

Draft Recovery Plan Revision for Seven Coastal Plants and the Myrtle's Silverspot Butterfly: *Chorizanthe valida* (Sonoma Spineflower)

[\[Click Here to View Document\]](#)

Original Approved: September 29, 1998

Original Prepared by: U.S. Fish and Wildlife Service, Ventura and Sacramento, California for Region 1 (Portland, Oregon)

We have identified the best available information that indicates the need to amend recovery criteria for this species since the completion of the original recovery plan. In this proposed modification, we synthesize the adequacy of the existing recovery criteria, show amended recovery criteria, describe the rationale supporting the proposed recovery plan modification, and propose additional recovery actions (as needed). The proposed modification is an addendum, which supplements the recovery plan, superseding the following pages: from Section I: pp. 25-29, and Section II: pp. 89-90 for Sonoma spineflower (*Chorizanthe valida*)¹. The proposed criteria amendments appear as an appendix that supplements the recovery plan, superseding only the indicated sections of the recovery plan.

**For
U.S. Fish and Wildlife Service
Region 8
Sacramento, California**

December 2018

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Regional Director, Pacific Southwest Region, Region 8,
U.S. Fish and Wildlife Service

Date: XXXXXXXXXXXXXXXXXXXX

¹ The superseded material includes only the specific recovery criteria and synthesis described for this species. We do not supersede material other than the recovery criteria with this amendment.

METHODOLOGY USED TO COMPLETE THE RECOVERY PLAN AMENDMENT

This review was prepared by the Sacramento Fish and wildlife Office (SFWO), following the National Recovery Program guidance issued in May of 2018. We (The U.S. Fish and Wildlife Service) used information from our files, the original recovery plan (1998a), the most recent 5-year review (2010), information from experts at the National Park Service (NPS), and the California Natural Diversity Database (CNDDDB) maintained by the California Department of Fish and Game. The Sonoma spineflower only exists on lands owned and operated by the NPS. Information from *Sonoma Spineflower* (Chorizanthe valida) *TE018180-4 Annual Report 2017* compiled by NPS biologists was the primary document relied on to inform decision-making. National Park Service biologists provided much of the documentation, observations, and data used to inform the amended recovery criteria. The amended criteria will be peer reviewed in accordance with the OMB Peer Review Bulletin following the publication of the Notice of Availability.

We developed amended recovery criteria by assessing threats to species using the Endangered Species Act's five listing-factors. We used concepts from the Species Status Assessment (SSA) framework (Service, 2016) to augment this process. While a full SSA is beyond the scope of this recovery plan revision, the Service used the SSA framework to consider what species need to maintain viability by characterizing the status of the species in terms of its resiliency, representation, and redundancy (Wolf et al. 2015; Schaffer and Stein 2000):

Resiliency describes the ability of populations to withstand stochastic disturbance. With increasing resiliency comes increased population size and growth rate. Habitat connectivity also increases resiliency. Generally, populations need abundant individuals within habitat patches of adequate area and quality in order to survive and reproduce in spite of disturbance.

Representation describes the ability of a species to adapt to changing environmental conditions over time. Populations with a wide variety of genetic and environmental diversity within and among populations have higher representation.

Redundancy describes the ability of a species to withstand catastrophic events. Generally, species which have adequate individuals within multiple populations, minimize potential loss from catastrophic events. Redundancy is high when multiple, resilient populations are distributed within the species' ecological settings and across the species' range.

ADEQUACY OF RECOVERY CRITERIA

Section 4(f)(1)(B)(ii) of the Endangered Species Act (Act) requires that each recovery plan shall incorporate, to the maximum extent practicable, "objective, measurable criteria which, when met, would result in a determination...that the species be removed from the list." Legal challenges to recovery plans (see *Fund for Animals v. Babbitt*, 903 F. Supp. 96 (D.D.C. 1995)) and a Government Accountability Audit (GAO 2006) have affirmed the need to frame recovery criteria in terms of threats assessed under the five delisting factors.

RECOVERY CRITERIA

See previous version of criteria in the recovery plan for Sonoma spineflower (*Chorizanthe valida*) (Section II, pp. 89-91) of the Recovery Plan for Seven Coastal Plans and the Myrtle's Silverspot Butterfly. [\[Click Here to View Document\]](#)

SYNTHESIS

Background and Status

Sonoma spineflower (*Chorizanthe valida*) is an erect-to-spreading annual herb in the buckwheat family (Polygonaceae). This federally endangered plant is endemic to the Point Reyes Peninsula along central California coast. Currently there is one wild, or natural, population within Point Reyes National Seashore (PRNS) (Reveal and Hardham 1989). Since its listing in 1998, National Park Service (NPS) botanists have implemented a number of introductions, at least five of which have been successful at establishing new occurrences (Parsons and Ryan 2018) (Service 1998a). The spatial distribution of the population fluctuates seasonally, but does not appear to be contracting (Williams 2008; Parsons and Ryan 2018). Staff at PRNS have conducted some level of monitoring since the species re-discovery, and efforts were improved in 2004 (Davis 1990; Parsons pers comm). Evidence shows that the surviving wild population of Sonoma spineflower occurs within California's annual coast-prairie grassland on Sirdrak sand. Sirdrak sand is a rare, well-drained Pleistocene soil type found in dunes with a 2-4% slope bearing to the north-northwest (NRCS 2007; Parsons and Ryan 2018). Most of the successful established populations of Sonoma spineflower have been introduced on Sirdrak soil. It is likely these drier, low nutrient soils exclude competition from perennial species of grasses and forbs (Amelia Ryan pers. comm). Within Marin County, 90% (about 2,300 acres) of the Sirdrak soil lies within PRNS. Outside of PRNS, there are also soils of this type within the vicinity of Dillon Beach and Rodeo Lagoon.

The confirmed historical range of Sonoma spineflower is limited (Service 1998a). The species is further constrained by inhabiting naturally rare habitat within its geographic range (Ryan, pers. comm.). In addition, the species has a poor ability to disperse by natural means (Parson and Ryan 2018). Due to efforts on the part of the NPS, the species **seems to be increasing in recent years**. However, habitat loss and degradation are still the main threats to Sonoma spineflower. Non-native plants, trampling from ~~hiking/recreation~~ and livestock, drought, and climate change all pose a continuing threat to the plant.

Threats

The most significant threat to Sonoma spineflower is degradation to **habitat**. Non-native and native grasses, herbs, and shrubs compete for sunlight and can, in some cases, alter the nutrient content of dune soils and thereby favor non-native annual species that expand rapidly under high nutrient conditions. PRNS' monitoring indicated that yellow bush lupine (*Lupinus arboreus*; California native possibly not native to Marin County) and coyotebrush (*Baccharis pilularis*) are threats to the wild population, along with non-native annual grasses in wetter years. Initially, common velvetgrass (*Holcus lanatus*) was thought to be a possible threat, but years of monitoring have shown that this species tends to be restricted to the adjacent soil type, Sirdrak Sand, Variant, which is much wetter. Yellow bush lupine, which is capable of fixing nitrogen,

has been shown by researchers to increase nitrogen content of the soils and thereby promote establishment of weedy, non-native annuals (insert citations from Maron, etc.). Some of the weedy, non-native annuals that are present in the wild population include *Festuca bromoides*, *Bromus hordeaceus*, *Aira caryophyllea*, *Cynosurus echinatus*). Because bush lupine and coyotebrush appear to pose a greater long-term threat to Sonoma spineflower than other non-native and native plants, PRNS staff has focused removal efforts on these species.

Research suggests that grazing might be an effective method for removing invasive plant species in areas occupied by Sonoma spineflower (Davis and Sherman 1992). Sonoma spineflower is probably unpalatable to grazers, unlike many of the invasive grasses (Davis and Sherman 1992). By allowing cattle and other livestock to graze, Point Reyes National Seashore leases federal lands to ranchers for grazing (Parsons and Ryan 2018). Staff at PRNS have worked with lessees to adjust agricultural infrastructure such as two-track ranch roads to benefit Sonoma spineflower populations in recent years (Parsons and Ryan 2018). Grazing by cattle is likely not a direct threat to the Sonoma spineflower; however, populations should be monitored to ensure threats do not exist from grazing (Service 2010).

Climate change could pose additional threats to the persistence of Sonoma spineflower. Assessing this threat is difficult, as the extent of average temperatures increases in California/Nevada is difficult to predict, as are the likely related changes to the level of threat posed by factors such as drought and fire (Loarie et. al. 2008; Keeley 2002). Literature on climate change includes predictions of hydrological changes, higher temperatures, and expansion of drought areas, resulting in a northward and/or upward elevation shift in range for many species (Blair et. al 2017; Loarie et. al. 2008).

AMENDED RECOVERY CRITERIA

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered at the point which it might be downlisted to threatened or that the protections afforded by the Act are no longer necessary and Sonoma spineflower might be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants. Downlisting is the reclassification of a species from endangered to threaten. The term “endangered species” means any species (species, sub-species, or Distinct Population Segment) which is in danger of extinction throughout all or a significant portion of its range. The term “threatened species” means any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Revisions to listing decisions, including delisting or downlisting a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered or threatened entity or not, based on the current scientific knowledge of existing threats. Section 4(b) of the Act requires a determination be made “solely on the basis of the best scientific and commercial data available.” Thus, recovery plans provide important guidance and measurable objectives against which to measure recovery progress. However, they serve as guidance for these actions, and are not regulatory documents.

Recovery criteria should help indicate when we would anticipate an analysis of the species' status under section 4(a)(1) would result in a determination in which the species no longer exists in a threatened or endangered status.

We provide both downlisting and delisting criteria for the Sonoma spineflower. These criteria supersede those included in the Recovery Plan for Seven Coastal Plants and the Myrtle's Silverspot Butterfly.

DOWNLISTING RECOVERY CRITERIA

In addition to what was included in the original recovery plan (Service 1998a), not in italics below, we have added new recovery criteria revisions, in italics below. Because the appropriateness of delisting is assessed by evaluating the five-factors identified in the Act, the recovery criteria below pertain to and are organized by these factors.

Factor A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range Protect existing populations and habitats.

The main threat to the persistence of Sonoma spineflower is habitat change and destruction. These threats must be reduced or eliminated in order to downlist, or delist, the plant. This will be accomplished when the following have occurred:

- A/1 *At least six successful populations have been established. These populations will be considered self-sustaining populations after 15 years, which includes a normal precipitation cycle.*
- A/2 *The area of each Sonoma spineflower population is maintained at or above approximately 2 acres in size².*
- A/3 *Invasive bush lupine cover at all sites is controlled at <1% within areas containing Sonoma spineflower.*
- A/4 *There are management measures implemented to address the threats of invasive species and other problems including... and off-road vehicles at some sites.*
- A/5 *Monitoring reveals that management actions are successful in reducing threats of invasive non-native species.*

Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The only known populations of Sonoma spineflower exist on lands owned and operated by the

² During prolific years, the wild population of Sonoma spineflower occupies an area of approximately 2 acres (Parsons and Ryan 2018). This is large enough for a population to persist for the foreseeable future.

National Park Service. Although recreation occurs on these lands³, populations of Sonoma spineflower are probably not threatened by recreational activities. Therefore, no criteria were developed for this factor.

³ The mission of the National Park Service is to preserve natural and cultural resources for public benefit.

Factor C: Disease or Predation

Cattle rarely graze on Sonoma spineflower (Davis and Sherman 1992). Research suggests grazing might actually benefit populations over time (Davis and Sherman 1992). Because there is little or no threat to the persistence of Sonoma spineflower from grazing, no recovery criteria were developed for this factor.

Factor D: Inadequacy of Existing Regulatory Mechanisms

The inadequacy of existing regulatory mechanisms not considered a threat to Sonoma spineflower at this time. Therefore, no recovery criteria were developed for this factor.

Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence

E/1 *The number of individuals within each Sonoma spineflower population remains at or above 90,000⁴ for 15 years⁵, which includes cycles of normal precipitation.⁶*

E/2 Seeds are stored in at least two Center for Plant Conservation certified facilities; seed germination, propagation, and out-planting propagation techniques are understood.

DELISTING

Full recovery of the Sonoma spineflower will occur when the dune systems they inhabit are secure, with evidence demonstrating non-native and, in some cases, native plants and other threats (such as ranch activities) are controlled and managers have shown their ability to keep threats under control. The Sonoma spineflower needs to be secure in their presently-occupied ranges, and opportunities should be taken to introduce these plants to restored habitat in or near historic ranges. The area occupied by the plants should increase commensurate with improving habitat conditions. The determination that delisting is possible must be based on at least 20 years of monitoring for the endangered taxa, to include wet and drought years.

Factor A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range Protect existing populations and habitats

A/1 *At least eight successful populations have been established on restored habitat [that] has been secured within the historic range. Populations will be self-sustaining after 15 years, which includes a normal precipitation cycle.*

A/2 *Further invasion or increase in non-native or native invasive plant species has been prevented, including perennial species such as bush lupine and coyotebrush, within all Sonoma spineflower populations.*

⁴ This number is based on expert opinion of NPS biologists managing the only extant population of Sonoma spineflower (Ryan 2018).

⁵ 15 years of monitoring is considered sufficient to ensure a population will persist for the foreseeable future (Service 1998a).

⁶ A normal precipitation cycle is a series of years that include above average, and below average rainfall conditions, starting and ending with average precipitation (Service, 1998b).

A/3 Habitat occupied by the species that is needed to allow delisting has been *voluntarily* secured, with long-term commitments and, if possible, endowments to fund [the] conservation of the native vegetation.

Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The only known populations of Sonoma spineflower exist on lands owned and operated by the National Park Service. Although recreation occurs on these lands³, populations of Sonoma spineflower are probably not threatened by recreational activities. Therefore, no criteria were developed for this factor.

Factor C: Disease or Predation

Cattle rarely graze on Sonoma spineflower (Davis and Sherman 1992). Research suggests grazing might actually benefit populations over time (Davis and Sherman 1992). Because there is little or no threat to the persistence of Sonoma spineflower from grazing, no recovery criteria were developed for this factor.

Factor D: Inadequacy of Existing Regulatory Mechanisms

The inadequacy of existing regulatory mechanisms is not known to threaten Sonoma spineflower at this time. Therefore, no recovery criteria have been developed for this factor.

Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence

E/1 *Ensure that seed banking practices, including seed germination, propagation, and out-planting propagation techniques, are understood and implemented as needed.*

E/2 *Seeds at banking facilities are renewed at a rate to ensure that seed stores remain viable in perpetuity.*

All classification decisions consider the following five factors: (1) is there a present or threatened destruction, modification, or curtailment of the species' habitat or range; (2) is the species subject to overutilization for commercial, recreational scientific or educational purposes; (3) is disease or predation a factor; (4) are there inadequate existing regulatory mechanisms in place outside the ESA (taking into account the efforts by states and other organizations to protect the species or habitat); and (5) are other natural or manmade factors affecting its continued existence. When delisting or downlisting a species, we first propose the action in the *Federal Register* and seek public comment and peer review. Our final decision is announced in the *Federal Register*.

Rationale for Recovery Criteria

We have amended the recovery criteria for Sonoma spineflower to include delisting criteria that incorporate the biodiversity principles of resiliency, redundancy, and representation (Service 2016) and threats addressed under the five factors. The amended criteria were developed based

on the Service's current understanding of the species needs and requirements. This understanding includes information gathered since the original recovery plan was published, such as more recent information about population status and trends, along with an updated understanding of the threats acting on the species, as summarized in the syntheses above. The criteria presented are based on the reduction of threats to the species, ensuring that sufficient redundancy exists to withstand potential catastrophic events, and they include a temporal aspect to ensure that the species are resilient to expected variation within a reasonable timeframe.

ADDITIONAL SITE SPECIFIC RECOVERY ACTIONS

The actions identified below are those that, based on the best available science, are necessary to bring about the recovery of all listed species in this amendment and ensure their long-term conservation. However, these actions are subject to modification as might be indicated by new findings, changes in species status, and the completion of other recovery actions. The actions listed here are new and should be considered in addition to the actions in the original recovery plan. The most stepped down (detailed) actions have been assigned a priority for implementation, according to our determination of what is most important for the recovery of these species based on the life history, ecology, and threats.

Key to Terms and Acronyms Used in the Recovery Action Narrative and Implementation Schedule:

Priority numbers are defined per Service policy (Service 1983) as:

- Priority 1: An action that must be taken to prevent extinction or to prevent a species from declining irreversibly.
- Priority 2: An action that must be taken to prevent a significant decline of the species population/habitat quality or some other significant negative impact short of extinction.
- Priority 3: All other actions necessary to provide for full recovery of the species.

The following Recovery Actions Narrative provides detail of the actions necessary to achieve full recovery. The priority assigned to each action is specified within parentheses at the end of the description.

The numeric recovery priority system follows that of all Service recovery plans. Because situations change over time, priority numbers must be considered in the context of past and potential future actions at all sites. Therefore, the priority numbers assigned are intended to guide, not to constrain, the allocation of limited conservation resources.

The actions below are based on the best available science and observations, which the Service believes are necessary to move towards the recovery and downlisting of Sonoma spineflower.

1. Establish or protect additional populations of Sonoma spineflower.

- 1.1 Introduce at least three new self-sustaining populations (Priority 1)
- 1.2 Continue work on seedbank dynamics with the goal of using the information to run a population viability analysis on the species (Priority 2).

2. Conduct research to better understand life history and annual establishment.

- 2.1 Determining the extent of Sirdrak Sand outside of the park to help inform the location of potential introduction sites (Priority 3).
- 2.2 Conduct an analysis of soil type and nutrients/water balance, vegetation cover, disturbance dynamics (grazing, rodents, rabbits) to identify new introduction sites (Priority 3).
- 2.3 Research the potential to augment nesting habitat for main pollinators near some of the current and future introduction sites (Priority 3).

3. Monitor and manage existing populations on protected lands.

- 3.1 Maintain shrub cover within existing sites at acceptable levels through removal, as necessary (Priority 3).
- 3.2 Determine where some of the main pollinators identified in the two years of study on Sonoma spineflower nest near these populations (Priority 3).
- 3.3 Research the potential to augment nesting habitat for main pollinators near some of the current and future introduction sites (Priority 3).

