



**RANCHO SANTA ANA BOTANIC GARDEN  
OCCASIONAL PUBLICATIONS**

**NUMBER 12**

**A CONSERVATION PLAN FOR *FRANKENIA PALMERI*  
(PALMER'S FRANKENIA) (FRANKENIACEAE)**

CARRIE A. KIEL



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## 1.0 EXECUTIVE SUMMARY

*Frankenia palmeri* S. Watson (Frankeniaceae) is a perennial shrub native to coastal regions in northwestern Mexico and adjacent extreme southwestern California. Plants typically occur in habitats regarded as saline or saline-sodic dominated by halophilic plant communities along arroyos, gullies, coastal hills, and stabilized dunes (Whalen 1987). Currently, there is no official federal or state sensitivity status assigned to *F. palmeri*. According to the California Native Plant Society (CNPS) list (2012), *F. palmeri* is a category 2.1 taxon and is considered seriously endangered in California but more common elsewhere. The decline or decrease of its natural habitat, primarily due to development along the coast, is the main threat to this species. Although plants are widely abundant in Mexico, there are only five documented occurrences of *F. palmeri* in the U.S. Of the five, one is considered to be the only natural population in the U.S.

## 2.0 SCOPE AND PURPOSE

A conservation plan for *F. palmeri* was undertaken because it is endangered in the U.S. and lacks both state and federal listing status. In addition, biological information available for this species is limited. The purpose of this plan is to present a compilation of all relevant data associated with *F. palmeri* and to identify potential threats and immediate conservation tasks. This document will serve as a primer for landowners, federal and state agencies, conservation organizations, and researchers who are committed to the preservation of this species.

## 3.0 METHODS

Field surveys were conducted in an attempt to locate historical U.S. populations based on data compiled from specimens in California herbaria (Consortium of California Herbaria [CCH] 2012) and plant databases (California Natural Diversity Data Base [CNDDB] 2012; San Diego County Plant Atlas Project 2012). In addition, several Mexican populations in Baja California and the Sonoran coastal region were surveyed. The number of individuals (mounds) per population, floral visitors and potential pollinators, flowering and fruiting time, associated species, habitat, and potential threats were recorded at each locality. Determining the number of individual plants at each population versus clones of the same plant was difficult because *F. palmeri* is rhizomatous and mat forming. In this document, population counts at the California localities are of individual, unconnected "mounds." At each population, with the exception of the San Dieguito

Lagoon, San Diego County locality, herbarium vouchers and plant material dried in silica for future genetic studies were collected and deposited at Rancho Santa Ana Botanic Garden (RSABG). Cuttings were taken from the single-known natural population, Sweetwater Marsh National Wildlife Refuge (element occurrence [EO] 2), and Silver Strand, Emory Cove (EO number not assigned) and were propagated in the greenhouse at RSA using 7% rooting hormone solution and perlite.

## 4.0 BACKGROUND

### 4.1 Taxonomic History

*Frankenia* L. is the only genus of Frankeniaceae. With approximately 80 species (Gaskin et al. 2004) the genus is distributed worldwide in dry temperate and subtropical regions on gypseous or saline-sodic soils. *Frankenia* is now treated as inclusive of a number of small or monotypic genera previously described in the family (Whalen 1987). For example, New World *Niederleinia* Hieron. (1 sp.) was not maintained in a regional study of Argentine Frankeniaceae (Correa 1966), and *Anthobryum* Phil. (2 spp.) was synonymized with *Frankenia* (Whalen 1987).

There have been relatively few taxonomic studies on *Frankenia*. The first classification was proposed by Niedenzu (1895, 1925) who recognized two subgenera primarily based on geography: subgen. *Afra* (all species from Africa and Eurasia) and subgen. *Oceania* (all species from the New World and Australia). Subgenus *Afra* is defined by sessile leaves, ovaries nearly twice as long as wide and flowers subtended by four fused bracts; in contrast, subgen. *Oceania* is characterized as having petiolate leaves, ovaries three times longer than wide, and flowers subtended by one pair of bracts. Subgenus *Oceania* was further divided into two sections, *Basigonia* and *Toichogonia*, based on placentation type and ovule number. In this treatment, *F. palmeri* was placed in subgen. *Oceania*, sect. *Basigonia*.

According to Whalen (1987), both Niedenzu's subgenera and sectional classifications of *Frankenia* are highly artificial and "untenable as natural groups." In the most recent systematic treatment of New World Frankeniaceae, Whalen (1987) recognized 14 species and four "putative" species alliances. These alliances were based on a combination of morphological and eco-geographical factors (primarily leaf morphology and soil types).

Whalen's treatment (1987) did not have a phylogenetic basis. In addition, there are relatively few phylogenetic studies that include species of Frankeniaceae; most are broad-scale studies of the order Caryophyllales that includes the family Frankeniaceae

(Cuénoud et al. 2002; Fior et al. 2006; Heubl et al. 2006). The most complete phylogenetic sampling of *Frankenia* to date is the study by Gaskin et al. (2004) which included only eight (four from the Old World and four from the New World) of the estimated 80 species. In a parsimony analysis based on molecular sequence data from plastid (*rbcL*) and nuclear rDNA (nrITS) data, Frankeniaceae are monophyletic with strong bootstrap support (100%) and sister to Tamaricaceae with equally strong support. *Frankenia palmeri* was not included in this study, and phylogenetic resolution was insufficient to infer species relationships within the family.

