxa</td>
<td>Medium</td>
<td>2014–2017</td>
</tr>
<tr>
<td>Ex-situ conservation</td>
<td>Generate a conservation seed bank collection from natural occurrences in the USA and Baja California</td>
<td>High</td>
<td>2014–2019</td>
</tr>
<tr>
<td>Life history</td>
<td>Investigate breeding systems, pollinators, seed production and predation, and seedling recruitment</td>
<td>High</td>
<td>2014–2019</td>
</tr>
<tr>
<td>assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey occurrences</td>
<td>Assess occurrences in Baja California for life history assessment and genetic study, as potential sites for long-term conservation of genotypes, and potential hybrid zones</td>
<td>Low</td>
<td>2014–2016</td>
</tr>
<tr>
<td>in northern Baja</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>California, Mexico</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bi-national</td>
<td>Cross-border conservation plan should be developed for this taxon to ensure its long-term survival</td>
<td>Medium</td>
<td>2014–2019</td>
</tr>
<tr>
<td>conservation plan</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
consequences, and it is likely that the USA and northernmost Baja California occurrences will become too distant to experience gene flow via cross pollination. Although little is known about the pollinators of this taxon, even bats do not usually fly more than 50 km round-trip (see Rabe et al. 1998) such that occurrences that are more than 25 kilometers apart are likely to be genetically isolated. Habitat fragmentation is therefore a serious concern.

Understanding the genetic basis of the two subspecies in Baja California would greatly inform conservation efforts. The transition zone between the two taxa should be investigated for seed-set in hybrid populations (if those do indeed exist). The southern subspecies (A. shawii subsp. goldmaniana) appears to have much higher rates of seed set and seedling recruitment, at least on the northern edge of its range (Sula Vanderplank, pers. obs. 2008 and 2009). A genetic study to understand the relationship between the three taxa in the ‘shawii’ alliance (A. shawii subsp. shawii, A. shawii subsp. goldmaniana, and A. sebastiana) would enhance our understanding of genetic distinctiveness of these taxa and whether the current taxonomy should be followed or revision is warranted.

7.7 List of Likely Participants in Conservation Efforts

Potential partners in the USA:
- California Native Plant Society (San Diego County Chapter and Baja California Chapters in particular)
- The Jiji Foundation
- California Department of Parks and Recreation: Border Field State Park and Torrey Pines State Reserve
- Environmental Operations and Planning Department, Naval Facilities Engineering Command, Southwest (Point Loma Naval Reserve)
- National Parks System: Cabrillo National Monument
- Rancho Santa Ana Botanic Garden
- RECON Native Plants, Inc.
- Huntington Botanical Gardens

Potential partners in Mexico:
- Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)
- Comité de Planeación para el Desarrollo del Municipio de Ensenada (COMPLADEM)
- Flora de Baja California A.S. Native Plant Nursery
- Jardín Botánico Todos Santos A.C.
- La Secretaría de Protección al Ambiente, Baja California (SPA)
- Nativ@5 A.C.
- Pronatura A.C.
- Sociedad de Plantas Nativas de Baja California A.C.
- Terra Peninsular A.C.
- The Jiji Foundation, Baja California Program
- Universidad Autónoma de Baja California (UABC)

8.0 IMPLEMENTATION

8.1 Action Assessment

Agave shawii subsp. shawii is of highly restricted distribution in the United States and declining abundance and range in Baja California, Mexico. Occurrences on both sides of the border are becoming increasingly disjunct due to development that is rapidly extending south along the coastal areas that this taxon occupies. The preservation of occurrences on both sides of the border is important to the conservation of this taxon.

8.2 Federal Listings

Agave shawii subsp. shawii may warrant listing under California statutes and/or the Federal Endangered Species Act. Petitioning should be considered as part of a bi-national conservation plan for this taxon, both in the USA and Mexico.

8.3 Other Actions

This taxon does not currently have any ongoing monitoring or adaptive management prescriptions, although it is included in San Diego County Multiple Species Habitat Conservation Plan.

8.4 Implementation Schedule

A suggested schedule of implementation is outlined in Table 3 (above).

8.5 Potential Difficulties in Implementation

The recent removal of almost the entire occurrence at Lichty Mesa has severely affected preservation of the plants there; reintroduction of the rescued plants onto the adjacent property of Border Field State Park may prove challenging and must be undertaken with extreme care.

Funding is needed to support a biological and genetic study of A. shawii subsp. shawii to produce data that will inform all conservation actions. Funding to update California Natural Diversity Database records for USA occurrences and to assist with the printing costs for
this plan was graciously provided by the Jiji Foundation and the California Native Plant Society, San Diego Chapter. However, additional funds are needed for establishment and long-term maintenance of seed-bank accessions, assessment of the genetic diversity of occurrences inside the United States, and studies of pollination biology and seed recruitment, as well as ongoing monitoring.

Difficulties in monitoring, site visitation, and sample collection may be encountered with regard to access and permit restrictions, especially on Point Loma peninsula ( Cabrillo National Monument and Naval Base Point Loma).

Establishing a seed bank collection that preserves adequate genetic diversity while following seed collection guidelines will depend on good weather conditions and reproductive success.

Maintaining genotypes and habitat/pollinator corridors may necessitate the purchase or lease of lands that support A. shawii subsp. shawii occurrences south of the U.S./Mexico border in Baja California.

ACKNOWLEDGMENTS

The Jiji Foundation and the San Diego Chapter of California Native Plant Society kindly provided funding for the publication and dissemination of this plan and for visiting the occurrences to update CNDDB records. The assistance of Wendy Hodgson, Lucinda McDade, Gary Wallace, Naomi Fraga, Elizabeth Friar, and Steve Boyd is greatly appreciated and has significantly improved this manuscript. The ongoing support and feedback of the Rare Plant Conservation Plans class was also appreciated.

I extend sincere thanks to Vince Scheidt, Todd Masilko, Cindy Burrascano, Kimberley O’Connor, Andrea Compton, Phil Rouillard, Jon Rebman, Sunamita Sanabria and Dianne Anderson for information on this taxon. For assistance with field work I am grateful to Dylan Hannon, Nina Hapner, Lisa Gover, Sergio Mata, Gonzalo Rodriguez, Jorge Ochoa and, in particular, Carrie Kiel and Linda Prince.

REFERENCES CITED

ANTEON. 2006. Expanded Site Inspection, Installation, Restoration site 4, Fleet Industrial Supply Center (FISC) Point Loma Naval Complex, San Diego, California. Department of the Navy.


NUMBER 14

Agave shawii subsp. shawii