LITERATURE CITED

- Blair, C.M., D.D. Ackerly, P. Z. Klos, J. Natali, T. E. Dawson, and S. E. Thompson. 2017. Hydrologic refugia, plants, and climate change. *Global Change Biology* 23:2941-2961.
- Davis, L. and R. J. Sherman. 1990. The rediscovered Sonoma spineflower at Point Reyes National Seashore. *Fremontia* 18:17-18
- Davis, L. and R. J. Sherman. 1992. Ecological study of the rare *Chorizanthe valida* (Polygonaceae) at Point Reyes National Seashore, California. *Madroño*. 39:271-280.
- (GAO) Government Accountability Office. 2006. Endangered Species: Time and Costs Required to Recover Species Are Largely Unknown (Publication No. GAO-20548).
- Keeley, J. E. 2002. Native American impacts on fire regimes of the California coast ranges. *Journal of biogeography* 29:303-320.
- Loarie, S.R., B. E. Carter, K. Hayhoe, S. McMahon, C. A. Knight, and D.D. Ackerley. 2008. Climate change and the future of California's endemic flora. *PLOS One* 3:110.
- Parsons, L., and A. Ryan. 2018. Sonoma Spineflower (*Chorizanthe valida*) TE018180-4 Annual Report 2017.
- Reveal, J.L. and C. B. Hardham, 1989. A revision of the annual species of *Chorizanthe* (Polygonaceae: Eriogoniodeae). *Phytologia* 66:98-198.
- Schaffer, M. L., and B. A. Stein. 2000. Safeguarding our precious heritage (Chapter 11), IN B.A. Stein, L.S. Kutner, and J.S. Adams editors, *Precious heritage: the status of biodiversity in the United States*. Oxford University Press, New York: 301-321.
- [Service] U.S. Fish and Wildlife Service. 1992. Endangered and Threatened Wildlife and Plants; Six Plants and Myrtle's Silverspot Butterfly from Coastal Dunes in Northern and Central California Determined to be Endangered. Final Rule. *Federal Register* 57:27848-27859
- [Service] U.S. Fish and Wildlife Service. 1998a. Seven Coastal Plants and the Myrtle's Silverspot Butterfly Recovery Plan. Portland, Oregon. 141 pp.
- [Service] U.S. Fish and Wildlife Service. 1998b. Recovery plan for serpentine soil species of the San Francisco Bay area, California, Region 1, Portland, OR. 442 pp
- [Service] U.S. Fish and Wildlife Service. 2010. Sonoma Spineflower (*Chorizanthe valida*) 5-year review summary and evaluation.
- [Service] U.S. Fish and Wildlife Service. 2016. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4 dated August 2016.
- Williams, A. 2008. Sonoma spineflower (*Chorizanthe valida*) Annual Report 2008. TE018180-4.

Wolf, S., B. Hartl, C. Carroll, M. C. Neel, and D. Greenwald. 2013. Beyond PVA: Why Recovery under the Endangered Species Act is More than Population Viability. *BioScience*. Vol 65 No. 2. Feb 2015. Madroño 61(1): 64-76.

In Litteris

Parsons, L. 2018. National Park Service. Electronic mail correspondence to Amelia Ryan, NPS, and Elizabeth Bainbridge, Sacramento Fish and Wildlife Office. July 20th. Subject: Recovery Plan Sonoma Spineflower.

Parsons, L. 2018. National Park Service. Phone interview with Elizabeth Bainbridge, Sacramento Fish and Wildlife Office, August 1, 2018.

Ryan, A. 2018. National Park Service. Electronic mail correspondence to Lorraine Parsons, NPS, and Elizabeth Bainbridge, Sacramento Fish and Wildlife Office. July 20th. Subject: Recovery Plan Sonoma Spineflower.

Ryan, A. 2018. National Park Service. Phone interview with Elizabeth Bainbridge, Sacramento Fish and wildlife Office, August 1, 2018.

Sonoma Spineflower (*Chorizanthe valida*)
TE018180-4
Annual Report 2018
April 2019



Chorizanthe valida S. Watson, Photo by Doreen Smith



Lorraine Parsons, Vegetation Ecologist
Point Reyes National Seashore
Lorraine_Parsons@nps.gov
Amelia Ryan, Vegetation Ecologist
Pinnacles National Park
Amelia_Ryan@nps.gov

Contents

	Page
List of Figures	ii
1.0 Introduction.....	1
1.1 Background.....	1
1.2 Ecology	1
1.3 Potential Threats to Sonoma Spineflower.....	4
1.4 Management History.....	9
2.0 Objectives and Methods.....	21
2.1 Draft Management Objectives	21
2.2 Draft Monitoring/Sampling Objectives	23
2.3 Monitoring Data Collection and Sampling Design.....	24
2.4 Propagule Collection.....	28
2.5 New Introductions.....	28
2.6 Invasives Removal	29
2.7 Pollinator Study	29
2.8 Seedbank Study.....	29
2.9 Data Management	29
2.10 External Research Study – Pollinators.....	29
3.0 Results.....	30
3.1 Monitoring and Mapping of Sonoma Spineflower Wild Population.....	30
3.2 Boundary Mapping of Areal Extent of Common Velvetgrass.....	33
3.4 Introductions	33
3.5 Management.....	39
3.6 Pollinator Studies	40
3.7 Seedbank Study.....	40
3.8 Other Research Studies	40
4.0 Conclusions.....	41
4.1 Summary	41
4.2. Future Management and Monitoring Activities.....	45
Appendix A: Sonoma spineflower maps	53
Appendix B: Plant Community Monitoring Data – 2010-2016.....	57
Appendix C: Pollinator Surveys Report – 2015	
Appendix D: Seedbank Dynamics Report – 2015	

List of Figures

	Page
Figure 1. Observed fecundity of Sonoma spineflower (based on Edwards 1999 and RSABG 2000).....	2
Figure 2. Average distance in meters of the common velvetgrass boundary from the known maximum extent of the Sonoma spineflower population.	5
Figure 3. NMS results showing similarity of sites	11
Figure 4. 1943 aerial photo showing the Sonoma spineflower natural population site....	12
Figure 5. Pre-restoration conditions: road effects on spineflower density.	12
Figure 6. Detail of Sonoma spineflower quadrat methods.	26
Figure 7. Census totals at Sonoma spineflower introduction sites: 2000-2014.....	28
Figure 8. Estimated population (left axis) with 95% CI of Sonoma spineflower in the macroplot 2005-2018.....	31
Figure 9. Estimated population of Sonoma spineflower in G Ranch introduction sites...	37
Figure 10. Estimated population of Sonoma spineflower in F Ranch introduction sites..	38
Figure 11. Estimated population of Sonoma spineflower in Schooner Creek introduction sites.	39

1.0 Introduction

Sonoma spineflower (*Chorizanthe valida*) is a federally endangered plant endemic to the Point Reyes Peninsula, currently consisting of one wild or natural population within Point Reyes National Seashore (PRNS). Since the only population was rediscovered in 1980, Seashore staff has implemented a number of introduction attempts, at least five of which have been successful in establishing new occurrences. PRNS has also conducted some level of monitoring since the species' re-discovery, with monitoring efforts being improved in 2004 in collaboration with the National Park Service's Inventory and Monitoring program (I&M) for the San Francisco Area Network (SFAN). This document represents PRNS' annual report to the U.S. Fish and Wildlife Service (USFWS) on its annual monitoring and management activities under Permit **TE018180-4** through 2017.

1.1 Background

Sonoma spineflower was believed to be extinct throughout its range until 1980, when a single population was discovered at PRNS by volunteers from the California Native Plant Society (CNPS). The population is located near the eastern end of Abbott's Lagoon on the Lunny (G) Ranch (Appendix A), approximately 15 meters (~50 feet) above sea level.

Prior to this discovery very little data was recorded about the species. The distribution of Sonoma spineflower prior to 1980 is unknown, although, historically, the species was believed to be restricted to sandy soils in coastal grasslands. It was first collected in 1840 by a Russian naturalist I.G. Vosnesensky and labeled "Fort Ross" on the herbaria sheet, but this was his base location, not necessarily the collection locale (Davis 1992). Other specimens have been recorded from "Sebastopol" and "Petaluma" in Sonoma County, but it is again unclear whether this was the collection locality or the place from which these samples were posted. A.D.E. Elmer collected several samples in 1903 with the Point Reyes Post Office listed as the locality (<http://ucjeps.berkeley.edu/consortium/>). The Point Reyes Post Office was located on the Historic F Ranch, close to Schooner Bay (Livingston 1993), which is approximately 1 mile south of the one known remaining wild population.

1.2 Ecology

1.2.1. Demography

Sonoma spineflower is an erect herbaceous annual in the Polygonaceae family (Hickman 1993), with individuals growing 10-30 cm tall and having soft-hairy stems and 10-50 mm long obovate leaf blades. The light-pink flowers form dense inflorescences that become rust-colored as the seeds develop. Blooming typically occurs June through August and is potentially dependent on temperatures and timing of precipitation, as is discussed later.

The exact germination requirements of this species are not known, but *C. pungens* *pungens*, another rare coastal spineflower of sandy soils, was reported to germinate in fall or winter after the onset of seasonal rains (Fox *et al.* 2006). This study found *C. pungens*

pungens seed germinated readily under a broad range of conditions, and current-year abundance and the previous year's seed production were strongly correlated, suggesting little seed banking (Fox *et al.* 2006).

While formal germination data for Sonoma spineflower is not available, data from germination trials conducted during accession of seed at Rancho Santa Ana Botanic Garden (RSABG) also supports this hypothesis: 94-100% of seeds germinated in trials immediately upon accession, with 96% of seeds germinating after 10 years in cold storage (RSABG 2000; see the discussion on seed accession in Section 1.4 Management History, below). These trials suggest that many of the seeds produced annually by Sonoma spineflower germinate the following season and that not much of the seed is "banked," although those seeds that are banked have at least intermediate long-term viability. However, at least one seeded introduction plot at PRNS that had no plants observed the first year had four the second year, so some seed banking may occur (PRNS unpub. data).

Some demographic data on Sonoma spineflower is available from monitoring conducted by PRNS on 12 seeded introduction plots established in four separate years. Within these plots, observed survivorship to flowering averaged 5%, with standard deviations ranging from 0-12% (PRNS, unpub. data). In contrast, data was also collected by PRNS staff on the fecundity of the wild population of Sonoma spineflower. The results, shown in Figure 1, indicated that 56% of flowers produce fertile seed. Of those that did not produce seed (29%), the main reason may have been lack of pollination, although other factors can result in pollinated flowers not producing seed, as well (Edwards 1999).

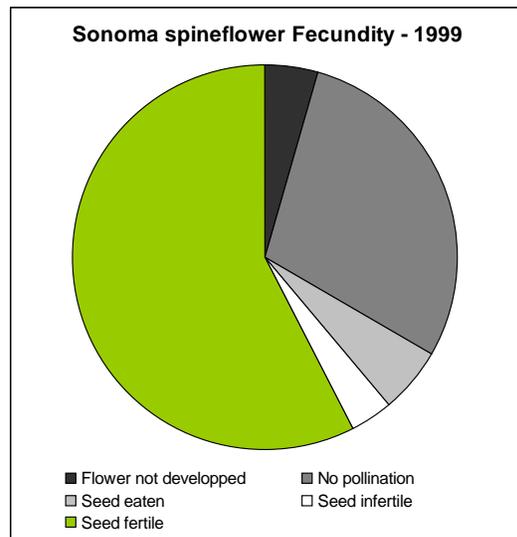


Figure 1. Observed fecundity of Sonoma spineflower (based on Edwards 1999 and RSABG 2000).

Sonoma spineflower appears to be able to reproduce both by selfing and via insect pollinators. Research conducted in 2010 as a part of a Preventing Extinction Grant found that, when pollinators were excluded, an average of $8.7\% \pm 2.5\%$ (S.E.) florets contained seed. Though selfing is possible, seed set was considerably higher in plants open to pollination, averaging $44.4\% \pm 6.9\%$ (S.E.). Pollinator research conducted in summer 2010 found that bumblebees (*Bombus* sp.) were by far the most frequent insect visitors to Sonoma spineflower, visiting 475 plants over during 52 observed visits, followed by honey bees (*Apis mellifera*), with 62 plants visited in 14 visits and bee flies (Bombyliidae), which visited six (6) plants in six (6) visits. It is unknown whether any species of bumblebee is more important than others. During his study, Davis observed yellow-faced bumblebees (*Bombus vosnesenski*), as well as honey bees (*Apis mellifera*), and solitary, ground nesting wasps (*Bembix americana comata*) visiting this species at

the wild population (Davis 1992). Proximity to pollinators- particularly bumblebees- may be an important determinant in the success of Sonoma spineflower introductions, and the ongoing viability of the wild population. Additional information on recent studies of Sonoma spineflower pollinators is detailed later in this report.

Some investigators have hypothesized that that Sonoma spineflower seed is dispersed by small mammals such as badger, pocket gopher and blacktail jackrabbit based on a generic trait of spineflowers (*e.g.*, Davis and Sherman 1992). However, Sonoma spineflower does not have hardened hooked or spreading involucre-tube awns like most of its congeners, which suggests that there is no apparent mechanism for long-range dispersal (Andrea Williams, PRNS, *pers. comm.*). Reintroduced populations have spread only a few meters from their original plots, suggesting minimal dispersal capacity. In addition, the fact that PRNS seed introduction sites that occur anywhere from 200-3,000 meters from the main population have established with some success, but have not expanded much beyond the original seed plot or spontaneously initiated new occurrences, also supports the hypothesis of limited dispersal capacity.

1.2.2. Habitat

The surviving wild population of Sonoma spineflower occurs within California annual coastal prairie grassland on the Sirdrak, Sand soil type, a well-drained Pleistocene dune sand with a 2-4% slope bearing to the north-northwest towards Abbotts Lagoon. Within Marin County, 90% (about 2,300 acres) of the Sirdrak, Sand low-gradient soil type lies in PRNS. Outside of PRNS, there are also soils of this type in the vicinity of Dillon Beach and a small deposit south of Rodeo Lagoon. This soil type is not present in Sonoma County (NRCS 2007).

This soil type has low to moderate water storage capacity and can support only a limited plant community (SCS 1985). These drier soils generally exclude the more mesic perennial species characteristic of the Coastal Grassland bordering the wild population of Sonoma spineflower. However, some of the non-native grassland species invade areas of this soil type that have been highly disturbed (Amelia Ryan, NPS, *pers. obs.*).

It is not known whether Sonoma spineflower is an edaphic endemic, limited to this specific soil type, or whether it once occurred on other soil types and was extirpated from these soil types due to changing land management or invasion by non-native species. Stebbins (1974 *in* Davis 1992) considered *Chorizanthe* to be a recently derived genus of Polygonaceae and a pioneer on xeric sites where little or no competition with other plants occurs. As Sirdrak, Sand probably represents evolving former dune soils that have yet to develop sufficient organic matter and fines to support a more dense Coastal Prairie community, it is possible that Sonoma spineflower has evolved to opportunistically colonize these developing soils, with metapopulations naturally becoming locally extirpated due to interspecific competition with Coastal Grassland species when soils become more fully developed.

As noted earlier, the historic distribution of Sonoma spineflower on the Point Reyes Peninsula is unknown. It was initially assumed that the Elmer specimens with the locality

listing of “Point Reyes Post Office” were collected in the immediate vicinity of the Post Office on F Ranch. Much of F Ranch is Sirdrak, Sand soil and supports a similar plant community to the wild population of G Ranch. It has been the site of successful (re)introduction attempts, and it may well have been the site of Elmer’s collection. However the specimens he collected, all attributed to the Point Reyes Post Office, include grassland, dune, wetland, and forest species, which suggest he collected at several locations around the Peninsula. Thus, though Sonoma spineflower is presumed to have once been more widespread, there is only a single confirmed wild occurrence of this species.

Other rare plant species occur in the vicinity of Sonoma spineflower, including Point Reyes horkelia (*Horkelia marinensis*), large flowered linanthus (*Leptosiphon grandiflorus*), North Coast phacelia (*Phacelia insularis* var. *continentis*), and Gairdner’s yampah (*Perideridia gardneri* ssp. *gardneri*). However, most of these species occur on other soil types that support Coastal Grassland.

1.3 Potential Threats to Sonoma Spineflower

1.3.1. Grazing and other Agricultural Management and Infrastructure

Both the wild and reintroduced populations lie on actively managed beef cattle ranches: the historic G and F Ranches. The impact of cattle on Sonoma spineflower is unclear. As with other *Chorizanthe* (Halligan 1974 in Davis 1992), the plant appears to be unpalatable to cows, and herbivory has very rarely been observed during monitoring (Davis 1992, A. Williams, NPS, *pers. comm.*). Davis hypothesized that the “spines” were a deterrent to grazing for Sonoma spineflower, as they are with other *Chorizanthe* (Davis 1992), but, as noted earlier, this species does not appear to have the hardened involucre of its congeners (A. Williams, *pers. comm.*). While trampling may negatively impact individual plants, a reduction in competition through grazing of non-native grasses, forbs, and shrubs may be beneficial to the population.

In an experiment examining the effects of grazing using cattle exclosures, Davis and Sherman (1992) found a much higher density of Sonoma spineflower in grazed areas, but plants within exclosures were more robust and had greater reproductive output. Recruitment was limited, though, and those populations decreased in abundance after the second year, while abundance of plants subjected to grazing continued to increase, which Davis and Sherman (1992) felt pointed to this species being a poor competitor.

Other agricultural management practices that could pose a threat to spineflower are roads, fencelines, troughs, and associated infrastructure.

1.3.2. Invasive plant species

Invasive species also pose a potential threat to Sonoma spineflower. Earlier PRNS reports (Edwards 1999) identified common velvetgrass (*Holcus lanatus*), yellow bush lupine (*Lupinus arboreus*), and non-native annual grasses as potential threats to the spineflower population.

The population is surrounded by the invasive perennial common velvetgrass on all sides. The outer perimeter of high-abundance velvetgrass areas (greater than 5% areal cover) surrounding the Sonoma spineflower population was mapped in 1999, 2000, 2005, 2006, 2010, 2011, and 2012. No significant changes in velvetgrass extent were evident from the 1999-2000 mapping, and while there did appear to be some encroachment towards the Sonoma spineflower sub-population in 2005, the 2006 mapping effort showed a velvetgrass boundary that was more similar to that occurring in 2000. The common velvetgrass boundary mapped in 2010 was very similar to that mapped in 2006 and did not overlap with the Sonoma spineflower population. In 2011, velvetgrass crept slightly closer to the spineflower population, but there was still no overlap with the 2011 spineflower population boundary. No overlap was evident from the 2012 mapping, either. Velvetgrass mapping is scheduled to occur every five (5) years: the next scheduled event would be in 2017.