#### 4.2 Species Description

*Frankenia palmeri* (Fig. 1–4) is a perennial sprawling shrub. Plants are rhizomatous, approximately 1–3 dm tall and 1–15 dm wide with salt-secreting glands on leaves and stems. The stems are decumbent, often partially buried in sandy soils, and form adventitious roots at nodes. The leaves are opposite, 4-ranked, oblong to linear-oblong, blades are entire, 2–7 mm long, <1 mm wide, tightly revolute, sparsely to densely puberulent and somewhat succulent. The inflorescence is a cyme to solitary flowers. The calyx is 3–5 mm long, 4–7 lobed, and synsepalous. Petals (4–7) are free, overlapping, 4–7 mm long, 1–3 mm wide, and white–pale pink. The stamens (3–5) are arranged in two subequal whorls, exserted, and slightly recurved; the anthers are reddish pink with white-cream pollen. The style is 1–2 branched. Fruits are single-seeded capsules 2–2.5 mm long, 0.6–0.9 mm wide, and dark brown. The seeds are 1.5–2 mm long, 0.6–0.8 mm wide, conical, and ivory-white to golden yellow. Chromosome number is  $n = 15$  (Whalen 1987; Kiel and Little 2012).

*Frankenia palmeri* was described in 1876 by Sereno Watson (Watson 1876). There are no known synonyms for this species (IPNI 2012; Tropicos 2012). In the most recent treatment of the genus (Whalen 1987), *F. palmeri* was placed in the *F. jamesii* alliance along with *F. jamesii* Torr. ex A.Gray, *F. gypsophila* I.M.Johnst., and *F. margaritae* Medrano. The four species are restricted to North America from southwestern U.S. to northern Mexico. The species alliance is characterized as having subterete leaves with tightly revolute margins (Fig. 4) and broad petioles, tubular calyces, and ovaries with basal-parietal placentation with an ovule number of  $\leq 3$ . Diagnostic characters of *F. palmeri* include funiculi fused almost the entire length to the ovary wall and a two-carpellate ovary (Whalen 1987).

Three species of *Frankenia* occur in California, two native, *F. palmeri* and *F. salina* (Molina) I.M.Johnst., and one naturalized, *F. pulverulenta* L. (Kiel and Little 2012). *Frankenia palmeri* and *F. salina* are shrubby perennials that have overlapping distribution ranges in

the Sonoran coastal region and the State of Baja California and northern Baja California Sur in Mexico. According to Whalen (1987), hybridization between the two species is not evident. *Frankenia palmeri* tends to favor upland areas, dunes, and transitional zones of salt marshes whereas *F. salina* frequents the mid- to upper-littoral zones of marshes. Morphological distinctions include: leaves and petals of *F. salina* are nearly twice the size of those of *F. palmeri*, leaves of *F. palmeri* are tightly revolute in comparison to the loosely revolute leaves of *F. salina* (compare Fig. 4, 5), and the style of *F. salina* is three-parted versus two-parted in *F. palmeri*.

Unlike the California native species, *F. pulverulenta* is a small herbaceous annual. This new detection at Ballona Marsh, Los Angeles County (*Coffin s.n.*, RSA), is native to Europe and Asia and is not known to co-occur with either *F. palmeri* or *F. salina* in California.

#### 4.3 Biology and Ecology

*Frankenia palmeri* typically flowers November to July, and fruiting occurs December to August (Whalen 1987). The wide range of flowering and fruiting times may be due to *F. palmeri*'s extensive north-to-south distribution in the Mediterranean climatic zone from San Diego County, California, to San Juanico Bay, Baja California Sur, Mexico. The flowering time for San Diego populations ranges from March to July (Kiel and Little 2012). Spring flowering times in this region may be associated with timing of winter rainfall. According to the San Diego County Water Authority (2012), the San Diego coastal region receives an annual rainfall average of 25 cm and 80% of the rainfall occurs during the months of December–March. In addition, variation in timing of germination and seedling survival may be correlated to winter rainfall. Studies by Noe and Zelder (2000, 2001) have shown that seasonal rains are an important influence on seed germination in salt marsh habitats, providing not only additional moisture, but also temporarily decreasing soil salinity. These studies showed a positive correlation between seed germination and reduced soil salinity in several salt-tolerant plants including *Frankenia*.

The flowers of *Frankenia* are nectariferous and considered entomophilous. A variety of diurnal insects such as bees, butterflies, flies, and moths have been documented as visitors for a number of U.S. *Frankenia* (U.S. Fish and Wildlife Service [USFWS] 2012). On several visits to populations of *F. palmeri* in San Diego County, both bees and flies were observed as floral visitors (C. Kiel, pers. obs. 2010). Specifically, *Chalicodoma browni* (Megachilidae) is a known visitor of *F. palmeri* (Krombein and Hurd 1979) in the U.S.



Fig. 1–4. *Frankenia palmeri*.—1. Habit.—2. Close-up of flowers.—3. Plant with a dime as scale.—4. Tightly revolute leaves with crystalline salt glands visible; also note bifid stigma. (Fig. 4: photo credit *PhillipRouillardphotography.com* 2008).

Seed dispersal mechanisms are not known for *F. palmeri*. For other North American species, such as federally listed *F. johnstonii* Correll, fruits do not appear to be specialized for dispersal, and seedlings are always found in close proximity to a mature plant (Cobb 2003). Because *F. johnstonii* and *F. palmeri* have similar fruit and seed morphology, seeds of *F. palmeri* likely disperse in a similar manner. In addition, seedlings of *F. palmeri* are usually found near mature plants (C. Kiel, pers. obs. 2009–2012).

#### 4.4 Habitat

*Frankenia palmeri* typically occurs in saline or saline-sodic habitats dominated by halophilic plant communities (Whalen 1987). The substrate is commonly sand, sandy clay, or gypsum soil along arroyos, gullies, coastal hills, or stabilized dunes in coastal wetlands (Fig. 6–9). In San Diego County, *F. palmeri* occurs in the upper transitional zone of coastal

salt marshes at an elevational range of 1.5–3 m (CNDDDB 2012) and on dune formations ca. 5 m above sea level (C. Kiel, pers. obs. 2009–2012). According to the National Weather Service (2012), the average yearly temperature in this region is ca. 16.6°C. *Frankenia palmeri* is commonly associated with *Abronia maritima* Nutt. ex S.Watson, *Atriplex californica* Moq., *Bromus madritensis* L. subsp. *rubens* (L.) Duvin, *Cakile maritima* Scop., *Cylindropuntia californica* var. *californica* (Torr. & A.Gray) F.M.Knuth, *Encelia californica* Nutt., *Lycium californicum* A.Gray, and *Sonchus oleraceus* L.

Based on compiled herbarium data (RSA) and field observations, Mexican populations of *F. palmeri* are common in upper transitional zones of salt marshes, lagoons, rocky slopes, dunes, and sandy washes (Fig. 8, 9). Some associated species include *Agave shawii* Engelm. var. *sebastiana* (Greene) Gentry, *Atriplex julacea* S.Watson, *Encelia ventorum* Brandegee,





Fig. 5. *Frankenia salina*. Note the loosely revolute leaves and pink flowers of *F. salina* in comparison to the tightly revolute leaves and white flowers of *F. palmeri* (see Fig. 2–4). (Photo credit: Sula Vanderplank).

*Euphorbia misera* Benth., *Lycium californica* A.Gray, and *Yucca valida* Brandegee.

#### 4.5 Distribution and Abundance

The distribution of *F. palmeri* is centered in the coastal regions of the Sonoran Desert in northern Mexico and the Baja California Peninsula (Fig. 10). Populations from the Baja California Peninsula extend northward from San Juanico Bay, Baja California Sur, to Colonet, Baja California. Sonoran populations occur from Kino Bay north to Cholla Bay and westward to Tiburón Island and Angel de la Guarda Island. Within the U.S., populations occur only in San Diego County, California (Whalen 1987). Interestingly, the California populations of *F. palmeri*, at the northern edge of the species' range, are disjunct from the northernmost Baja California populations in Colonet (Fig. 10) by approximately 175 km. The apparent decline in



Fig. 6–9. Habitat of *Frankenia palmeri*.—6, 7. The only known natural population of *F. palmeri* in the U.S., forming large semi-continuous mounds at Sweetwater River Marsh (EO2), San Diego County.—8. Along dune formations in the village of El Desemboque, Sonora, along the Gulf of California.—9. Dominating the habitat near Estero la Pinta, Sonora, near the Gulf of California.

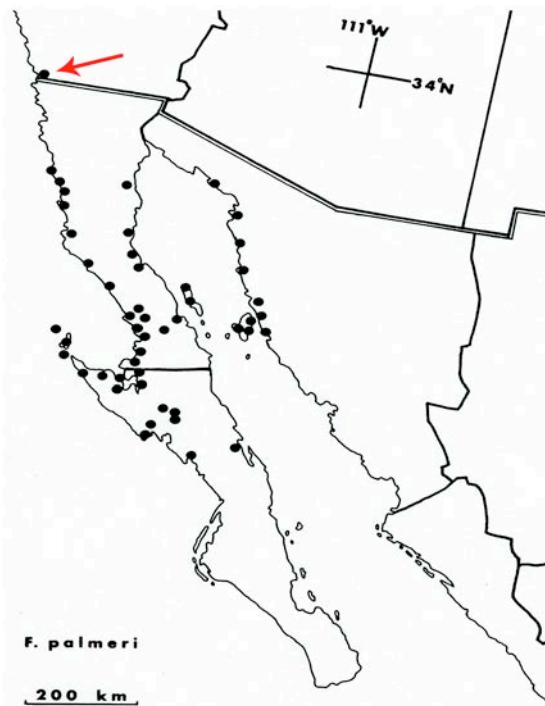


Fig. 10. Distribution of *Frankenia palmeri* (from Whalen 1987). The red arrow indicates the disjunct U.S. populations in San Diego County, California.

abundance of U.S. populations in comparison to Mexican populations (Fig. 10) may be associated with this distribution pattern.