When annually mapped boundaries for common velvetgrass are compared to the maximum known extent of the Sonoma spineflower population, there does seem to be an overall downward trend ($R^2=0.47$; Figure 2), but it is difficult to know whether or not this trend is biologically significant, given the potential for both human and GPS unit error. As noted earlier, the boundary of the natural population overlaps remarkably with that of its soil type, Sirdrak, Sand (SCS 1985). This soil type is described as “somewhat excessively drained soil in rolling dune-like areas” sandy with “low to moderate available water capacity” (SCS 1985). The adjacent soil type, much of which is dominated by common velvetgrass, is Sirdrak, Variant, described as “somewhat poorly drained.” This is due to a weakly cemented, discontinuous hardpan or impermeable layer between the depths of 38 and 59 inches. Permeability of this Sirdrak, Variant soil is rapid to a depth of 38 inches and very slow below this depth (SCS 1985). This probably encourages establishment of common velvetgrass, which is a facultative wetland plant species that generally grows in meadows or on moist soils (Hickman 1993, Crampton 1974). The

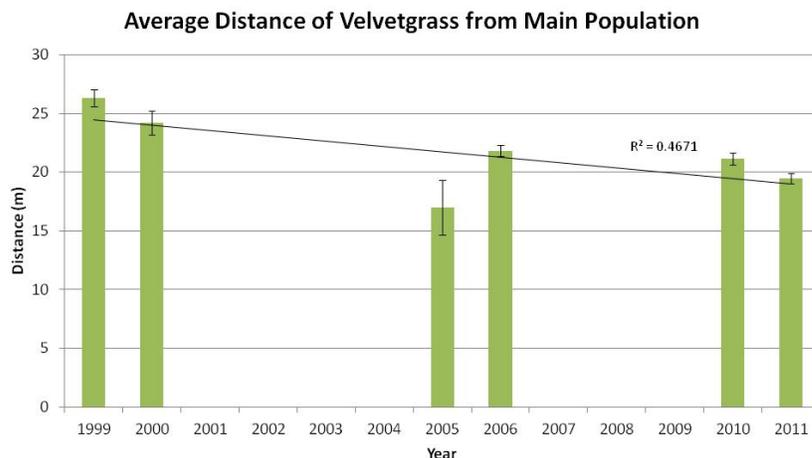


Figure 2. Average distance in meters of the common velvetgrass boundary from the known maximum extent of the Sonoma spineflower population.

past decade of mapping suggests that common velvetgrass is largely restricted to the more mesic Sirdrak, Variant soil type that directly adjoins the Sirdrak, Sand soils that Sonoma spineflower occurs on.

What remains unclear at this point is whether boundary fluctuations reflect cyclical variations

(i.e., suitable soil may extend a bit farther away from the edge of the Sirdrak, Variant soil type on wetter years) or a slow creep into the Sirdrak, Sand habitat (i.e., by slow increase in the soil organic matter making the habitat permanently more suitable).

So, while common velvetgrass may not appear to be a threat – or, at least, the primary threat – at this point, it nevertheless remains important to monitor the velvetgrass boundary, because, with climate change and other factors, it may move into Sonoma spineflower and end up outcompeting this species.

Though still disputed by some, it is likely that yellow bush lupine was originally restricted to south of the San Francisco Peninsula (see discussion in *Recovery Plan for Seven Coastal Plants and the Myrtle Silverspot Butterfly* USFWS 1998). Numerous reports from the latter half of the 19th century discuss the benefits of using yellow bush lupine to stabilize dune sands (i.e., Mallery 1877, McLaren 1899). It may be that it was introduced to Point Reyes to help stabilize the moving dunes of the peninsula and protect grazing lands. In the 1943 aerial photo, shrubs seems to be relatively absent from the Sonoma spineflower site, which is no longer the case. This species is known to facilitate invasion by non-native species -- in particular annual grasses -- by increasing soil nitrogen and organic content (Maron and Connor 1996, Pickart *et al.* 1998). Liam Davis (Davis 1992) reported bush lupine to be present at the site in 1988-1991, but did not record its density. In a 1997 letter to the USFWS, Davis recommended the removal of bush lupine from the spineflower site as a key recovery measure.

Velvetgrass and bush lupine are not the only threats to Sonoma spineflower. Sonoma spineflower occurs in a habitat dominated by non-native annual grasses and forbs (*Festuca bromoides*, *Bromus hordeaceus*, *Aira caryophyllea*, *Cynosurus echinatus*). Both Sonoma spineflower and the closely related *C. pungens* are known to be affected by competition with annual grasses (Davis and Sherman 1992, Zabor 1993 in Kluse and Doak 1999).

A long-term study of a northern California grassland found that years that favor annual grasses alternate with years that favor annual forbs (Pitt and Heady 1978). Maximum standing crop of annual grasses in June was found to be strongly correlated with the mean minimum temperature in November, the time of germination, and positively correlated with the number of days of greater than 0.25 in rainfall in October-November and March-April (Pitt and Heady 1978). In general, studies of California annual grasslands have found that annual grasses do better in years with continuous moisture and do poorly in years where early rains are followed by a period of drought (Pitt and Heady 1978).

Studies of other rare coastal annuals have found climatic variables to be an important determinant of plant establishment success (Parsons and Whelchel 2000, Fox *et al.* 2006, Levine *et al.* 2008). Because we have very little systematically collected data for the natural populations, extrapolations of the effect of multi-year climatic patterns on spineflower abundance are difficult. For example, in 2009, comparing Sonoma spineflower population totals to annual rainfall, we found an apparent strong negative correlation ($r^2 = 0.727$) between population size and rainfall total. In 2010, a year with both high rainfall and high population numbers, this correlation collapsed ($r^2 = 0.103$),

highlighting the pitfalls of assuming relationships without sufficient data.

Using weather data collected between 2005 and 2010, PRNS attempted to build a model of the climatic factors that affect Sonoma spineflower using multiple regression analysis (MRA). The resulting model found spineflower numbers to be negatively correlated with October-December (fall) rainfall, but positively correlated with April-June (spring) rainfall (See Ryan and Parsons 2012 for more details). Incorporation of data from 2011 reduced the R^2 from 0.922 to 0.813, but, even so, the high correlation suggests that the model did identify some important factors, but that it may also be missing one or more important components.

One of those components may be that it's not only intra-annual variation in fall or spring rainfall that matters, but climatic patterns between consecutive years. The years 2005, 2009, and 2010 had the highest spineflower population estimates, and 2006, the very lowest. The years 2005 and 2009 were years of above average rainfall following two years of drought. The year 2009 had high rainfall, but three long periods (5-8 weeks) of very little rain between large rainstorms, one of them being after germinating rains. The year 2010 also had a 4-week drought following germinating rains. The dry periods for two years prior to 2005 and 2009 may have reduced seed production of annual grasses relative to that of spineflower, situating spineflower to take advantage of the above average rainfall periods in 2005 and 2009. In addition, long periods of drought in 2009 and after germination in 2010 may also have reduced competition for Sonoma spineflower within that year (2010). In contrast, 2006 was a very high rainfall year that followed an above average rainfall year, and it had continuous rains throughout the growing season without any periods of drying, which may have represented optimal conditions for annual grasses.

No plant community data is available for 2005 and 2006, but PRNS started to assess vegetation cover within the macroplot in 2010. Appendix B shows the absolute cover of the 28 species that averaged the highest cover over the seven-year sampling period to date (2010 – 2016) and compares them with the cover in the 1989 Davis plots. Non-native plant cover was lower in 2010 than that reported by Davis in his 1989 exclusion plots, as was non-native grass cover (32.9% vs. 50.5% in 1989; Ryan and Parsons 2012). In 2011, however, non-native vegetation cover increased from 56.4% in 2010 to 74.5%, and non-native grass cover also jumped to 52.5% (Ryan and Parsons 2012).

Four of the five most common species over the seven-year period of sampling are non-natives. On years dominated by non-natives, there was higher cover overall, and that increased cover mostly came from non-natives, specifically, non-native annual herb species such as dandelion species (*Hypochaeris*, *Leontodon*), and sheep sorrel (*Rumex acetocella*). Absolute cover of individual non-native species was highly variable from year-to-year (Table 2), especially for annuals. Brome fescue (*Vulpia/Festuca bromoides*; annual non-native) was 43-44% cover in 2011 and 2012, but only 8% cover in 2014. Sheep sorrel (perennial non-native), varied from 9-37% over the seven -year sample period; hawkbit varied from 2-22%; hedgehog dogtail (*Cynosurus echinatus*; annual non-native) varied from 2-35%, and soft chess brome (*Bromus hordaceus*; annual non-native)

varied from 3-23% (though one common annual non-native, ripgut brome-*Bromus diandrus*, was not highly variable over the same period).

During this period, the only years in which natives outnumbered non-natives in terms of relative cover were 2014 and 2015. In both of these years the species with the highest cover was sandmat (*Cardionema ramosissimum*), a native perennial whose absolute cover did not fluctuate as much as many of the other species. The two years with the highest relative native cover had the lowest total absolute cover (138% and 147% compared to 200-300% for all other years), but did not necessarily have higher absolute native cover.

The pattern in 2014 and 2015 versus the other years between 2010 and 2016 is particularly interesting considering that California was well into an extended drought period during those two years. While hard on native species, low rainfall conditions can ultimately benefit them by decreasing establishment of annual and perennial non-native species, many of which respond best in average to above-average rainfall conditions ((Hobbs & Mooney 1991; Dukes & Mooney 1999; (Milchunas & Lauenroth 1995; White et al. 1997 in Alpert et al. 2000). It is perhaps not surprising that, in 2011, when rainfall and non-native cover were high, spineflower abundance was low, dropping from 958,380 to 370,940 (Ryan and Parsons 2012). The abundance of non-native species and, in particular non-native grasses, in a given year may be an important determinant in the density of Sonoma spineflower, given the potential for competition.

In future years, it would be interesting to compare both plant community composition (especially non-native annual grasses) and spineflower population estimates to seasonal rainfall totals for each year to see if, as others have found (Pitt and Heady 1978; see discussion in Section 1.3.2), heavy early rainfalls lead to higher cover of non-native grasses and lower cover of natives in general and Sonoma spineflower in particular.

1.3.3. Seedbank dynamics

Another inter-annual factor that could affect spineflower abundance between consecutive years is the amount of seedbank from the previous year (Ryan and Parsons 2012). Unlike some species that only germinate in favorable years, one of spineflower's congeners, *C. pungens*, has been found to have a short-lived seedbank that germinates readily under varying conditions, with seedling abundance perhaps more dependent on seed set the previous year than climatic conditions during the current year (Fox et al 2006). Though they found a weak negative correlation between winter rainfall and spineflower seedling abundance, a higher percentage of seeds germinated in these conditions, and they suggested the negative correlation was an artifact of seed set in the previous years (Fox et al 2006). Seed viability tests of Sonoma spineflower have found this species to have extremely high germination rates with no special handling required, suggesting Sonoma spineflower may likewise have a short-lived seedbank, although seed under laboratory conditions germinated 92%-100% even after 10 to 20 years. The number of these seedlings that survive to flower/seedset -- when the population is estimated -- may depend a great deal on competition. Thus, spineflower abundance in a given year may

reflect both competition and survival to seedset the previous year, as well as competition/survival in the present year. See Section 1.4.8 for more discussion of PRNS studies on seedbank dynamics.

1.4 Management History

Historical management of Sonoma spineflower has focused on three primary strategies: monitoring of the existing wild population and of potential threats, introduction and monitoring of new occurrences; research studies; alterations to grazing or other ranching practices; removal of invasive or weedy species; and seed collection for long-term accession at selected botanical facilities.

1.4.1. Monitoring

Between 1980 and 2001, PRNS staff and volunteers from the local California Native Plant Society estimated the numbers of individual plants within the wild population at irregular intervals. Starting in 2001, PRNS staff conducted trials of various sampling methodologies and approaches at the wild population in an attempt to establish a more rigorous quantitative monitoring program. Between 2001 and 2004, PRNS and staff from the NPS Inventory and Monitoring Program explored a number of sampling approaches varying in quadrat size and shape and sampling strategies (*e.g.*, stratified random, subjectively placed to represent different density groups), but none appeared feasible based on apparent accuracy in reflecting total Sonoma spineflower numbers or the ability to later statistically analyze data. As the result of 2004 trials, in 2005, PRNS staff and their partners designed a quantitative sampling monitoring program within a 40m x 100m macroplot within the wild population to estimate number of plants per year. This sampling program has been conducted every year since 2005. This method is described in more detail in section 2.3.

1.4.2. Introduction of New Populations and Sub-Populations

Since 1988, the Seashore has conducted at least four separate efforts to reintroduce Sonoma spineflower. See Appendix A for a detailed map showing seed plot location as of 2011. Through these efforts, a total of 12- 2m² experimental seed plots of 1,000 seeds each were established for the purpose of creating new populations.

The first experimental seed plots were installed in 1988 near the extant population (Seed plots X, Y, Z; Davis and Sherman 1992). Though these sites were within a few hundred yards of the main population and on areas of similar topography, only plot Y was located on the Sirdrak, Sand soil type, at least based on the current soil map for Marin County (SCS 1985). Plots X and Z were located on Sirdrak, Variant, a less well-drained soil.

In 1999, two more seed plots (G1, G2) were installed on Sirdrak, Sand near plot Y, the only successful prior introduction plot at that time. At the same time, another plot called the “dune” plot was installed on a stabilized dune (soil type Dune lands) to the north of Abbott’s Lagoon, following consultation with former USFWS biologist Peter Baye. Baye suggested that the Sonoma spineflower, like other spineflower species, may grow in other sandy habitats with natural disturbance (wind, slope erosion), but is presently isolated by

unsuitable or competitively disadvantageous habitats and has no mechanism of transport to suitable sites. Baye further suggested that establishing seed plot over a wide range of habitat types would identify possible habitats for introduction and expansion of its range. However, no adult plants were produced from seeds sown in the dune plot, even during the first year (PRNS, unpub. data). This is the only documented trial of introducing this species to younger dune soils.

As noted earlier, herbarium data indicate that the species was historically present in the vicinity of Bull Point on F Ranch, nearly 1 mile south of the main population (Davis and Sherman 1992). In 1999, the first plot (F1) was installed at Bull Point. In 2000, two more seed plots were installed (F2, F3), and another three were installed at the site in 2002 (F4, F5, F6).

In early 2011, five new experimental introductions were implemented as part of a Preventing Extinction grant from USFWS. Rather than relying on “gestalt” or best professional judgement on the part of park staff or other biologists, this study attempted to approach the habitat suitability analysis for future introductions using soil type and grazing/disturbance regimes as screening factors and then collecting both biotic and abiotic (e.g., soils) information on both existing spineflower populations and potential introduction sites. This data was then incorporated into Non-Metric Multidimensional Scaling (NMS) multivariate statistical analysis, a robust not-parametric ordination technique, and the list of potential introduction sites was refined by selecting those sites that appeared fell closest to the most successful existing spineflower sites in terms of biotic and abiotic conditions. In fall 2011, these experimental introductions were augmented with additional seed, and five additional plots were established. The success of these introductions is discussed later in this report.

Park staff continued to use this model in later years to drive siting of additional introduction attempts. In winter 2015, two new introduction plots were installed at Schooner Creek and F Ranch directly adjacent to two very successful earlier introductions at these areas, G3 and F5, respectively. Additionally, while scouting for the 2014-2015 introduction sites, another potential introduction area was identified just south of the Abbotts Lagoon Trail in the Evans Ranch lease. This area appeared very similar to the wild population in terms of soil type, plant cover, species assemblage, and general biotic conditions. In fall 2014, soil samples and plant community information were collected from two spots in this location and soils were sent for analysis at A&L Western Ag Laboratories (Modesto, CA).

Relationships between the sites based on soils and plant communities were explored using NMS, as before. The NMS analysis (Figure 3) indicated that one of the two potential Abbotts Lagoon introduction plots, the more southern of the two, was very similar in soil composition to one of the wild population site samples. However, both plots fell within the range of the wild population in terms of biotic and abiotic conditions, so both sites were chosen for attempted introductions. These introductions were conducted in the winter of 2015-2016 and are discussed in more detail later. The success of more recent introduction attempts is also discussed in more detail later in this

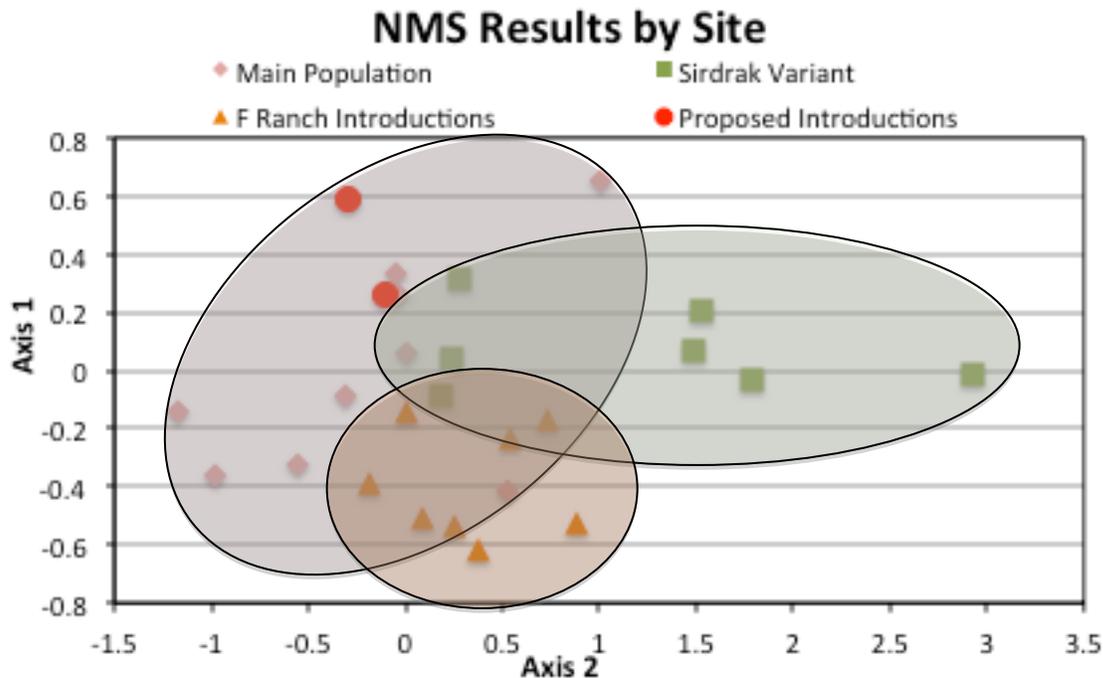


Figure 3. NMS results showing similarity of sites based on soils samples at two proposed introduction sites (red circles) compared with the main (wild) population (pink diamonds), earlier F ranch introductions (orange triangles), and Sirdrak variant soils which do not support Sonoma spineflower (green squares).

document.

1.4.3. Grazing and Ranching Management

Over the last few decades, PRNS staff has worked with the Lunny Family to make several changes to grazing and agricultural infrastructure to benefit the Sonoma spineflower population. New fencing has been deliberately located far enough away from the Sonoma spineflower population, so that any potential impacts from cattle associated with fencing (e.g., congregating and rubbing on fences) is situated away from these sensitive resources (Figure 4). At one point, there had been discussion about splitting the pasture in which Sonoma spineflower occurs into three smaller pastures, but this change was never implemented. This change in grazing regime could potentially have beneficial effects on the natural population and some of the introduction sites by removing cattle during flowering and seed set (February 15 – August 1).