In the U.S. there are three documented and two undocumented element occurrences of *F. palmeri* (see Fig. 11 and Table 1 for a summary), all of which are located in the San Diego County coastal region (CCH 2012; CNDDDB 2012). The California Department of Fish and Game (CDFG) tracks rare taxa in the State through the CNDDDB. The CNDDDB assigns consecutive element occurrence (EO) numbers as each new occurrence of a target taxon is reported. The CNDDDB has records for two native occurrences and one occurrence derived from translocated specimens. The first occurrence (EO1) is a colony of ca. 16–20 mounds spreading along coastal dunes at Border Field State Park. This population is thought to be translocated from the Sweetwater River Marsh Refuge/Chula Vista Nature Center in Chula Vista (EO2) (Phil Roullard, Stewardship Assistant/CA State Parks, pers. comm. 2008). The well established Sweetwater population (EO2) is the only known extant natural population from the U.S. It is located near the office building and boardwalk where two broadly spreading colonies were documented each containing a total of ca. 100–150

mounds (C. Kiel and S. Vanderplank, pers. obs. 2009). At this site other populations have been documented near the shoreline at the “D-Street fill,” an area between the Chula Vista Nature Center and the Port of San Diego marine terminal (National City) (note from herbarium voucher *Barth & Gregory 71*, CCH 2012). The third (EO3) from Silver Strand bayside at Silver Strand Beach State Park is listed as “likely extirpated” (CNDDDB 2012). The population was last documented in the mid-1930s (herbarium vouchers *Purer 5613, 5628* and *Gander 156-2*, CCH 2012) and was not rediscovered through collecting efforts for the San Diego County Plant Atlas project (2012) piloted by the San Diego Natural History Museum or work related to this project.

The two undocumented populations (EO numbers not assigned) are located bayside at Emory Cove on Silver Strand and at San Dieguito River Park. The population at Emory Cove consists of approximately five to seven small mounds and is located just south of the likely extirpated EO3 locality. There is a strong possibility, however, that this population is a transplant from the Sweetwater Marsh Preserve (EO2) due to restoration work at Chula Vista Wildlife Reserve and Emory Cove by the Port of San Diego (Lauren Kershek, Fish and Wildlife Biologist, pers. comm. 2012). The second undocumented occurrence (EO not assigned) is located at San Dieguito River Park in an area that is part of the on-going San Dieguito Lagoon Restoration project. This recently (2010) discovered population was likely introduced from the Baja California Peninsula in a shipment of shells for wetland renovation and reconstruction (note from herbarium voucher *Rebman 20366*, CCH 2012). Approximately 50 mounds were recorded at this site.

Unlike populations in the U.S., *F. palmeri* in Mexico dominates the native coastal scrub bordering the shoreline along the central Gulf Coast of the Sonora Desert (Skinner and Pavlik 1994; Wickens 1998; C. Kiel, pers. obs.; see Fig. 8–10) and the upland sections of the transitional zone in salt marshes in Bahía de San Quintín, Baja California (Neuenschwander et al. 1979; C. Kiel and S. Vanderplank, pers. obs. 2009). *Frankenia palmeri* is common in the flats at Guerrero Negro and on the Vizcaíno Peninsula and also can be dominant in subshrub scrub on Pacific islands such as Cedros and San Benito (Jon Rebman, Curator of Botany—San Diego Natural History Museum, pers. comm. 2009).



Fig. 11. Distribution map for *Frankenia palmeri* in San Diego County, generated in ArcGIS software (ESRI, Redlands, CA). Native populations are shown as dots and non-native populations are represented as squares. CNDDB element occurrence [EO] numbers are indicated.



Table 1. Summary of occurrences of *Frankenia palmeri* in the U.S. In the “Threats” column, letters A–E refer to the threat categories specified in section 4(a)(1) of the Endangered Species Act.

Name of occurrence	EO number	Owner/Manager	Native or non-native population	Population status	Threats
Border Field State Park	EO1	California State Dept. of Parks and Recreation	Native (translocated from EO2)	ca. 16–20 mounds	A. trampling C. insects D. inadequate regulatory mechanisms
Sweetwater Marsh (including D-Street fill)	EO2	USFWS Refuge	Native	Two broadly spreading colonies 100–150 mounds in each	A. non-native plants C. insects E. loss of genetic diversity
Silver Strand State Beach/Silver Strand	EO3	California State Dept. of Parks and Recreation	Unknown	Likely extirpated	–
Emory Cove/Silver Strand	EO not assigned	Port of San Diego/U.S. Navy	Native (likely translocated from EO2)	5–7 mounds	A. trampling and development C. insects
San Dieguito River Park	EO not assigned	San Dieguito River Valley Regional Open Space Park Joint Powers	Non-native (from the Baja California Peninsula)	ca. 50 mounds	–

#### 4.6 Population Trends

Population trends for this species are unknown due to lack of research and collection data. There have been no demographic studies of *F. palmeri* and it is thus not possible to assess population trends. Some evidence might be deduced from specimens, but there are few records for *F. palmeri* in CCH (2012) and the CNDDDB (2012). Of the 14 collections listed in CCH (2012), only five specimens were collected after 1938, but collecting efforts may be unrelated to population trends.

#### 4.7 Threats and Limiting Factors

According to the CNDDDB (2012), development is the only documented threat to *F. palmeri*. However, after reviewing literature and visiting populations in San Diego County, other potential threats were observed. The potential threats to U.S. populations are listed below according to the five factors of section 4(a)(1) of the Endangered Species Act, as amended (Act) for consideration in listing decisions.

A. The present or threatened destruction, modification, or curtailment of its habitat range. Habitat degradation from human disturbance, particularly from develop-

ment, recreation, and agriculture, is a major threat to *F. palmeri* in coastal regions. Threats such as residential development and road maintenance can limit the area and damage the habitat available for the species in its natural range. Signs of trampling and debris were observed near stressed mounds of *F. palmeri* at Tijuana Estuary Center (EO1) and Silver Strand (EO not assigned) (C. Kiel, pers. obs. 2009–2012) (Fig. 12). The population at Silver Strand is particularly sensitive to habitat degradation because it is located near a housing development and along a popular public bike trail and Highway 75 (Fig. 12). In urban/agricultural areas such as San Diego County, contaminants from pesticides and fertilizers, and fresh water runoff from surfaces, rooftops, and roads can permanently alter the hydrology of salt marshes (Noe and Zelder 2000). Although the population of *F. palmeri* at Sweetwater Marsh (EO2) is protected from direct human disturbance, the reserve is located in a disturbed watershed (Noe and Zelder 2000). Within the lower watershed of the reserve where *F. palmeri* occurs, urban runoff has increased and apparently enabled a number of non-native plants to dominate the native salt marsh vegetation (e.g., *Atriplex semibaccata* R.Br., *Bromus diandrus* Roth, *B. madritensis* subsp. *rubens*, *Raphanus sativus* L., and *Sonchus asper* (L.) Hill (Noe and Zelder 2000; C. Kiel and S. Vanderplank, pers. obs. 2009).





Fig. 12. Evidence of stress to a population of *Frankenia palmeri* on Silver Strand (EO not assigned) caused by human disturbance (trampling and debris). This population is adjacent to a recreational bike path and Highway 75.

B. Overutilization for commercial, scientific, or educational purposes. There is no evidence of overutilization of this species for commercial, scientific, or educational purposes.

C. Disease or predation. The biological control agent *Diorhabda elongata* (Asian leaf beetle; Coleoptera: Chrysomelidae), may potentially threaten populations of *F. palmeri*. The beetle is released for the purpose of killing and controlling the spread of exotic *Tamarix ramosissima* Ledeb. (saltcedar; Tamaricaceae). *Tamarix ramosissima* is highly invasive and causes deterioration of riparian ecosystems in western North America. Beetle releases could potentially have a negative impact on *F. palmeri* because *Tamarix* and *Frankenia* are closely related (Cuénoud et al. 2002; Gaskin et al. 2004; Fior et al. 2006; Heubl et al. 2006) and co-occur in San Diego County and Baja California (Herr et al. 2009). Although the beetle's larvae preferentially feed on *Tamarix* spp., North American *Frankenia* are also food

sources (Lewis et al. 2003; Milbrath and DeLoach 2006; Herr et al. 2009). In a study by Herr et al. (2009), *Diorhabda* larval development was tested on various *Frankenia* taxa from North America. The percentage of eggs laid on *F. palmeri* (mean of  $23.6 \pm 2.65\%$ ) was the highest recorded of *Frankenia* taxa in any of their choice tests. Larval survival on *F. palmeri* was  $38.7 \pm 8.3\%$  compared to  $92.0 \pm 6.5\%$  on *T. parviflora* controls. Interestingly, the high larval survival rates recorded on *F. salina* (mean of  $80.0\text{--}92.0 \pm 1.3\%$ ) were not significantly different from the *Tamarix* spp. controls. Survival rates on *Frankenia* taxa measured in this study were more than twice as high as those recorded in a previous study by Milbrath and DeLoach (2006) using the same *Diorhabda* populations and *Frankenia* species. This study indicates that sensitive populations of *Frankenia* growing in close proximity to saltcedar could sustain feeding damage by *D. elongata* larvae that may be moving out of areas containing highly defoliated *T. ramosissima*. These impacts may be transient, but assessments under realistic conditions in

isolated regions are warranted before the release of the beetle in San Diego County.

D. Inadequacy of existing regulatory mechanisms.

There are existing regulatory mechanisms in place at several of the localities where *F. palmeri* occurs (EO1 and EO2). However, there is no specific management in place that directly focuses on this plant species. In particular, the population at Borderfield State Park (EO1) is located within the federally listed and endangered western snowy plover nesting site. The regulatory mechanisms at this site are specifically focused on the preservation of habitat for the western snowy plover and not *F. palmeri*.

E. Other natural or man-made factors affecting its continued existence.

At this time, further examination of known populations is needed to determine natural or human-made factors that affect its continued existence. In terms of natural factors, plants of this species may be vulnerable owing to the fact that they occur at the far northern edge of the range of the species. As a result, there is a potential threat of loss of genetic diversity due to the significant disjunction from the Mexican occurrences and/or potential lack of genetic diversity at native occurrences.

#### 4.8 Conservation Status

*Frankenia palmeri* is currently listed as a CNPS 2.1 species (rare in California but common elsewhere). It is ranked as S1.1 (very threatened/1–5 occurrences) in the State of California and G3G4 globally (G3 = rare or uncommon; G4 = widespread and abundant). At present, there is no protection at the state, federal, or international level and there are no existing management plans for this species.

### 5.0 CONSERVATION

#### 5.1 Conservation Objectives

In an effort to conserve populations of *Frankenia palmeri* in San Diego County, the following conservation objectives should be considered:

1. Conduct field assessments of all known occurrences and assess the specific research and conservation needs at each.
2. Preserve and maintain all known habitats where *F. palmeri* occurs. With the exception of the population at Emory Cove on Silver Strand, the populations in San Diego County occur on protected land, so preservation of habitat is both feasible and easily monitored.
3. Conduct propagation and seed bank studies for the purpose of re-establishing *F. palmeri* in areas with low abundance and adequate habitat. If population augmentation occurs, only plants with the appropriate genotypes will be planted. *Frankenia palmeri* is easily propagated and can thrive with proper care in a greenhouse setting (C. Kiel, pers. obs. 2009–2012). Seed material should be deposited in a long-term storage facility under Center for Plant Conservation (CPC) guidelines and continuously monitored for viability.
4. Decrease the impact of all known threats. Potential threats include trampling, development, biological control agents, and invasive plants.
5. Document the pollination biology and seed dispersal mechanisms of *F. palmeri* and monitor reproductive success.
6. Conduct molecular studies on *F. palmeri* with the purposes of assessing genetic diversity within and among populations. It is desirable to include Mexican populations from both the Sonoran and Baja California Peninsula coastal regions in these studies.