Agricultural infrastructure can also impact population viability. For decades, a two-track ranch road ran through the center of the natural population, bisecting it and increasing the potential of mortality through crushing by ATV and truck vehicles. Aerial photos flown in 1943 show the road was well established at that time (Figure 4). This road was used actively for ranch activities until recently. While the road would appear to have the potential to impact this species, related species such as *Chorizanthe pungens* are often found along roadsides and other disturbed sites (USFWS 1998, McGraw and Levin 1998), possibly because the road creates gaps in the dominant coastal shrub cover. A

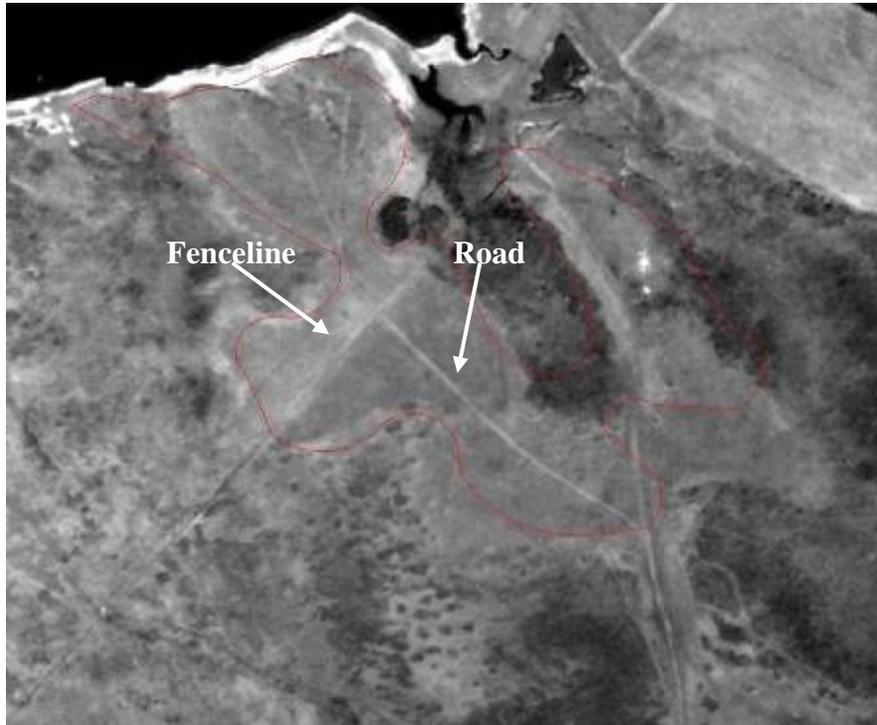


Figure 4. 1943 aerial photo showing the Sonoma spineflower natural population site. The boundary of the Sirdrak, Sand soil type is outlined in red.

comparison of plant abundance inside and outside the road footprint showed the road area had significantly less Sonoma spineflower than adjoining non-road areas (paired samples t-test, road vs. immediately adjacent, $n=33$, $p<0.0001$; Figure 5). In December 2010, PRNS worked with contractors to re-align the road, which included installing motor vehicle barriers and creating a new two-track alignment at least 50 feet outside of the Sonoma spineflower population boundary.

In 2011, the first year since road relocation, average plant density in the former road bed did not differ significantly compared to 2010 (57 ± 7 S.E. plants/m² vs. 67 ± 16 S.E. plants/m², respectively). When overall site density is taken into account (by dividing road density by average macroplot density), the road site had significantly higher similarity to the macroplot average (Ind. samples t-test, $p<0.01$). Despite decades of use, some recovery of the former roadbed already appeared to have occurred after only one year. Future monitoring will determine whether this site recovers altogether. Data has been collected on spineflower density both within and outside of the road corridor since 2010, but data has not been analyzed due to lack of resources.

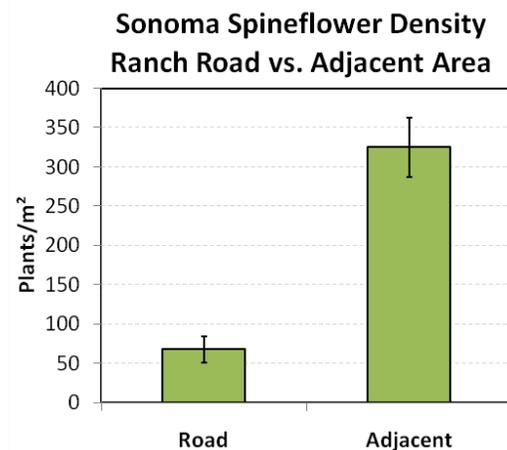


Figure 5. Pre-restoration conditions: road effects on spineflower density.

1.4.4. Invasive Species

Because bush lupine has appeared to pose a greater threat at this time to Sonoma spineflower than common velvetgrass, removal efforts were undertaken in 2010 and 2011 to eradicate some of the medium- and large-sized shrubs using funds from the USFWS Preventing Extinction grant. These medium to large-sized shrubs numbered from several hundred to a few thousand individuals. The ultimate goal of controlling bush lupine cover at the site at <1%, and Management Objectives call for an increase of no more than 10% over a two-year period.

Approximately 98-99% of individuals with stem diameter >0.5 cm were removed from the spineflower site and the adjacent Sirdrak, Sand soils. Total area covered -- including the spineflower site and adjacent areas -- was a little more than 10 acres. Initial work was completed in December of 2010. Another round of removal occurred in August 2011, after site monitoring and after seed set. As in 2010, 98-99% of individuals with stem diameter >0.5 cm were removed from the spineflower site.

The first phase of removal efforts in 2010 resulted in a drop in percent cover of bush lupine from 4% in 2010 to 2% in 2011 (Ryan and Parsons 2012). In 2012-2013, cover of bush lupine still exceeded target goals, but cover had seemingly dropped or remained equivalent to 2011. In 2012, bush lupine cover was estimated to cover approximately 1.0% of the wild population. In 2013, the percent cover increased slightly to 1.5%, which technically represented a 50% increase. Because of this, PRNS applied for and received a small grant from the USFWS for removal of bush lupine and coyote brush (*Baccharis pilularis*), which had also expanded within the wild main population boundaries. Removal efforts were undertaken in fall 2014, 2015, and 2016, with the ultimate goal of controlling bush lupine cover at the site at <1%.

Until 2014, no invasive plants had been removed since 2011. The first phase of removal efforts in 2010 resulted in a drop in percent cover of bush lupine from 4% in 2010 to 2% in 2011 (Ryan and Parsons 2012). The ultimate goal of controlling bush lupine cover at the site at <1%, and Management Objectives call for an increase of no more than 10% over a two-year period. In 2012-2013, cover of bush lupine still exceeded target goals, but cover had seemingly dropped or remained equivalent to 2011, even without active removal. Plant community monitoring data shows that 2014 removal effort resulted in an even more dramatic decrease in bush lupine cover than after 2010 removal efforts, from 3.2% to 0.2%, a decrease of 94%. In 2015, bush lupine had dropped to <0.01% cover. However, in 2016, cover increased back up to 2.1%.

During some of this same period (2010-2013), coyote brush also increased in the grassland, nearly doubling in cover from 2.6 to 4.8%. Comparison of mapping in 1999 and 2015 also reflect an increase: total cover in the main and sub-populations of coyote brush increased from 584 m² to 1370 m² (PRNS internal mapping data). This species is undisputedly native to the area, but appears to be increasing at the site as well, possibly due to changes in grazing regime. Once established, however, this species has been shown to facilitate the conversion of grassland into shrubland, a potential significant threat to Sonoma spineflower.

Examination of four samples collected beneath coyote brush during the seedbank study (Section 3.7) found no fresh Sonoma spineflower seedbank (indicated by involucre still red) in the upper soil layer in areas with coyote brush, though one sample on the edge of a bush had older darker seeds in the sample, probably from before the bush expanded. This suggests that the presence of coyote brush suppresses Sonoma spineflower and that coyote brush expansion could potentially reduce available habitat for the spineflower.

Coyote brush removal did not occur until 2015. Removal reduced aboveground coyote brush cover in the main population area by 60 percent, based on mapping immediately afterwards, but by summer 2016, much of the apparently removed coyote brush had vigorously resprouted from buried roots or branches, and plant community cover monitoring found that the percent cover of coyote brush had actually increased. It is possible that the incomplete removal of the coyote brush actually stimulated growth in response. Because only a small amount of funding remained in this project, removal efforts in the fall of 2016 concentrated primarily on bush lupine removal, as this was less time consuming and seemed more effective.

1.4.5. Seed Accession

Sonoma spineflower faces potential extinction because it has only one extant natural population. To mitigate against the threat of extinction, seeds have been collected by PRNS staff from the wild population and are preserved in cold storage at RSABG.

The first accessioning efforts took place between 1990 and 2000. In 1990, 418 seeds of Sonoma spineflower were accessioned for long term storage. In 1999 and 2000, an additional 1,184 and 2,439 seeds, respectively, were accessioned. In total, 3,987 seeds from this earlier collection period are under storage at RSABG. Three germination trials were performed in 2000 on 49-50 seeds from each year collected, with germination rates varying from 94-100% germination, even with seeds that were at least 10-years-old (RSABG 2000). In 2010, viability of 20-year-old seeds were tested, and 100% of the seeds germinated (M. Walls, RSABG, *pers. comm.*).

In November 2010, as part of the USFWS Preventing Extinction grant, PRNS staff sent 434 seeds of Sonoma spineflower to the University of California Botanical Garden for processing. Based on yearly monitoring that estimates size of the natural population, there were well in excess of 1,000,000 plants in 2011, so the removal of 24 plants following seed set for seed banking was not felt to threaten the survivorship or genetic diversity of the natural population. Of these, 327 seeds from 17 mothers came from the natural population at G Ranch, and 107 from seven mothers came from the F Ranch reintroduction site. After processing, 50% of these seeds were sent to the RSABG facility and 50% were sent to the National Center for Genetic Resources Preservation (NCGRP) in Denver, Colorado: by sending seed to two different facilities, PRNS ensures that these resources are not completely lost in case one of the facilities is destroyed during a catastrophic disaster such as fire.

1.4.6 Preventing Extinction Project

In 2009, Point Reyes National Seashore received a grant from the USFWS to take steps

to prevent possible extinction of Sonoma spineflower by improving habitat and establishing new introduction sites (Improvement of Habitat and Reintroduction of Sonoma spineflower at Point Reyes National Seashore, Agreement NO: 81420-9-H535). This project included five components:

- a) realignment of the historic ranch road that bisects the wild population (see *Grazing and Ranching Management* above),
- b) removal of bush lupine from the wild population and immediate vicinity (see *Invasive Species* above),
- c) habitat assessment through analysis of soil and other physical and biological variables to generate information that was used for planning new Sonoma spineflower introduction attempts;
- d) collection of seed of Sonoma spineflower and other endangered species at PRNS for continued accession at either RSABG or other facility (see *Seed Accession* above).
- e) establishment of new introduced populations or sub-populations through sowing of seed (see *Introduction of New Populations and Sub-Populations*);

Most of these activities were completed in 2010 or early 2011 and are covered in the *Preventing Extinction of Sonoma Spineflower (Chorizanthe valida)* Report (Ryan and Parsons 2012) already submitted to the USFWS.

1.4.7 Pollinator Study

The "health" of the pollinator population can affect the viability of a species such as Sonoma spineflower without adequate pollination, not enough seed may be produced, which could adversely impact a species' reproductive success and lead eventually to extinction of individual populations or even an entire species. Inadequate pollination can also limit the success of new introductions by reducing seed output. Adequate pollination relies not only on the number of pollinators present, but the number of effective pollinators. Ultimately, inadequate or ineffective pollination can have potentially adverse consequences for genetic diversity within special status plant species by eliminating reproduction within obligatory outcrossing species or forcing self-compatible species to self-pollinate more, which has strong implications for heterozygosity.

Sonoma spineflower is somewhat of an anomalous species. Despite its name, it no longer occurs in Sonoma County, and it's unclear whether it ever actually did occur there. It was believed extinct until members of the California Native Plant Society (CNPS) found a single population at G Ranch within Point Reyes National Seashore (Seashore) in the 1980s. Needless to say, existence of only a single population has broad implications for the long-term viability for this species, with the spineflower being much more vulnerable than its more common congeners such as San Francisco Bay spineflower (*Chorizanthe cuspidata* var. *cuspidata*; CNPS 1B.2) to threats from environmental degradation, stochastic events, genetic issues, and changes in climate related to global warming. Extremely limited species' distribution can also wreak havoc on pollinator-plant relationships, particularly for pollinators that may "specialize" on particular plant species, with low plant numbers resulting in sharp declines in pollen and nectar supply that then

may encourage pollinators to shift to other plant species or possibly even cause localized extinction of specialized pollinators.

While little information has been collected on pollination ecology of Sonoma spineflower since the G Ranch was found, some studies have been conducted on other spineflower species. Wasps, bees, flies, and butterflies constituted the principal insect visitors to *Chorizanthe pungens* var. *hartwegiana* (Ben Lomond spineflower; USFWS 2001). Moldenke (1976) observed several different types of insects visiting *Chorizanthe* flowers, including wasps, bee flies, unspecified tiny species of insects, and generalist bees. A large diversity of insects visited robust spineflower (*Chorizanthe robusta* var. *robusta*) both at a coastal scrub population (Sunset Beach) and a more inland woodland-chaparral location (Pogonip) in Santa Cruz County, with bees, beetles, flies, wasps, and moths observed (Murphy 2003). Within the larger taxonomic orders, there was also a lot of diversity, with 14 insect families at Sunset Beach and 13 families at Pogonip considered “frequent” visitors to robust spineflower. Bees or hymenoptera accounted 40% of all flower visits at the more coastal Sunset Beach site and 61% of all visits to the more inland population (Murphy 2003). Halictine or metallic bees accounted for a large proportion of the bee visitors observed at the coastal site, with far fewer visits by honeybees and bumblebees (*Bombus*; Murphy 2003). While Hymenoptera represented a larger proportion of the total visitors at the inland population, most of the visitors actually were wasps, not bees, with halictine and bumblebees relatively low in number comparatively (Murphy 2003).

Recent studies completed on a southern California species, *Chorizanthe parryi* var. *fernandina* (San Fernando Valley spineflower), indicated that five insect species accounted for about 75% of the visitors at one population (Newhall; *Apis mellifera*; two species of ants; two species of beetle), while another species, the small red ant, alone constituted almost 40% of the visitors to the other population (Newhall; Jones *et al.* 2009). Native bees were observed infrequently at either site during the study (Jones *et al.* 2009).

In 2009, Point Reyes National Seashore received a grant from the USFWS to take steps to prevent possible extinction of Sonoma spineflower by improving habitat and establishing new introduction sites (Improvement of Habitat and Reintroduction of Sonoma spineflower at Point Reyes National Seashore, Agreement NO: 81420-9-H535). This project included five components, one of which involved a detailed study of biotic and abiotic variables for the different natural and introduced populations to improve evaluation of potential future introduction sites. One of the biotic variables studied was pollination ecology of Sonoma spineflower.

During this study year, the primary insect visitors to spineflower at both the natural and introduced observation sites were bumblebees (Hymenoptera; Apidae; Anthophoridae; *Bombus*); honeybees (Hymenoptera; Apidae; Anthophoridae; *Apis mellifera*); bee flies (Bombyliidae); and ants (Hymenoptera; Formicidae; Ryan and Parsons 2011). This list corresponds well with the list of visitors observed by Davis (1992), a former Seashore employee who characterized the insect visitors during his study on the effect of grazing

on Sonoma spineflower. In that particular year, *Bembix americana comata* (solitary ground nesting wasp), *Bombus vosnesenkii* (yellow-faced bumblebee), and *Apis mellifera* represented the most common insect visitors to the natural or “wild” spineflower population (Davis 1992).

The pollinator studies conducted as part of the Preventing Extinction Grant study primarily identified species to functional groups (bee, fly, ant, etc). In 2013, the Seashore issued a research permit to Brad Kelly of CNPS to conduct a more detailed survey of pollinators of Sonoma spineflower in the wild population and introduced populations. His survey efforts found that a variety of insects, including a number of bumblebee species, ants, tiny beetles, flies, solitary bees, and wasps. Bee visitors included species in the genera *Bombus*, *Melissodes*, *Colletes*, and *Lasioglossum*. Five species of *Bombus* were observed: *B. vosnesenskii*, *B. caliginosus*, *B. bifarius*, *B. melanopygus*, and *B. californicus*. In addition, solitary wasps such as *Bembix* were often observed nectaring on Sonoma spineflower. Other visitors to Sonoma spineflower included some flies (Diptera), possibly in the Bombyliidae (beefly) family, and butterflies such as *Plebejus icarioides parapheres*.

Though *Bombus* are very numerous and probably the most frequent visitor to Sonoma spineflower, it is unclear that they are the prime pollinator in all cases (Kelly, unpub. data). *Bombus* are recognized as especially effective pollinators of “buzz-pollinated” plants like tomatoes, manzanita, and shooting star, where the morphology of the bee and the flower contribute to pollination (ibid). In those cases, the bee hangs under the flower and buzzes the pollen onto its ventral surface where the stigma can pick up pollen from visits to other flowers (ibid). When visiting Sonoma spineflower, they often already have full pollen loads from lupine and are mostly nectaring (ibid).

Smaller bees that crawl across the surface collecting pollen and nectar might prove more effective at pollinating this flower (Kelly, unpub. data). It might be that the continued expansion of the introduced population at Coast Guard Road/Schooner Creek -- at a time when other spineflower populations appear to have been severely impacted by the drought -- is partially due to higher numbers of more effective pollinators. Two species of small *Lasioglossum* bees were observed on Sonoma spineflower at the main G Ranch site (wild population) and at one of the new introduction sites at the Coast Guard Road or Schooner Creek site (ibid). At the Coast Guard Road/Schooner Creek site, they were observed in large numbers on the flowers when the temperature warmed up and appeared to be collecting both nectar and pollen (ibid). Kelly noted that these small bees might be a very effective pollinator of Sonoma spineflower (ibid). If that is the case, it might be possible to encourage nesting in the area of other populations.

The Seashore received funding from USFWS in 2014 to conduct further pollinator studies in 2015. The study was intended to build upon the information collected by previous National Park Service studies and more recent surveys by Kelly by determining whether there were differences in the suite of pollinators present at each of the existing spineflower sites and whether the presence of certain pollinators may be associated with better reproductive performance. If so, these differences would need to be taken into

account when selecting introduction sites. Monies from the USFWS funded hiring of a contractor with a background in entomology to conduct more quantitative pollinator watches that assessed the number of visits by individual insect species. In addition, in 2014-2015, Mr. Kelly continued to survey insects present at the G Ranch, F Ranch, and Schooner Creek sites.

Our efforts to better understand pollination ecology of this species were hindered, to some degree, by climate-related factors. At the time of the surveys in summer 2015, California was considered to be in the fourth – and seemingly driest – year of a four-year drought. While rainfall totals for 2012 and 2013 appeared average, both years were considered much drier than normal from a statewide perspective. Conditions became even drier in 2014 and 2015. While rainfall totals seemingly increased in 2015 relative to 2014, most of this increase came from torrential rains in December 2014, and the late winter/early spring was one of the driest periods on record, with the state of California declaring a Drought State of Emergency in January 2015.