#### 5.2 Conservation Criteria

The criteria for successful conservation of *Frankenia palmeri* are listed below:

1. After populations have been carefully assessed (e.g., number of individuals, evidence of sexual reproduction, percent cover, percent cover of non-natives, flower and fruiting time and abundance, habitat description), they should be revisited annually. Data should be recorded and compared from year to year. If individual plants are healthy and population size shows a positive trend over the next ten years, continuous monitoring can be reduced.
2. All landowners where *F. palmeri* occurs have been notified of its rare status and are encouraged to participate in the preservation of this species and its habitat.
3. Seed production is monitored, viable seeds are being produced, and seedlings are in evidence.
4. Populations with few individuals at present have been augmented via seed banks or outplanting of nursery grown plants.
5. Threats to this species have been significantly reduced in all occurrences.
6. The genetic diversity within and among populations, and pollination and seed dispersal mechanisms have been well documented for this species.
7. The impact of non-native plants on plant viability and establishment has been assessed, and appropriate steps are taken to mitigate impacts as necessary.



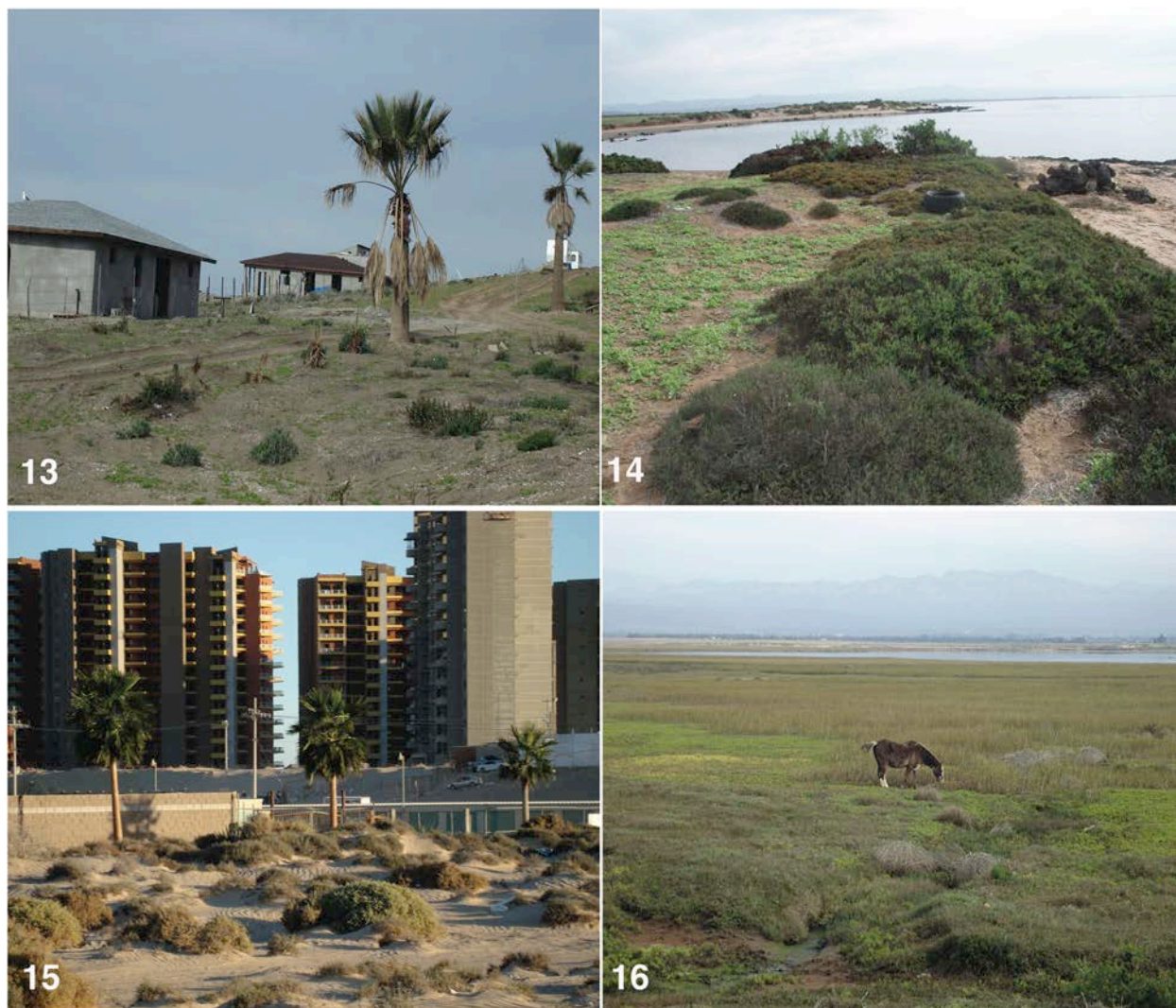


Fig. 13–16. Out-of-state considerations: examples of possible threats to *Frankenia palmeri*.—13. The beginning stages of a housing development in San Quintín, Baja California, Mexico.—14. Debris and exotic *Carpobrotus edulis* (midground) at a housing development site near a population of *F. palmeri* (rounded mound in foreground) in San Quintín, Baja California.—15. *Frankenia palmeri* growing near a high-rise development near Puerto Peñasco, Sonora, Mexico. Evidence of off-highway vehicle use is apparent at this population.—16. Grazing in a salt marsh containing *F. palmeri* in Baja California.