There were some striking similarities – and dissimilarities – between surveys conducted in 2010 and 2015. In 2010, the majority of insect visits within the Sonoma spineflower pollinator observation sites came from bumblebees, which also accounted for a disproportionate number of the spineflower plants visited within the plot (Ryan and Parsons 2011). Of the total visits to observation sites in 2010, bumblebees totaled 51 visits; honeybees, 14 visits; beesflies, 6 visits; and ants, 2 visits (ibid). The numbers become even more disproportionate when looking at total number of spineflower plants visited by different species, with bumblebees visiting a total of 475 spineflower plants at all observation sites; honeybees, 62 plants; and beesflies, 6 plants (ibid).

In 2015, the diversity of visitors to spineflower expanded dramatically relative to 2010. In 2010 surveys, only four species were observed visiting Sonoma spineflower: in 2015, that number jumped to 28. The number of insect species visiting per plot averaged 3.7 ± 0.6 (S.E.) in 2015, compared to 1.5 ± 0.6 (S.E.) in 2010 (GLM, $df=1$, $F=7.2$, $P=0.011$; log-transformed). This change may relate, in part, to the fact that the number of monitoring sites expanded in 2015 to include Schooner Creek, AT&T, and the G Ranch Introduction sites as well as F Ranch and G Ranch Main/Sub-Population, but other factors probably played a role, as well, including doubling of the observation time (from 45 to 90 min) and hiring of a more highly trained person to conduct surveys in 2015. In contrast, the mean number of visitors per plot remained equivalent (GLM, $df=1$, $F=0.2$, $P=0.63$, log-transformed). On average, 4.5 ± 1.0 (S.E.) insects visited spineflower plants in plots in 2010, while 4.1 ± 0.9 (S.E.) visited plants in plots in 2015: visitor numbers were adjusted in this analysis to account for differences in observation. In essence, then, in 2010, there were fewer species visiting spineflower, but, on average, there were more of those four taxa than of all the 28 taxa observed visiting in 2015.

Visitors to Sonoma spineflower in 2015 spanned a very broad number of taxonomic orders, including Hymenoptera (bees, wasps, and ants), Diptera (flies), Coleoptera (beetles), and Lepidoptera. One glaring difference between 2010 and 2015 in terms of insect visitors to spineflower is the utter absence of honeybees in 2015, which

represented the second highest visitor to this species in 2010 (Ryan and Parsons 2011) and was a prevalent visitor in the 1992 study (Davis 1992). These results are particularly interesting, given what has been occurring with the collapse of managed honeybee populations across the United States in recent years due to factors such as parasites, fungi, viruses, pesticides, declining plant diversity, and interaction between some or all of these factors (Harvard Kennedy School 2015). While most of the research has been focused on managed honeybee populations, wild populations also appear to be on the decline: one Ohio State University researcher, Dr. James Tew, proclaimed that honeybees in the wild in North America have been virtually wiped out by recent climatic conditions and two parasitic mites (Kershner, Ohio State University, no date). Kelley notes that it's possible that honeybee populations near Sonoma spineflower may have succumbed to the drought or to some of the other factors affecting other managed and wild honeybee populations in North America.

A complete description of the findings from this study can be found in the complete report in Appendix C (Parsons and Ryan 2016).

1.4.8 Seedbank Study

Prior to the Preventing Extinction project (Ryan and Parsons 2011), very little was known about the life cycle of Sonoma Spineflower. Demographic studies were conducted as a part of that project which followed the plant species from seedling to seed-set. One component missing from that study was the characterization of the seed bank of Sonoma spineflower, about which there is very little information. Prior introduction efforts have revealed that this species can live for at least two years in the soil and that seeds kept in cold storage germinate readily even after 20 years (Ryan and Parsons 2011). Collecting seed bank information is a key component in performing a population viability analysis, and gives us a better understanding of the species as a whole.

Soil samples collected had 600 involucre on average, but only 41% of those involucre contained seed. Of those with seed, 56% appeared to be from the same year (red in color), while 44% were black or gray, which was interpreted to mean that they had overwintered. Newer seed (red involucre) averaged 1,107 seeds/m² (1,021-1,193 95% C.I.), and older seed averaged 867 seeds/m² (801-933 95% C.I.), with a total of 1,975 mean seeds/m².

In 2014, population sampling estimated the density of plants within the macroplot as 59 (42-76 95% C.I.). In 1999, 2010, and 2011, seed output was totaled for 50-150 plants. Mean seed output ranged between 30-33 seeds per plant, averaging 31. Based on these numbers, one might therefore expect a seed density in the macroplot of ~1,828 seeds/m² (1,309-2,347 95% C.I.) This is actually quite a bit higher than the actual density of seeds found in the upper 2 inches (5 cm) and supports the idea that the red seeds could very well represent only the current year's seeds. However, as noted earlier, only the upper 5 cm of soil were sampled as a part of this study. Therefore, the actual seedbank may be a little higher.

A higher proportion of older (black) involucre were empty (1:1.6 black full:empty)

compared to 1:1.2 for red), which would be expected as some of the filled ones germinated in year past. One might expect even higher proportion to be empty involucres, but some of the seed in the black involucres may be no longer viable, yet persisting in the soil. Seeds associated with black involucres seemed to be more brittle and prone to disintegration (Amelia Ryan, NPS, *pers. obs.*).

A preliminary look at Population Viability Analysis using the RAMAS Software found that, as the majority of the seedbank is from the year before, the Sonoma spineflower trajectory (population growth or extinction) was extremely sensitive to the percent of seeds that germinate on a given year and the percent of those seeds that remain viable in the seedbank for a second or third year. A change in the percent of seed that germinate on a given year by as little as 1-2% was the difference between population growth and extinction.

The seedbank study illuminated that the majority of seed seems to be from the same year as sampling occurred. Further, older seed often seemed less viable. Preliminary population viability analysis suggests that the continued viability of this population may be very tenuous, depending on seed viability of older and newer seed and the percent of new seed that germinate on a given year. Overall, this study was very useful, as the composition of the seedbank highlights a potentially large obstacle to the long-term viability of this species. Further study on the viability and percent of seeds germinating would allow a full population viability analysis.

A complete description of the findings from this study can be found in the complete report in Appendix D (Ryan 2016).

2.0 Objectives and Methods

2.1 Draft Management Objectives

The primary objective of the Park Service in its management of the only known population of Sonoma spineflower is recovery as outlined in the U.S. Fish and Wildlife Service (USFWS) Recovery Plan (1998). In addition, the NPS policy on management of Threatened or Endangered Plants and Animals (NPS 2006, Section 4.4.2.3) requires PRNS staff to survey for, protect, and strive to recover all species native to national park system units that are listed under the Endangered Species Act. The Park Service will fully meet its obligations under the NPS Organic Act and the Endangered Species Act to both proactively conserve listed species and prevent detrimental effects on these species. To meet these obligations, the Park Service will cooperate with both the USFWS and National Marine Fisheries Service (NMFS) to ensure that Park Service actions comply with both the written requirements and the spirit of the Endangered Species Act.

The Recovery Plan that includes Sonoma spineflower lists the following criteria for its downlisting (USFWS 1998):

1. Habitat occupied by the species that is needed to allow delisting has been secured, with long-term commitments and, if possible, endowments to fund to conservation of the native vegetation,
2. Management measures are being implemented to address the threats of invasive species and other problems, including grazing, pedestrians, and off-road vehicles at some sites.
3. Monitoring reveals that management actions are successful in reducing threats of invasive non-native species.
4. Additional restored habitat has been secured, with evidence of either natural or artificial long-term establishment of additional populations, and long-term commitments (and endowments, where possible) to fund conservation of the native vegetation.
5. Management plans must be approved and implemented for the one population, and
6. Two additional populations have been established and sustained with long-term management.

To be delisted Sonoma spineflower (and the other plant species included in the recovery plan) must meet the following criteria (USFWS 1998):

- Full recovery of these taxa will be achieved when the dune systems they inhabit are secure, with experience to demonstrate that exotic plants and other threats

(recreational use, off-road vehicles, etc.) are controlled and managers have demonstrated their ability to keep the threats under control.

- The taxa need to be secure in their presently-occupied ranges, and opportunities should be taken to introduce these plants to restored habitat in or near historic ranges. To be counted toward recovery, (re)introduced populations should be naturally reproducing in vegetation that also appears to be persisting without excessive maintenance or “gardening.”
- The area occupied by the plants should increase commensurate with improving habitat conditions. The determination that delisting is possible must be based on at least fifteen years of monitoring for the endangered taxa, to include wet and drought years.
- For some of the species, aspects of demography and population biology must be understood to be assured that populations are likely to persist. The species can be considered for delisting when sites are secure from habitat modification (development), occupied habitat is stable or improving and free of weed invasion.

PRNS had, therefore, previously identified the following management objectives to meet each of the above criteria identified in the Recovery Plan (USFWS 1998):

1. *Maintain the number of flowering Sonoma spineflower in the main (“wild”) sub-population at “G” Ranch in Point Reyes National Seashore at or above 30,000 individuals during “wet” periods (years when rainfall exceeds 25 inches annually): this number corresponds to approximately 50% of individuals present during the “wet” year of 2006. During dry years (years when rainfall falls below 25 inches annually), the wild population would be maintained at or above 300,000 individuals (mean for “dry” years – 1 S.D.) during “dry” years. If populations fall below these numbers for three consecutive years, management actions will be triggered to support the population. (Criterion 5)*
2. *Maintain the wild Sonoma spineflower population areal extent at least within -1 SD of the average acreage measured during monitoring conducted between 1999 and the present. This would correspond to approximately 2.0 acres. If the areal extent falls below 2.0 acres for at least three consecutive monitoring cycles, management actions will be triggered to expand the population through active seeding and other efforts (Criterion 5).*
3. *Prevent the encroachment of *Holcus lanatus* (common velvetgrass) on the perimeter of the sub-populations (Criteria 2 & 3). If the common velvetgrass perimeter overlaps with more than 10% with either wild or sub-population area (at its greatest extent) for more than two consecutive monitoring cycles, management actions will be triggered to remove common velvetgrass in areas where encroaching on the population and possibly in other areas along the perimeter.*
4. *Prevent further invasion or increase in *Lupinus arboreus* (bush lupine) or coyote brush (*Baccharis pilularis*) within the main population (Criteria 2 & 3) by maintaining its frequency at or below 2010 levels (or at or below 2009 pilot data*

frequency of 0.6). If bush lupine increases substantially in frequency (10%) during two consecutive monitoring cycles, management actions would be triggered to remove the shrub from the wild population.

5. *Maintain abundance of Sonoma spineflower within at least four of the most successful previous introductions at or above 25% quartile of the median plant count within approximately the first 10 years after introduction. The most successful historic introductions to date have been Populations Y (est. 1988), G1 (est. 1999), F2 (est. 2000), F5 (est. 2002), and F6 (est. 2002): at the time the Management Objectives were refined, the 2011 introductions were considered too recent to be incorporated. If any of the four most successful introductions have plant numbers that fall below the 25% quartile of the approximately 10-year median plant abundance for three consecutive years, management actions would be triggered to bolster these introduced populations through additional seeding and other management efforts.*
6. *Introduce at least two more populations successfully, with successful being defined as supporting plants for three or more consecutive years within the first five years after introduction.*
7. *Determine the optimal timing and duration of grazing on Sonoma spineflower and develop guidelines to trigger management (Criterion 2) using residual dry matter (RDM) protocols.*

It is not clear that the natural habitat of Sonoma spineflower ever extended beyond the Point Reyes Peninsula, therefore, it is possible that the habitat needed to allow downlisting (Criteria 1 & 4) is already secured for the conservation of native vegetation as consistent with the mandate of the Park Service.

By 2018, it is not clear that the establishment of plant abundance criteria for the wild population based on “wet” years and “dry” years is a valid construct. While higher amounts of rainfall, particularly in certain seasons, do appear to impact spineflower numbers, the threshold numbers developed do not appear to have been adequately supported by data collected subsequently. More data needs to be collected to develop ecologically meaningful population thresholds. Therefore, this Management Objective will be re-crafted in 2019 in order to provide the park with a more meaningful way of assessing when management action might be needed. This is discussed in more detail later in this document.

2.2 Draft Monitoring/Sampling Objectives

1. Monitor plant numbers in the wild Sonoma spineflower population in order to detect the natural range of temporal and spatial variability in population densities. We want to be 85% certain of detecting a 30% change (increase or decrease) in the mean density per quadrat of Sonoma spineflower individuals between the baseline year of 2005 and the current monitoring year, and we are willing to accept a 15% chance of making a false-change error.

2. Census the introduced Sonoma spineflower populations or occurrences in order to determine whether plants are present and, if so, their approximate numbers and the trend in numbers from year to year;
3. Monitor the areal extent of the wild Sonoma spineflower population to determine whether the population is expanding or contracting. We are interested in detecting a 10% change (increase or decrease) in the areal extent of the wild Sonoma spineflower population between each monitoring cycle;
4. Detect trends in the encroachment of common velvetgrass and other non-native or native invasive species in or on the perimeter of the population. We want to detect an overlap of more than 10% of the perimeter given that the accuracy of our instruments is ± 1 or more meters, depending on the instrument used. We also want to be 90% certain of detecting a 15% change (increase or decrease) in the frequency of bush lupine or other potential invasive or weedy non-native species (e.g., soft chess/*Bromus hordaceus*), with a 15% chance of making a false-change error.
5. Monitor the cover of other plant species co-occurring with Sonoma spineflower in the main population to track potential invasion by other invasive or weedy non-native (or native) species.
6. Incorporate monthly rainfall and temperature data into data analyses to evaluate trends in plant numbers relative to climate-associated variables;
7. Evaluate ways to incorporate monitoring of grazing effect on Sonoma spineflower temporal and spatial abundance and the success of past and future introduction efforts, perhaps through reinitiating RDM plots.

2.3 Monitoring Data Collection and Sampling Design

2.3.1. Quantitative Monitoring of Sonoma Spineflower within Wild Population

PRNS staff estimate the number of flowering Sonoma spineflower stems annually within a subjectively-chosen plot representing approximately 40% of the wild population. Monitoring employs a quantitative sampling design developed by PRNS staff in 2005 with assistance from Park Service I&M and Pacific West Regional (PWR) staff. This sampling protocol was designed and implemented for the first time in 2005 and has been implemented annually since then.

The sampling objective of the monitoring program is to provide information that is *85% certain of detecting a 30% change* (increase or decrease) in the density of Sonoma spineflower individuals per quadrat within a representative macroplot between each monitoring cycle, *with a 15% chance of erroneously concluding that there has been a change when no change has actually occurred, due to sampling bias* (Type I error). In other words: when monitoring shows that there has been a substantial (30% or greater) change in the abundance of spineflower within the quadrat, there will be an up to 15% chance that that result was reached in error and that change in abundance was less than 30%. In addition, there is also a chance that a significant change in density might have occurred in years in which there appears to be no statistically significant change: this Type II error rate is related to the power of the test, which relies on sample size and inherent population variability. Due to the power of the sampling design, the chance for a Type II error is also 15%. To test this, each year we will determine if there has been a

significant change in the population using a two-tailed t-test, assuming equal variances. If there has been a significant change, we will determine if it was at least 30%. If there has not been a change detected, we will do a *post-hoc* power analysis to determine if we had the appropriate power to detect change that year.

Annual monitoring is directed by biologists familiar with rare plant management and monitoring. In addition, the observers that will conduct monitoring are tested annually: all observers individually count at least two segments in common and compare numbers. Any person with counts more than 10% different from the rest of the team's counts is excluded from counting during monitoring and acts as a recorder. The 40m X 100m permanently located macroplot is conceptually divided into 33 0.05m X 40m linear density quadrats. The first quadrat is located at a random starting point at any 0.1m interval between 0 and 3 m (for example 1.7m) along the 100m long edge of the plot. Subsequent quadrats are placed systematically every 3m thereafter (4.7m, 7.7m...97.7m). The 0.05m X 40m quadrat is broken into 40 0.05 m X 1 m quadrats. All flowering individuals rooted within the 0.05m X 1m quadrat are counted (Figure 6). Breaking the long, narrow 0.05m X 40m quadrat into 40 smaller quadrats both allows counting to occur in smaller units and provides additional spatial data on Sonoma spineflower distribution for year to year.

Monitoring is typically done at or just past peak flowering: PRNS staff conclude from past observation that flowering peaks typically in late June or early June, and flowers remain visible and attached to stems after pollination and post-peak desiccation. In 2018, it was conducted on June 7.

2.3.2. Mapping of Areal Extent of Wild Population

Observers also collect photo documentation of the site and map the extent of the Sonoma spineflower population (Appendix A). Almost every year since 1999, the perimeter of the main population and sub-population has been carefully mapped using GPS. The population boundary is inclusive of all individuals at the site on a given year. The outer edge of plant occurrence is flagged and then recorded using a GPS unit. The outer perimeter 10m in radius beyond the last recorded plants is swept to make sure that there are no additional individuals. The Sonoma spineflower population boundary was not mapped in 2017 or 2018.

2.3.3. Mapping of Areal Extent of Common Velvetgrass (*Holcus lanatus*)

In addition to monitoring changes in abundance, the boundary of the perennial non-native grass, common velvetgrass, has been mapped, because there has been concern that this species may be invading into the Sonoma spineflower habitat. In 1999, 2000, 2005, 2006, 2010, and 2011, the encroaching edge of common velvetgrass was mapped using GPS. Based on recommendations from previous years' results, we had proposed to conduct monitoring of the boundary of common velvetgrass no less than every five years. Mapping was conducted in 2012, so the next scheduled mapping was supposed to occur in 2017: Mapping of velvetgrass was conducted on June 15, 2017. It was not conducted in 2018.