### 5.3 General Conservation Actions

#### Specific site visits

All known occurrences of *F. palmeri* should be visited yearly to monitor status. Assessment of the species should include the following data: number of individuals or mounds per population, number of plants in fruit or flower, number of juveniles, GPS coordinates of each occurrence, digital images of the populations and their habitats, and description of habitat status, including any observed threats. After careful assessments of each population, CNDDDB records of *F.*

*palmeri* should be updated yearly with current data on each occurrence.

#### Documenting reproductive biology

Knowledge of *F. palmeri*'s reproductive biology may provide an important key to conservation of the species. Although flowers are visited by a variety of insects, the effective pollinators are unknown. Insect visitors should be recorded and collected for expert identification and deposition in a regional collection. Examination of pollen load to identify *Frankenia* pollen should be undertaken. In addition, pollination experiments should be conducted to test for self-

compatibility and percent fruit set. Assessment of other unknown reproductive data on *F. palmeri* such as seed dispersal mechanisms, seed predation, and germination/seedling establishment requirements and rates may also provide insight on determinants of the plant's rarity in California. It is especially important to examine the environmental conditions required for efficient seed germination. Studies have indicated that fresh water influence in the winter and early spring encourages germination in salt marsh habitats (Noe and Zelder 2000, 2001). Establishing weather stations at each population to gather rainfall and temperature data may aid in the understanding of effective germination conditions for *F. palmeri*.

#### Documenting the pattern of genetic variation

The genetic diversity within and among populations of *F. palmeri* should be assessed. From each population, a small amount of leaf material should be collected from several individuals (all individuals if the population is small) and preserved in silica gel for molecular analysis. The most proximate Mexican populations in northern Baja California and Sonora are particularly important for the assessment of population dynamics and genetic diversity of California populations as these are the most likely sources of new genotypes, whether via pollen or seed dispersal into California. Examining genetic differentiation between the U.S. and Mexican populations could possibly reveal an explanation for the disjunct distribution (Fig. 10) between U.S. and Mexican populations.

#### Maintaining the genetic diversity of each population

It is important to understand and conserve genetic diversity of species, especially in natural populations with few individuals. To successfully preserve populations, seeds should be collected from each natural population and maintained in a conservation seed bank. In addition, it would be beneficial to conduct *ex-situ* propagation from cuttings. Cuttings of *F. palmeri* from populations at Sweetwater River Marsh have been successfully propagated and cultivated in the greenhouse at RSABG, Claremont. The propagated plants should be maintained off site until suitable habitat for outplanting or re-planting is determined.

### 5.4 Site-Specific Actions

#### (EO1) Borderfield State Park

The population at Borderfield State Park is located on land managed by the California State Parks. Research and habitat restoration within the reserve is conducted in partnership with the USFWS and the

Southwest Wetland Interpretive Association. At this locality, plants of *F. palmeri* were transplanted from the Sweetwater Marsh locality and grow within a known western snowy plover nesting site. The western snowy plover is a federally listed and endangered species. The bird's nesting site is closely monitored and protected by the Borderfield park staff and USFWS. Although the nesting area is fenced off from the public, there are still signs of human disturbance. Both trampling and debris were observed at the occurrence site (C. Kiel, pers. obs. 2009). Surveys should be conducted to determine the impacts of human disturbance and non-native species to this population. This population is also located near the U.S./Mexican border and may be impacted by border fence maintenance and surveillance. Possible threats to this population imposed by border control efforts should be assessed and minimized.

#### (EO2) Sweetwater Marsh National Wildlife Refuge, San Diego Bay

The Sweetwater Marsh site (Fig. 6–7), which is managed by the USFWS, is the only known natural population (not translocated) of *F. palmeri* in the United States. This site is bordered by a shipyard and residential area. Although the population is next to the refuge's office and near a boardwalk path in order to protect it from visitors, a number of non-native plant species including *Atriplex semibaccata*, *Bromus diandrus*, *B. madritensis* subsp. *rubens*, *Raphanus sativus*, and *Sonchus asper* were observed at this site (C. Kiel and S. Vanderplank, pers. obs. 2009). Removal and control of non-natives should be conducted at this location. Because this is a natural population it is important to consistently monitor *F. palmeri* at this site and conduct *ex-situ* propagation and seed-banking studies. In addition, it is desirable to preserve this genotype and assess the genetic distance between this population and the non-native population at San Dieguito (EO not assigned) that likely originated from the Baja California Peninsula.

#### (EO not assigned) Silver Strand, Emory Cove

This population, composed of approximately five to seven mounds, is located on land maintained by the USFWS adjacent to the bike trail along Highway 75 near San Diego Bay. Of the four known occurrences, this population is the most vulnerable to habitat destruction. Unlike the other sites, it is not located in a gated reserve or protected from human disturbance. Evidence of trampling and debris from the highway were observed near stressed plants (Fig. 12). These plants were smaller and typically had fewer leaves and flowers than plants that showed no evidence of trampling damage. Surveys should be conducted to

determine impacts of recreation use and road maintenance on this population.

(EO not assigned) San Dieguito River Park

San Dieguito River Park is located in central San Diego County, at the northern edge of the City of San Diego. This population occurs on land managed by the San Dieguito River Valley Regional Open Space Park Joint Powers Authority. Six governments (the County of San Diego and the cities of Del Mar, Escondido, Poway, San Diego, and Solana Beach) plan restoration efforts and operate and maintain the river park. *Frankenia palmeri* was discovered in 2010 in a restored wetland area near San Dieguito Lagoon. This population was likely introduced from Baja California in a shipment of shells for wetland renovation and reconstruction (note from herbarium voucher *Rebman 20366*, CCH 2012). Genetic studies should be conducted on this population to determine the genetic distance in comparison to known natural U.S. populations. In addition, it is desirable to monitor the growth and viability of this introduced population in comparison to known natural populations in San Diego County.

#### 5.5 Conservation Tasks

The conservation tasks for *F. palmeri* are as follows:

1. Survey occurrences: Monitor and survey all existing populations.
2. Biological and ecological assessment: Study breeding systems, pollinators, and seedling establishment.
3. Conduct ex-situ conservation: Propagate and cultivate clones in a controlled greenhouse facility with the intention of increasing population sizes or to establish additional new populations in suitable environments.
4. Genetic study: Determine genetic diversity within and among populations.

#### 5.6 Out-of-State Considerations

With the exception of the four U.S. populations in San Diego County, *F. palmeri* occurs in Mexico throughout the Baja California Peninsula and Sonoran coastal regions. The Mexican populations are more robust and widespread than the U.S. populations. It would be beneficial to future restoration efforts to study the reproductive biology, genetic diversity, and habitat of the Mexican populations in comparison to *F. palmeri* from the U.S.

The coastal regions of Baja California and Sonora are rapidly undergoing development for commercial and residential purposes (C. Kiel and S. Vanderplank, pers. obs. 2009). Populations of *F. palmeri*, particularly those near the coasts, are vulnerable to habitat destruction or modification due to construction of homes, resorts, and associated infrastructure. Signs of habitat degradation are apparent at a number of sites visited in both regions (C. Kiel and S. Vanderplank, pers. obs. 2009). Tracks from recreational off-highway vehicle usage and debris were documented at populations near popular tourist destinations such as Puerto Peñasco, Ensenada, and San Quintín, Baja California (Fig. 13–15). In addition to human disturbance, land cleared for development promotes the growth and establishment of invasives or non-native plants. *Carpobrotus edulis* (L.) N.E.Br., a highly invasive species, was documented as a dominant plant in surveyed areas where land was cleared near San Quintín (C. Kiel and S. Vanderplank, pers. obs. 2009). Agricultural disturbance, particularly grazing (Fig. 16), is another potential threat to *F. palmeri* in Baja California where farms and large commercial agricultural enterprises are common.

#### 5.7 List of Likely Participants in Conservation Efforts

- Border Field State Park—Tijuana River National Estuarine Research Reserve
- California Department of Parks and Recreation (San Diego)
- California Native Plant Society (San Diego Chapter)
- Rancho Santa Ana Botanic Garden (Claremont)
- San Diego Natural History Museum
- San Dieguito River Valley Regional Open Space Park Joint Powers Authority (San Diego)
- Sierra Club (San Diego Chapter)
- Southern California Botanists (Claremont)
- Sweetwater Marsh National Wildlife Refuge (USFWS)

## 6.0 IMPLEMENTATION

### 6.1 Action Assessment

With only one known natural population of *F. palmeri* in the United States, it is important to preserve and maintain this species and its habitat by implementing the conservation tasks listed above. Human disturbance, invasive and/or non-native plants, trampling, loss of genetic diversity, and the loss of habitat pose a threat to the existence of this species.

### 6.2 State and/or Federal Listing

Currently, there are no state or federal listings for *F. palmeri*. Considering its limited distribution in the U.S., and the threats described above, the species is a potential candidate for both federal and state listing. An investigation and assessment, following the guidelines set forth in the Federal Endangered Species Act, as amended, and the California Endangered Species Act is required to consider *F. palmeri* for listed status.

### 6.3 Other Actions

RSABG was granted funds from both CNPS and the JiJi Foundation to conduct field surveys for this species yielding the data that are presented here. Remaining funds will be used to monitor populations in San Diego County for the next two years (2013 and 2014).

### 6.4 Implementation Schedule

To ensure the conservation of *F. palmeri*, the implementation of conservation tasks should be conducted by priority and within the timeframe as listed in Table 2 below.

### 6.5 Potential Difficulties in Implementation

Lack of funding may impede implementation of the tasks listed in Table 2, particularly tasks 2 and 4. In addition, the populations at Tijuana Estuary Center and San Dieguito Lagoon can be difficult to access since both are located within the federally listed and endangered western snowy plover and least tern nesting sites, respectively.

Table 2. Implementation schedule for *Frankenia palmeri*.

Task	Description	Timeframe	Priority
(1) Survey and monitor occurrences	Monitor and survey populations every year for 10 years	2013–2022	High
(2) Biological and ecological assessment	Study breeding systems, pollinators, seed germination, and seedling establishment	2013–2015	High
(3) <i>Ex-situ</i> conservation	Propagate cuttings and cultivate in a greenhouse facility with the intention of increasing population sizes or establish additional populations	2013–2015	High–medium (dependent upon number of individuals in a population)
(4) Genetic study	Determine the genetic diversity between and among the populations	2013–2015	Medium

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