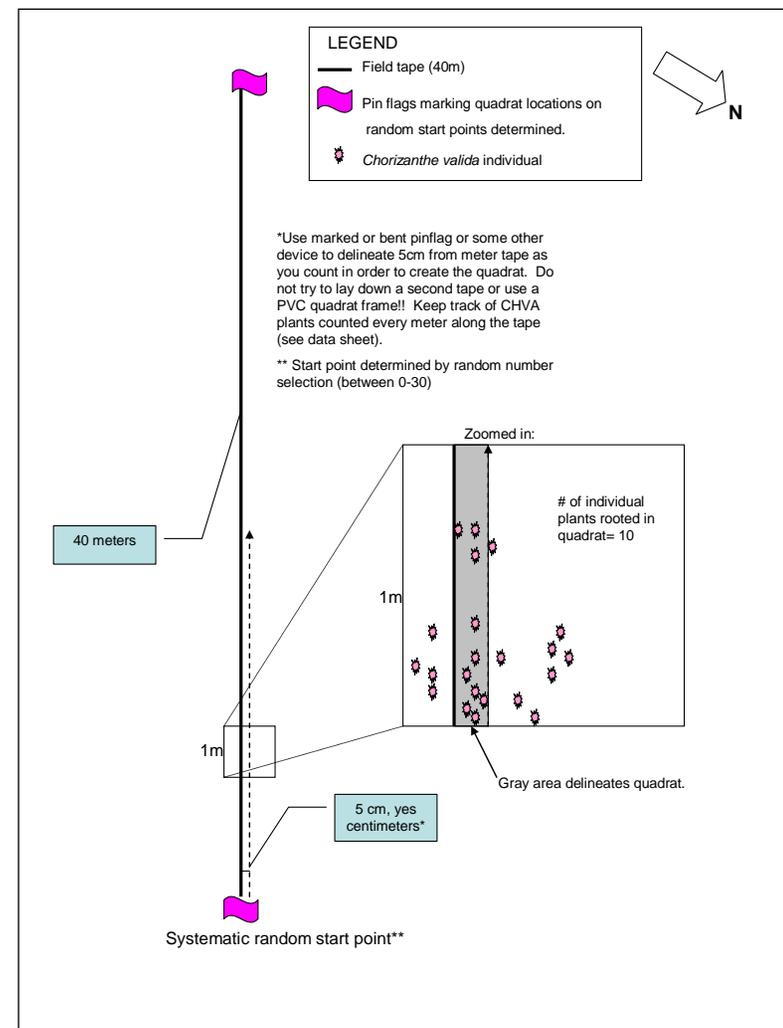
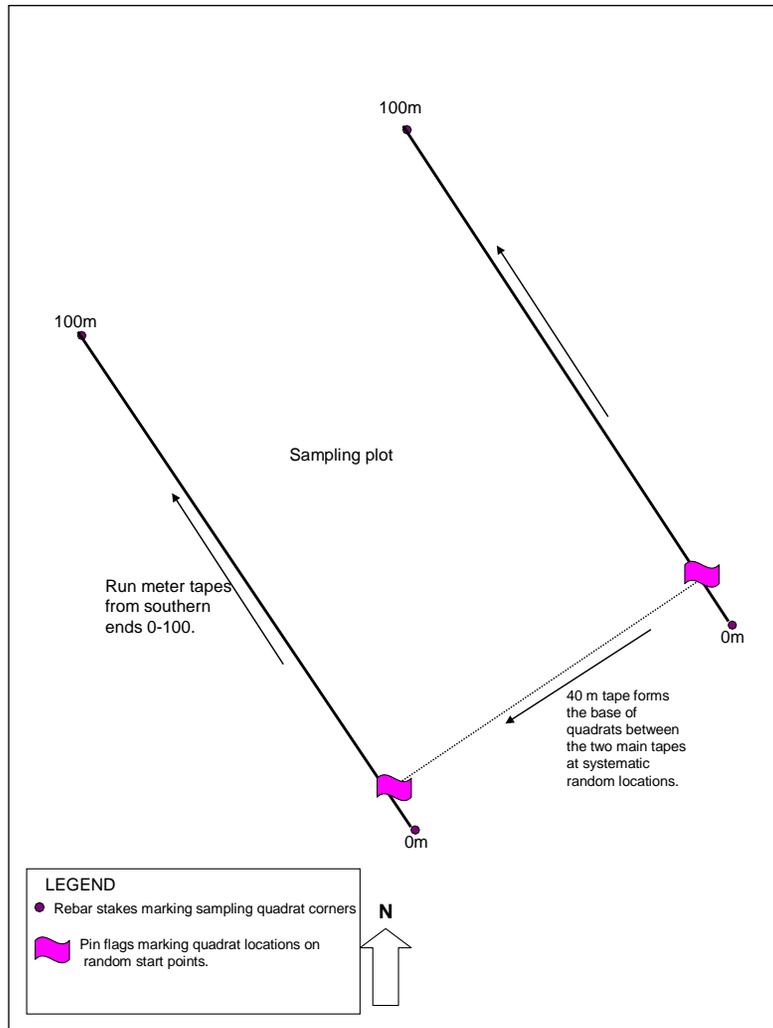


Figure 6. Detail of Sonoma spineflower quadrat methods.

The boundary is created by circumnavigating the Sonoma spineflower population following the edge between uninvaded (less than 5% areal cover) and invaded habitat. The purpose of this mapping is to examine the rate and extent of spread of common velvetgrass adjacent to the Sonoma spineflower wild and sub- populations. An examination of the data gathered between 1999 and 2000 and between 2005 and 2006 suggests that the rate of change in the common velvetgrass boundary from one year to the next may be less than the error of the GPS units used (~ 2m). It should be noted that, in 2017, the boundary was mapped using the extent of area with less than 30% velvetgrass rather than less than 5%.

When mapping is performed, data collected are compared to the maximum known extent of the Sonoma spineflower population for that year to look both at average distance away from the population and to look at percent overlap.

2.3.4. Plant Community Sampling

In 2009, plant community composition sampling was attempted using nested frequency quadrats. This proved to be too time-consuming to complete in the time allotted. In 2010, frequency sampling was again attempted using 0.25 m² quadrats which were calculated from 2009 data to best capture the greatest number of plant species. However, this once again proved to be too time consuming and was abandoned. Instead, since 2010, plant community has been sampled using point intercept every 2 m along 17 100-m transects. Each plant touching a pin-flag of ~1 mm diameter is noted. A total of 50 readings are typically taken along each transect. Absolute percent cover for the 100m X 100m area are estimated by summing the number of readings for each species by the total possible number of readings (850). Native and non-native cover is determined by calculating the relative cover of the sum of all the plant species excluding the absolute cover of bare ground. In past reports, relative cover has been used, but absolute cover is now used instead, as it more closely reflects species response to the environment.

The plant community sampling transects are overlaid on the 40 m-by-100 m macroplot, but extend another 30m in either direction. The transects are larger than the actual macroplot to increase the chance we would capture any systematic invasion of the spineflower habitat from the edge by species such as common velvetgrass. The 17 plant community transects correspond with every other Sonoma spineflower sampling transect. The point intercept method has been conducted every year since 2010. Community sampling was not conducted in 2018.

2.3.5. Census of Introduction Sites

Established introductions are monitored each year by census. PRNS biologists navigate to the site using GPS units of sub-meter accuracy. Once the site is located, all individuals within the site are counted. In 2017, all reintroduction sites except X, Z, and Dune were visited. Sites X and Z have not been located in nearly two decades. The “Dune” site was relocated by chance in December 2010, but no remains of Sonoma spineflower were seen. Some of the introduction sites were censused in June 2018, specifically Y, G1, G3a, G3b, G3c, G3d, ATT1a, and ATT1b.

2.3.6 Data Analysis

For reporting purposes, quadrat counts are averaged, and standard deviation and coefficient of variation are calculated. Number of plants in quadrats is used to estimate total number of plants in macroplot based on the total area sampled relative to the overall macroplot area. In past years, the relationship between rainfall parameters and population totals was analyzed using the R^2 value of linear and exponential regressions. Power analysis is performed in DSTPLAN according to procedures outlined in Appendix 16 in “Measuring and Monitoring Plant Populations” (Elzinga et al. 1998). All other statistical analyses are typically performed using Microsoft Excel, MiniTab, or another statistical program.

2.4 Propagule Collection

No propagule collection for seedbank accession occurred in 2018.

2.5 New Introductions

No new introductions were conducted in 2018. The last round of introductions was in 2015-2016, when NPS staff decided to implement the first round of introductions in the vicinity of the two most successful introductions from years past (Figure 7). Both of these sites are located on the ranch of David and Delores Evans.

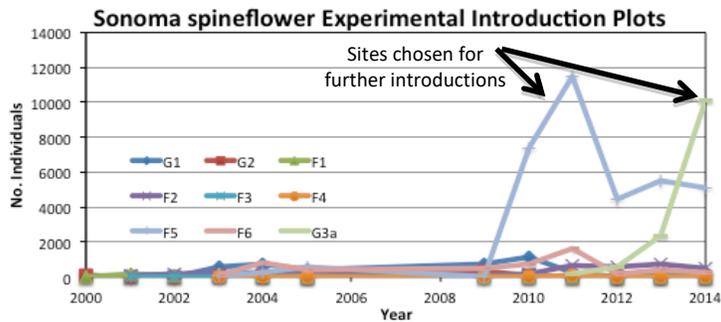


Figure 7. Census totals at Sonoma spineflower introduction sites: 2000-2014.

2.5.1. Ongoing Activities for Existing Introductions

Sites are generally censused annually to assess the success of introduction efforts. The most successful sites will be considered candidates for additional seed sowings in future years.

2.5.2. Introduction Success Criteria

Experimental introductions will be considered successful when they have maintained self-sustaining populations for five (5) years. However, those experimental populations that show the most initial success may be augmented with additional seed material before that time has been completed to increase the chances of achieving a viable population at apparently appropriate sites. Introductions will be considered as non-experimental additional populations when sites have maintained a minimum self-sustaining population for a consecutive 15-year period that includes drought years. Fifteen years is considered long enough to subject sites to a representative range of climatic variability. At this point, however, we have not yet determined what constitutes a minimum number of plants to constitute a viable population. The natural or wild population has varied by more than an order of magnitude (60,000-960,000) over the first decade in which a systematic estimate of the plant numbers in the main population has been conducted, which greatly complicates assigning a number to the minimum number of plants needed to maintain a

viable population.

2.6 Invasives Removal

Invasive plant removal generally occurs in fall after Sonoma spineflower seed set so removal activities will not impact the growth and reproduction of this species. No invasives removal activities were conducted in 2018.

During past invasives removal activities, efforts have been focused on removing all identifiable bush lupine, particularly those beyond the seedling stage, using a combination of hand pulling and hand tools. Bush lupine is distinguished from the smaller varied lupine (*Lupinus variicolor*) by its more upright habit and hairier leaves. Varied lupine is a much smaller, sparser, prostrate perennial lupine that produces far fewer leaves than bush lupine, and does not seem to modify soil properties (and thus facilitate other invasions) to anywhere near the same degree as bush lupine. Once removed, bush lupine shrubs are stacked in piles in an adjacent area of moister soil where biomass can decompose, but where any seeds are unlikely to germinate. In recent years, some coyote brush has also been removed, even though it is a native species, because it appeared to be spreading within the population. Similar removal techniques have been used.

The effects of these invasives removal efforts have been assessed by using plant community data that is collected as part of the macroplot monitoring. Vegetation community data has been collected every year since 2010 within a 2.5-acre area centered on the macroplot where Sonoma spineflower population numbers are estimated.

2.7 Pollinator Study

No PRNS-directed pollinator studies were conducted in 2018.

2.8 Seedbank Study

No seedbank studies were conducted in 2018.

2.9 Data Management

Spatial and tabular data is maintained at PRNS. GIS Data is housed in the GIS server (S:\GIS\vector1\veg\rareplants\covers\Chorizanthe). This database includes the most up to date spatial information for each sub-population and introduction site. The PRNS rare plant database also houses rare plant data, including federal, state, and locally listed species. This database is set up in a similar format to the California Natural Diversity Database (CNDDDB). GIS data and tabular database are both available to regulatory agencies and potentially other organizations upon request. Additional details on monitoring methods, including setup and training, can be found in the draft monitoring protocol on file at PRNS.

2.10 External Research Study – Pollinators

No external monitoring was performed on pollinators in 2018.

3.0 Results

3.1 Monitoring and Mapping of Sonoma Spineflower Wild Population

3.1.1 Macroplot monitoring results

Our sampling objective targeted being able to detect a 30% change in density of spineflower per quadrat within the macroplot established within the main wild population relative to 2005 baseline numbers. In 2005, estimated average plant density per quadrat was 280.1 ± 131.2 (S.D.) plants/quadrat, with the lower bounds of a 30% change being 196.1 plants/quadrat. PRNS felt that, from a biological perspective, it was more important to err on the side of concluding that there was a change in density when it might not have actually occurred and, therefore, be at least 85% certain of detecting this 30% change in density, with a chance of making a false change error set to a maximum of 15% (allowable p-value). By this criteria, density of spineflower in macroplot quadrats differed significantly from the baseline year of 2005 in 11 of the 14 years of sampling since then, with nine (9) of those differences being densities 30% lower than the average density in 2005. Six (6) of the last seven (7) years have had significantly lower average plant densities than 2005 despite some dramatic climatic variation in terms of rainfall. Two monitoring years (2009 and 2010) supported statistically significant higher plant densities than 2005. Three years (2007, 2011, and 2015) were not statistically different from 2005 ($p > 0.3$): 2007 and 2015 had Minimum Detectable Change (MDC) levels of either 30% or lower (e.g. 20%), but MDC objectives were slightly exceeded in 2011 (MDC=33%), although the power of the analysis was actually higher than the targeted 85% (95%).

From average densities of spineflowers in macroplot quadrats, annually, we calculate estimates of total population density within the extent of area covered by the macroplot. Estimated numbers within the primary “wild population” are shown in Table 1. During this 14-year period, average estimated abundance of spineflower within the wild population was 327,668 individuals, with a median estimated abundance of 246,600. It should be noted that, despite efforts to reduce variability in the sampling design, the coefficient of variation during these years has roughly averaged 60%, so these estimates are, truly, “estimates.” Preliminary Management Objective criteria called for maintaining Sonoma spineflower above different threshold abundance levels established for wet and dry years. For the purposes of this analysis, “wet years” ($>>$) were years with considerably more than average rainfall, whereas years with “average” rainfall ($= \sim 19$ inches) or slightly above ($>=$) or below ($<$) average rainfall (Table 1). As shown in Table 1, in terms of meeting Management Objectives, which included supporting equal to or more than 30,000 plants in “wet” (>25 inches) years and equal to or more than 300,000 individuals in “dry” years (<25 inches), results have been equivocal. Based on these data, Management Objectives have been met nine (9) of the last 13 years, with 2018 not meeting management objectives for a “dry” year.

As was discussed earlier, these targeted numbers for wet and dry years represented somewhat arbitrary objectives, as not a lot of data existed when Management Objectives

Table 1. Sonoma spineflower sampling results from macroplot: 2005-2018.

	Estimated # plants in macroplot	95% CI	Maximum # of plants	Minimum # of plants	Rainfall relative to Avg	Meet Mgt Objectives?
2005	560,171	89,627	649,798	470,544	=	
2006	62,580	16,744	79,324	45,836	>>	Y
2007	441,480	89,499	530,979	351,981	<	Y
2008	259,740	54,381	314,121	205,359	<	Y?
2009	710,460	206,817	917,277	503,643	<<	Y
2010	958,380	246,416	1,204,796	711,964	>/=	Y
2011	370,740	63,038	433,779	307,702	>/=	Y
2012	95,460	39,099	134,559	56,361	<	N
2013	152,760	37,218	189,978	115,542	<	N
2014	233,460	66,301	299,761	167,159	<	N
2015	452,460	122,265	574,725	330,195	</=	Y
2016	198,240	60,960	259,200	137,280	>>	Y
2017	85,920	26,272	112,192	59,648	>>>	Y
2018	11,100	9,271	20,371	1,829	<	N

Population Estimate

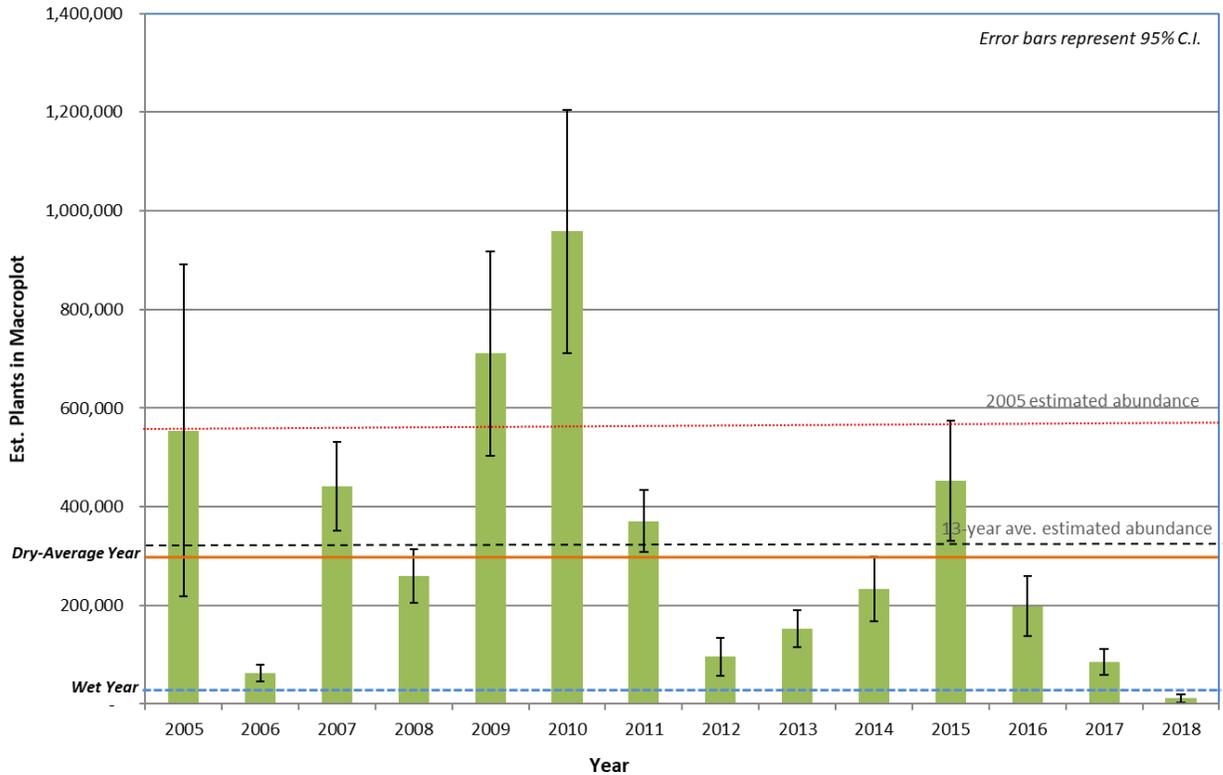


Figure 8. Estimated population (left axis) with 95% CI of Sonoma spineflower in the macroplot 2005-2018 with thresholds for management on a Dry-Average Year (300,000) and a wet year (30,000), indicated. Those years that met the criteria for a wet year are indicated in blue. The black dotted line indicates a 14-year average population size, and the orange dotted line indicates the 2005 estimated abundance benchmark.

were first developed in terms of population trends in response to climatic variation. For example, “wet” year target objectives were based on 50% of the plant numbers present in 2006, in which there was about 26 inches of rain in the Abbotts area. Based on average estimated plant numbers for the first few years, abundance initially appeared to be lower in “wet” years than either “average” or “dry” years. However, in more recent years, the initial hypothesis that “dry” years would produce more plants has not been necessarily upheld by comparing rainfall totals and estimated spineflower abundance in Table 1. The low numbers in the drought years suggest that both much higher and much lower than average rainfall conditions may be sub-optimal. On the other hand, plant numbers dropped dramatically in the first “dry” year of 2012, but increased steadily in subsequent “dry” years regardless of the exact amount of rainfall. (Rainfall totals for rain years 2011-2012 through 2013-2014 were well below average, and all three years (2012-2014) were considered much drier than normal from a statewide perspective.) The mechanism at work here may be low germination and reproductive success in drought years and high competition in wet years. As discussed earlier at length, the relationship between climatic factors and germination, competition, and survival to reproduction appears much more complicated than a simple correlation between annual rainfall and plant abundance.

Ultimately, both of the benchmarks established – average plants per quadrat in 2005 when transect-based sampling was initiated or preliminary estimates of average abundance during wet or dry years -- appear to be inadequate to determine what is really transpiring with this population. Between the two, however, the 2005 benchmark appears to capture better population trends as shown in Figure 8, which suggest that, generally, plant numbers were higher between 2005 and 2011 and have dropped since then, with the exception of 2015. Based on preliminary Management Objectives, low numbers during the three year-period of 2012-2014 should have triggered management actions to support the population. However, as established here, it is difficult to conclusively determine a trend in plant numbers due to comparatively short monitoring period and the extreme variability in climatic conditions during the monitoring period. Annual plants are known for minimizing germination and reproductive efforts during dry years. Because of this, PRNS chose not to take direct management action at that time, though it did undertake several indirect efforts to improve spineflower numbers (specifically shrub removal and new experimental introductions elsewhere).

With only one wild population, however, it is important to understand what factors may be driving this high variability because stochastic events at a single location inherently risk the entire species. Given this high variability, park staff needs to try and develop better target criteria in terms of plant numbers for mandating management action. Certainly, the general decline in plant abundance after 2011 is of great concern, as is the fact that the park recorded the lowest-ever estimated abundance at this population in 2018.

3.1.2. Population Extent for Wild Population

Since 2010, the areal extent of the wild population has ranged from 3.2 acres (2012) to 4.2 acres (2016). Population boundary data was not collected in 2017 or 2018. The main population is typically greater than 2 acres in size, while the sub-population is less than

an acre. Between 2005 and 2010, the wild population averaged 3.16 acres with a standard deviation of 0.75 acres and ranged from 2.06 acres in 1999 (main= 1.75 acres) to 4.19 acres in 2010 (main= 3.35 acres). The maximum extent of the Sonoma spineflower population area – or the combination of the outer boundary in all mapped years -- totals 4.49 acres. In none of the monitoring years has the spineflower population dropped below the acreage threshold of 2 acres, which was established in the Management Objectives.

Though population numbers of Sonoma spineflower vary dramatically from year to year, the population boundary shows a high degree of fidelity. From Sonoma spineflower's smallest (1999) to largest (2010) extent, the population boundary expanded by an average of only 9 m. Some of this variation in acreage may result from differences in boundary mapping technique between different teams of biologists. PRNS has attempted to minimize this type of error by specifying more clearly in the Monitoring Protocol the exact technique for boundary mapping. An examination of the spatial distribution of the quadrats shows the highest densities from year to year seem to occur in the same vicinity, suggesting that there is not much movement in the population. The outline of the population boundary is similar to – though slightly smaller than -- the soil type boundary, again highlighting the apparent importance of this soil type to the persistence of Sonoma spineflower.

3.2 Boundary Mapping of Areal Extent of Common Velvetgrass

Common velvetgrass boundary was mapped in 2012 and again in 2017, as specified by the Monitoring Protocol. Since annual/biennial spread rate does not appear to be greater than the potential error of spatial data (2- to 3m), park staff determined that mapping could seemingly be conducted on an approximately 5- year cycle without loss of information or threat to the Sonoma spineflower population. In 2017, the area with less than 30% cover of velvetgrass totaled 9.4 acres, which is considerably larger than the spineflower Wild Population area of 4.2 acres measured in 2016. Based on visual observations, the velvetgrass appears largely relegated to the adjacent wetter Sirdrak Variant soil type. This continues to support PRNS' contention that velvetgrass does not pose as much of a threat as some other species (e.g., bush lupine, coyote brush, non-native annual grasses) to population viability.

3.3 Plant Community Sampling

Plant community sampling started in 2010, and that year -- which was a record year for Sonoma spineflower abundance – has been used as the baseline year. Plant community sampling was not conducted in 2017 or 2018.

3.4 Introductions

3.4.1 Existing Introductions

Table 3 lists all of the historic introduction plots for Sonoma spineflower.

Only some of the introduction sites were monitored in 2018 due to staffing and time

constraints. Introduction sites monitored included Y and G1 at G Ranch near Wild Population, G3a-G3d near Schooner Creek, and ATT 1a-1b at AT&T. None of the F Ranch sites were censused. In 2017, all introduction sites were monitored, except H1a, H1b, RCA1, and RCA2 (Table 2).

In general, Sonoma spineflower abundance in introduction plots – both older and newer ones – dropped in the 2012-2018 period relative to the period immediately prior (2009-2011). Over the period 2009-2018, approximately five (5) plots established prior to 2005 appeared to be self-sustaining, maintaining -- with only a very few exceptions -- numbers above the 25% quartile for 2009-2017. These plots are Y and G1 at G Ranch and F2, F5, and F6 at F Ranch. Five (5) older plots definitively have not persisted (G2, F1, F3, Z, and Dune), and another is very questionable based on recent data (F4). As discussed earlier in this document, X and Z have not been located since 1991 and are believed to have failed. Plots X, Z, (and Dune) were established on soils other than the Sirdrak, Sand – the soil type on which the wild population is located – although some of the other unsuccessful plots were also on Sirdrak, Sand, so soil type is no guarantee. The difference in soils may have contributed to their failure, though, whether due to interspecific competition or because this species is a true edaphic endemic, or because of other factors, is undetermined. The 1999 plots established at G Ranch (G2) and in the dunes have also not fared well. G2 has not been found since 2010. Similarly, some plots established at F Ranch in 1999-2000 have also failed: F3 hasn't supported plants since 2002, and plants have not been seen at F1 since 2011.

Some of the more recently established plots finally have enough data to provide some preliminary evaluations of population trend. Populations G3a and, to a lesser extent, G3b at Schooner Creek appear well-established and consistently support some of the highest abundances of plants within introduction plots. Of the newer introductions for which we have enough data, four (4) plots appear to be failures (H1a, H1b, F8a, and F8b), and four (4) others are questionable (F7a, F7b, ATT1a, and ATT1b). In general, then, PRNS is meeting the management objective of having at least four (4) of the five (5) most well-established populations or plots support enough plants to exceed the 10-year 25% quartile very consistently. The populations at Schooner Creek appear on track to exceed these standards, as well, which addresses another management objective of having at least two (2) newer introduction plots supporting plants for at least three (3) years the first five (5) years after introduction. ATT1a and ATT1b also met this standard.

As was discussed in previous reports, there is no obvious correlation between seed plot numbers and yearly rainfall totals. However, the dynamics of a newly established occurrence or population may be different from the natural population. For example, if the site is suitable, the population may grow to fill available habitat even during seemingly unsuitable heavy rainfall years, because the population hasn't reached "carrying capacity," or reproduction may be low even under optimal environmental and climatic conditions because appropriate pollinators have yet to "find" the newly established plants. Furthermore, ideal climatic conditions may not be the same between different micro-sites.

Table 2. Number of flowering individuals at introduction sites. NC refers to not censused. NF indicates the population was not found. Est. indicates the year established. Means since plot establishment and 25% quartile range since 2009 are presented for most successful introductions prior to 2010. Data not shown from RCA1 and RCA2 and Dune introductions, which never produced plants.

Census Year	Y	X	Z	G1	G2	F1	F2	F3	F4	F5	F6
1988	Est.	Est.	Est.								
1989	22	38	98								
1990	193	3	2								
1991	182	19	9								
1993	345	?	?	Est.	Est.	Est.					
~											
2000	691	0	0	54	68	34	Est.	Est.			
2001	433	0	0	14	38	182	77	0			
2002	NC	0	0	NC	NC	80	201	4	Est.	Est.	Est.
2003	3,886	0	0	600	73	205	225	0	41	99	103
2004	1,777	0	0	750	82	92	247	0	32	295	807
2005	1,429	0	0	432	13	22	300	0	32	564	425
~											
2009	1,130	0	0	729	321	0	67	0	6	NC	512
2010	4,277	0	0	1,172	62	13	208	0	29	7,403	743
2011	3,385	0	0	281	NF	16	620	0	85	11,483	1,638
2012	15	0	0	4	NF	0	616	0	23	4485	151
2013	171	0	0	77	NF	0	775	0	37	5550	400
2014	378	0	0	272	NF	0	475	0	9	5112	263
2015	793	0	0	188	NF	0	462	0	4	7499	159
2016	1101	0	0	278	0	0	338	0	0	2063	106
2017	468	0	0	271	0	0	2,431	0	0	7,104	380
2018	605	NC	NC	539	NC	NC	NC	NC	NC	NC	NC
Median	792	~	~	272			475			6,327	380
25% Quartile	378			188			338			4,955	159

Table 2, continued. Introductions after 2010.

Census Year	G3a	G3b	G3c	G3d	H1a	H1b	H2a	H2b	F7a	F7b	F8a	F8b	ATT1a	ATT1b
2010	Est.				Est.				Est.		Est.		Est.	
2011	187	Est.			1	Est.			278	Est.	149	Est.	554	Est.
2012	606	14			0	25			252	83	4	12	data lost	data lost
2013	2327	571	Est.		0	0			24	2	6	16	61	76
2014	10137	1217	17	Est.	0	0			10	0	0	0	55	146
2015	3938	187	23	18	0	0	Est.	Est.	0	0	0	0	77	129
2016	3622	321	34	21	33	17			0	0	0	0	74	91
2017	10,147	952	0	163	NC	NC	3	0	0	0	0	0	268	701
2018	928	134	0	0	NC	26	326							
Median	3,622	446											69	129
25% Quar.	1,467	221											57	76

As the Wild Population appears to have been struggling somewhat during the past seven (7) years, having a sizeable population that equaled or exceeded the 14-year average estimated abundance only one of those years, evaluating trends for the introduction sites – both new and old – could provide some insight into what factors might be affecting both wild and introduced populations. Interestingly, population trends at the introduction sites in G Ranch near the Wild Population mirror those of its larger neighbor, with estimated plant numbers generally higher between 2003 and 2011 (Figure 9). Plant abundance at least for Site Y – the bigger and more stable of the introduction sites -- shows a bit of a bell-shaped curve between 2012 and 2018, with the highest numbers in 2016. This same bell-curve is evident between 2012 and 2018 in the Wild Population, with the highest numbers in 2015, though, instead (Figure 8). However, numbers did not decline as drastically in 2018 in the introduced sites, as they did in the Wild Population (Figures 8-9).

In contrast, the pattern in estimated abundance at nearby F Ranch displayed a different trend than those at G Ranch. Introduced site F5 had peak abundances in 2011, but maintained very high numbers between 2011 and 2017: no monitoring was conducted between 2006 and 2008, so the population trajectory cannot be determined for that time interval, and low numbers between 2001 and 2005 could be ascribed to the fact that these sites were newly established (Figure 10). While not as wildly successful as F5, F2 supported fairly moderate, but consistent, numbers of plants, with peak abundance actually in 2017 (Figure 10). Of these three most successful sites, only F6 showed a steady pattern of decline in plant numbers after 2011 (Figure 10).

It is difficult to determine trajectories for newer introduction sites such as the Schooner Creek ones, which were established between 2011 and 2015, but for the older sites (G3a and G3b), sites appeared to establish very quickly, posting very high abundances in 2014 and 2017, with much lower numbers in 2018 (Table 2; Figure 11).

Large-scale climatic trends alone cannot account for the trends in these populations or the differences in population patterns among the geographically clustered introduction sites and the Wild Population. As noted earlier, there may be micro-site differences in climate, but these would be expected to be relatively minor given these sites' relative geographic proximity and similarity in topographic conditions (flat to somewhat undulating grassland hills). Almost all of the extant introduction sites were located on the same soil type as the Wild Population (Sirdrak, Sand), thereby largely negating any potential effect of the parent soil material. Seeds for the oldest introduction sites were collected from the Wild Population, with newer ones initiated using a mix of Wild Population and introduction site seeds, thereby genetically homogenizing populations and reducing the potential for a genetic effect on recruitment and survival-to-flowering.

Based on general similarity in patterns between most of the immediately adjacent sites, controls on these populations would appear to be localized to the general area and could include factors such as intensity and timing of cattle grazing, intensity and timing of grazing of other herbivores and ground-dwelling mammals, and possibly pollinator

Estimated Plant Numbers at Y and G1 Introduction Sites at G Ranch

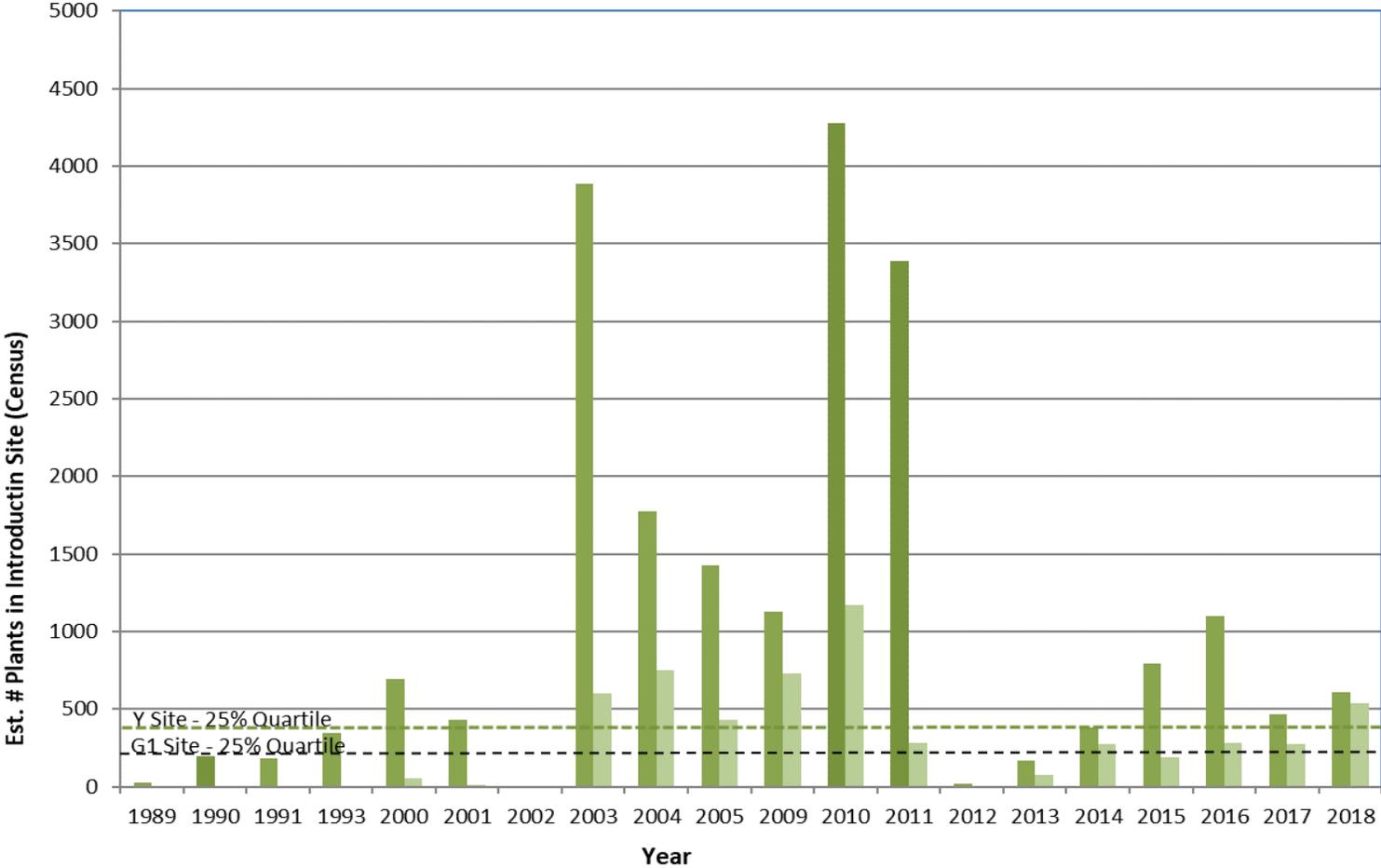


Figure 9. Estimated population of Sonoma spineflower in G Ranch introduction sites between 1989 and 2018. Monitoring was not conducted between 1993 and 2000 and 2006 and 2008. The dashed lines represent the 25% quartile estimated abundance for each site, which is tied to Management Objectives for this species.

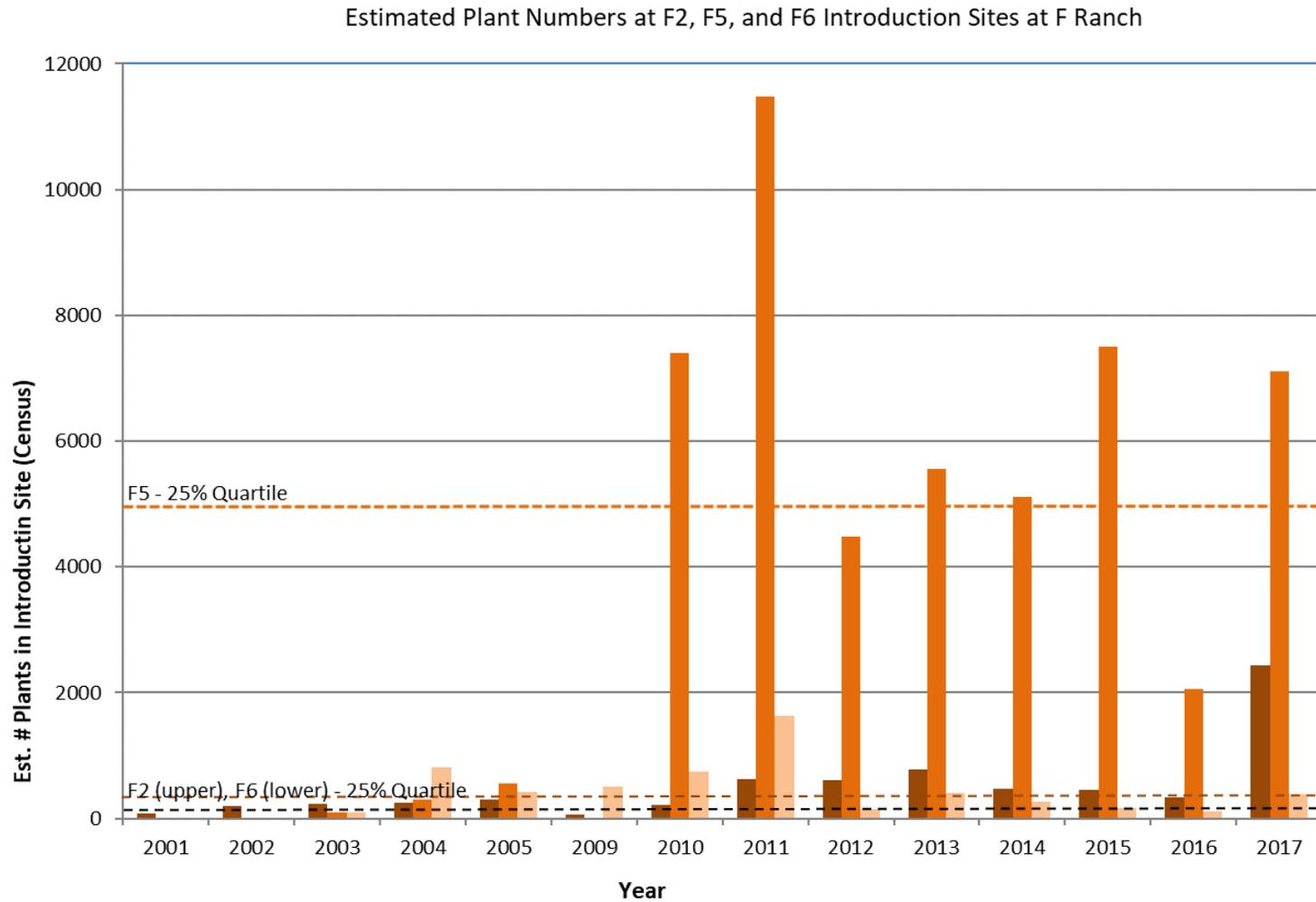


Figure 10. Estimated population of Sonoma spineflower in F Ranch introduction sites F2, F5, and F6 between 2001 and 2017. Monitoring was not conducted between 2006 and 2008 and in 2018. The dashed lines represent the 25% quartile estimated abundance for each site, which is tied to Management Objectives for this species.

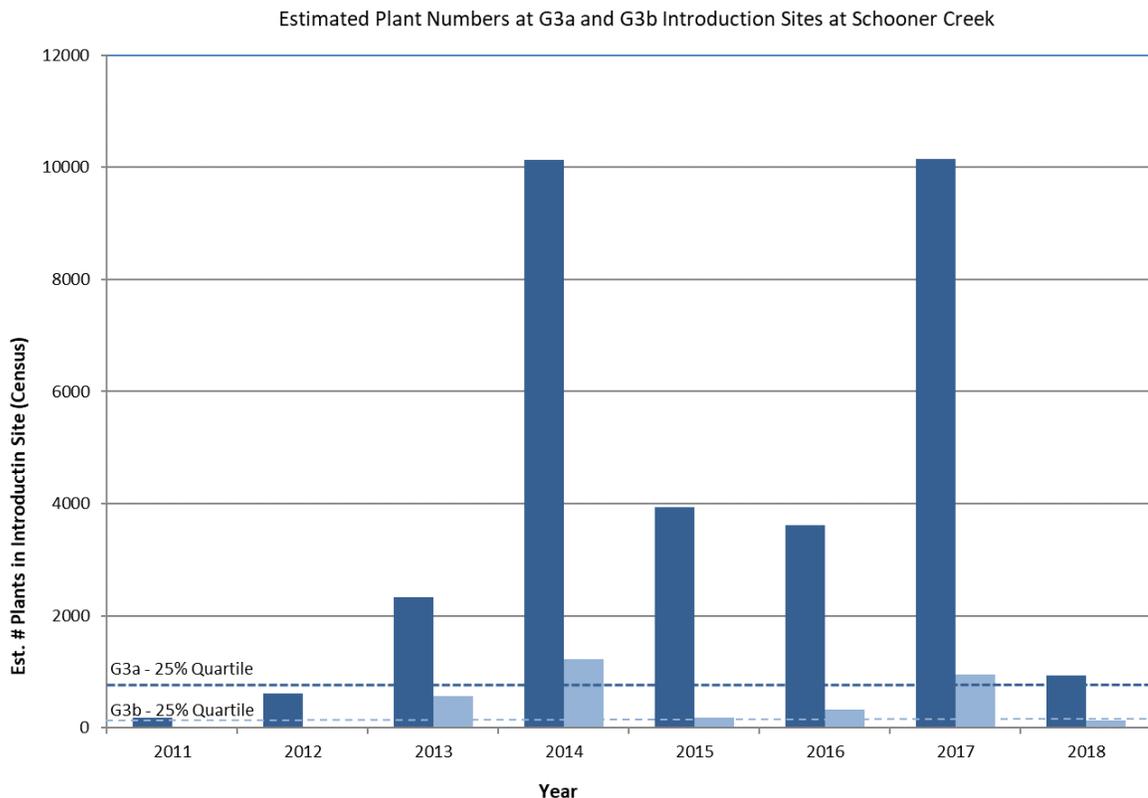


Figure 11. Estimated population of Sonoma spineflower in Schooner Creek introduction sites G3a and G3b between 2011 and 2018. The dashed lines represent the 25% quartile estimated abundance for each site, which is tied to Management Objectives for this species.

abundance and composition. The influence of pollination factors may be minimal, at least in the case of G Ranch, however, as results from a pollinator study conducted in 2015, however, suggested that species composition, total number of visitors, and species richness of pollinator taxa varied considerably between the Main and Sub-Population areas of the Wild Population and the introduced sites at G Ranch, which is not consistent with the similar patterns in annual population abundance documented between the Wild Population and Site Y (Parsons and Ryan 2016).

3.4.2 New Introductions

No new introductions were conducted in 2018.

3.5 Management

3.5.1 Grazing and Ranching Management

PRNS has been collecting data on density of Sonoma spineflower within and outside the road footprint since the ranch access road was relocated in 2010, but data has not been analyzed in recent years due to lack of funding.

3.5.2 Invasives Removal

There was no invasives removal in 2018.

3.6 Pollinator Studies

There were no pollinator studies in 2018.

3.7 Seedbank Study

There were no seedbank studies in 2018.

3.8 Other Research Studies

There were no other research studies in 2018.

4.0 Conclusions

4.1 Summary

4.1.1 Year in Review

In 2018, PRNS continued monitoring both the Wild Population of Sonoma spineflower, as well as a select number of the introductions located at G Ranch and ATT.

In the Wild Population, Sonoma spineflower population estimates continued to decline in 2018, posting some of the lowest estimates recorded since monitoring began in 2005. In general, the population appears to have been in a slump since 2011, with the possible exception of 2015, where numbers equaled or exceeded the 14-year average of 327,668. Interestingly, trends in spineflower abundance in the Wild Population somewhat mirror those of the nearby introduced sites at G Ranch, with both showing highest numbers between 2003/2005 and 2011 and then generally lower numbers between 2012 and 2018. Between 2012 and 2018, a somewhat bell-shaped curve in abundance is evident in both the Wild Population and the more populous G2 introduction site, with smaller, but still strong, peaks in abundance recorded in 2015 and 2016, respectively. The trends in population abundance at G Ranch are quite divergent from those at the other introduction areas (sites F2 and G3a), specifically F Ranch and Schooner Creek. The two seemingly most successful introductions, which is based on a consistent history of moderate to high plant numbers, actually had relatively high numbers most of the years between 2012 and 2018.

This disparity in population trends would seemingly rule out that trends are largely based on precipitation patterns and cycles of wet years and dry years, as all of the sites are within close proximity and probably vary little even in terms of microclimate. In addition, almost all of the sites occur on the same soil type and derive from the same local genetic material. This suggests that plant abundance must be driven by factors localized to each general population area. These factors could include intensity and timing of cattle grazing, intensity and timing of grazing by other herbivores, including ground-dwelling mammals, and pollinator dynamics. The influence of pollination factors may be minimal, at least in the case of G Ranch, however, as results from a pollinator study conducted in 2015, however, suggested that species composition, total number of visitors, and species richness of pollinator taxa varied considerably between the Main and Sub-Population areas of the Wild Population and the introduced sites, which is not consistent with the similar patterns in annual population abundance documented between those areas (Parsons and Ryan 2016).

The trends evident in Figure 8 are probably a better guide as to the status of the Wild Population than the Management Objectives we established early on regarding abundance during “wet” and “dry” years. Based on these data, Management Objectives have been met nine (9) of the last 13 years, with 2015-2017 meeting Management Objectives, but not 2018 (“dry” year). By Sampling Objective criteria, density of spineflower in

macroplot quadrats differed significantly from the baseline year of 2005 in 11 of the 14 years of sampling since then, with nine (9) of those differences being densities 30% lower than the average density in 2005. Six (6) of the last seven (7) years have had significantly lower average plant densities than 2005 despite some dramatic climatic variation in terms of rainfall.

Neither our original estimate of expected plant abundance during wet and dry years nor plant densities during the initial year of sampling in 2005 appears to be a valid, long-term benchmark for assessing the Wild Population. In fact, Management Objectives were not met between 2012 and 2014, which should have prompted management action by PRNS, but plant numbers then rebounded strongly in 2015. There does not seem to be a one-to-one correlation between total rainfall and plant numbers, and, if there is, it appears to be a much more complicated relationship involving both intra- and inter-annual patterns in precipitation. Variability in plant numbers at different sites during wet years and dry years is probably related to slight differences in habitat structure and suitability for spineflower, such that dry weather affects plant abundance at certain sites more than others, thereby complicating efforts to discern a consistent pattern between years. It may be even further complicated by the complex interactions between years such that the number of successive years of drought or higher rainfall determines plant abundance or seedbank dynamics.

For this reason, the numbers established do not appear to be a valid threshold for determining when action is required, however, we currently do not have enough information to make any reasonable counter-suggestions. These numbers will continue to be evaluated after future monitoring events to determine whether more realistic and valid Management Objectives can be set for the minimum number of plants estimated for the Wild Population. A stronger Management Objective might be based on long-term average and median abundances within the population, but more years of monitoring are needed to determine a valid mean and median for this population. During the 14 years of monitoring to date, average estimated abundance of spineflower within the wild population was 327,668 individuals, with a median estimated abundance of 246,600. It should be noted that, despite efforts to reduce variability in the sampling design, the coefficient of variation during these years has roughly averaged 60%, so these estimates are, truly, "estimates." Also, any long-term average or median will be influenced by any changes impacting the population adversely, thereby perhaps artificially reducing what plant abundance might be at full carrying capacity.

The Wild Population has generally met other Wild Population-related Management Objectives. Areal extent of spineflower has exceeded 2.0 acres every year of monitoring, and the extent of common velvetgrass has not encroached into the Sonoma spineflower population area. The bigger issue appears to be encroachment of bush lupine and coyote brush into the Main Population: the Management Objective for bush lupine calls for cover of bush lupine to be maintained below the level of 4%. Cover of bush lupine has not exceeded 4% since 2010.

In terms of the introduction plots, the well-established plots or populations continued to

do well. This included five (5) older plots dating from before 2005 (Y, G1, F2, F5, and F6), as well as two (2; G3a and G3b) and possibly four (4; ATT1a and ATT1b) newer introduction plots dating after then. This continued success of some of the introduction plots meant that PRNS also met Management Objectives tied to establishing new, self-sustaining populations of spineflower.

Though Sonoma spineflower continues to thrive at PRNS, threats to this population still exist. Cattle grazing and ranching activities may have beneficial or potentially detrimental effects at the site depending on timing and intensity: insufficient grazing or no grazing in spring may allow non-native or native species to outcompete spineflower for resources or reduce spineflower numbers indirectly through shading. Wet years usually result in a flush of non-native annual grasses and herbs, but even native species such as bush lupine and coyote brush can threaten spineflower by encroaching on its natural habitat of sparsely vegetated grasslands. Population viability of spineflower may also depend on a robust pollinator community and a suite of other flowering plant species to sustain pollinators when spineflower is not in flower. Pollinators are threatened by many issues, including habitat development and management, disease, and competition with non-native species. Ultimately, results of the seedbank study and the preliminary population viability analysis suggests that this species is very vulnerable to stochastic events such as prolonged drought, as its seedbank in native soils may be very short-lived. With climate change expected to dramatically affect climatic trends, this may become a considerable concern for long-term viability of this species.

4.1.2 The Future

One of the most concerning factors— and the hardest to predict — is the effect of climate change. Projected changes to climate patterns along coastal California have the potential to significantly affect the viability of Sonoma spineflower and the flora of the Point Reyes Peninsula. Recent modeling efforts by a UC Berkeley team predicted that two-thirds of California's endemics could suffer more than an 80 percent reduction in geographic range by the end of this century due to rising temperatures and altered rainfall (Loarie *et al.* 2008). Under the worst-case scenario, diversity within regions could drop by as much as 25% either from extinction or relocation (Loarie *et al.* 2008).

The success of rare annual species is closely tied to climate patterns (Higgins *et al.* 2000, Levine and Rees 2004, Levine *et al.* 2008). PRNS's data suggest that Sonoma spineflower density may be tied to the pattern of rainfall, if not total amounts. On average, recent projections show little change in total annual precipitation in California or in the Mediterranean pattern of rainfall, with most falling during winter from north Pacific storms (California Climate Change Center 2006). However, one climate model does predict slightly wetter winters (+1.5 inches/year), while another predicts slightly drier winters with a 10 to 20 percent decrease in precipitation (-6.2 inches/year of precipitation; Cayan *et al.* 2006 in Dukes and Shaw 2007; California Climate Change Center 2006). In general, more variability is expected in rainfall, with potentially larger storms and longer dry periods, which will undoubtedly affect Sonoma spineflower and other rare plants in PRNS and elsewhere.

While climate change is predicted in general to increase ambient air temperature by 1.7 degrees Centigrade (3.0 degrees Fahrenheit) to as much as 5.8 degrees Centigrade (10.4 degrees Fahrenheit) by the end of this century (Cayan *et al.* 2006 in Dukes and Shaw 2007, Cayan *et al.* 2008), the increase in temperature gradient between the coast and inland areas caused by soaring inland temperatures may actually lead to a decrease in temperatures along the coast (Snyder 2008).

Cooler temperatures along the coast would seemingly favor continuation of the fog belt that typically cloaks the coast during the summer and days when temperatures soar in inland areas. The frequency of fog closely approximates the temperature differential between coastal and inland weather stations (Johnstone and Dawson 2010). Interestingly, while predicted changes discussed above would suggest a potential increase in fog, some researchers believe that, over the last 100 years, the range of fog frequencies has declined from approximately 48 to 64 percent around 1900 to typically between 31 and 48 percent from 1980 to 2000 (Johnstone and Dawson 2010). As with rainfall, the future of fog remains a topic of active debate.

Changes to fog patterns may have implications for Sonoma spineflower persistence. The annual rainfall on Point Reyes Peninsula is quite low (averaging 18 inches at the Lighthouse), and many plant species at Point Reyes depend on fog-derived moisture for survival (Ingraham and Matthews 1995). On the other hand, species depend differentially on fog. A study of coastal grasslands around Bodega and Tomales Bays found common velvetgrass to be highly reliant on fog drip for summer moisture (Corbin *et al.* 2005). As discussed above, common velvetgrass occurs around the perimeter of the Sonoma spineflower population and has been postulated as a potential threat. Decreasing frequency of fog might actually favor the drought-tolerant spineflower species over common velvetgrass.

Another way that changes in fog patterns could affect Sonoma spineflower is through changes in the amount or pattern of solar radiation. Recent analyses by PRNS in the Draft Preventing Extinction Report (Ryan and Parsons 2011) showed that the phenological cycle and plant height of Sonoma spineflower appears to be strongly correlated with solar radiation. While, in general, solar radiation might be expected to increase with “warming” of most of California, if temperatures along the coast were to cool, and fog, to increase, as some have predicted, solar radiation would be affected.

Increased nitrogen deposition due to higher atmospheric nitrogen levels is another human-induced change with the potential to significantly alter ecosystems. Although extremely patchy, nitrogen deposition rates in parts of California are among the highest in the United States (Fenn *et al.* 2003). Under one future scenario, global nitrogen deposition was estimated to increase by more than 250 percent (Lamarque *et al.* 2005). Increased nitrogen deposition can interact with climate changes. In northern California, most nitrogen deposition occurs as wet deposition, and while nitrogen is deposited at rates as high as 16 kg/hectare/yr in northern California, generally in areas of extensive fog exposure these rates are as high as 90 kg/hectare/yr (Bytnerowicz and Fenn 1996, Blanchard and Tonneson 1993, Fenn *et al.* 2003b in Dukes and Shaw 2007). Thus,

whether precipitation and fog incidence increases or decreases has the potential to significantly affect the soil nitrogen levels on the Point Reyes Peninsula.

It is possible that even if incidence of fog decreases, soil nitrogen levels will increase due to a high rate of deposition due to a combination of increased atmospheric deposition and continued agricultural management. Increased nitrogen would likely favor weedy annual grasses, as has been documented in serpentine soils (Weiss 1999) and in sandy soils where bush lupine increased soil nitrogen by fixation (Maron and Connors 1996). Common velvetgrass is also extremely responsive to increases in soil nitrogen (Abrahams *et al.* 2009).

The effects of these changes on Sonoma spineflower are hard to predict right now, but we hope to use additional information collected in future years from monitoring and data analysis to refine our understanding of how Sonoma spineflower might respond to climate change and what actions we can take to ensure its continued survival in the face of this and other threats to species viability.

4.2. Future Management and Monitoring Activities

PRNS needs to take into account that staff resources are limited and focus future monitoring activities accordingly. Recommendations for future actions include:

- Continue to monitor the macroplot *annually* until reasonably confident that a baseline encompassing seasonal variation has been established (15 to 20 years). ***PRNS currently has 14 years of data.***
- Monitor the population boundary *every other year* in future years, starting in 2018. ***The next boundary monitoring is scheduled to be in 2019.***
- Don't re-map the boundary of common velvetgrass unless there appears to visually some evidence of change.
- Continue to monitor the cover of other plant species within macroplot *every third year* to evaluate variability in plant numbers and potential response to climatic and competitive effects. ***The next plant community monitoring is scheduled be in 2019, but there may be enough staff resources to complete this monitoring in 2019.***
- Continue monitoring at least the most successful introduction plots *annually* to determine status of introduction. Try to revisit some of the less successful sites on a rotating basis annually.
- Continue to refine the monitoring protocol and refine the Sampling Objectives, as appropriate.
- Refine the Management Objectives, as more data becomes available.
- Perform bush lupine and coyote brush removal as much as possible in the wild population and in such a way that data may be collected to assess its ongoing threat.
- Evaluate success of current introduction plots for possible additional augmentation of most successful ones.
- Explore the opportunity to augment pollinator populations or pollinator habitat both near Wild or natural populations and introduction populations.

- Compile historic grazing information and work with PRNS Range Ecologist and the G Ranch to develop a grazing plan to benefit the species.

Conservation of the Sonoma spineflower is a high priority for PRNS, and PRNS staff is dedicated to managing and monitoring this species to ensure its continued survival in the park.

5.0 Literature Cited

- Abraham, J.K., J.D. Corbin, and C.M. D'Antonio. 2009. California native and exotic perennial grasses differ in their response to soil nitrogen, exotic annual grass density, and order of emergence. *Plant ecology*. **201**:445–456.
- Barrett, S.C. 1988. The evolution, maintenance, and loss of self-incompatibility systems. Pages 98-124 in J. Lovett Doust and L. Lovett Doust, eds. *Plant reproductive ecology*. Oxford University Press, New York, NY.
- Barrett, S.C.H. 2002. The evolution of plant sexual diversity. *Nature.com* **3**:274-284.
- Barrett, S.C.H. 2003. Mating strategies in flowering plants: the outcrossing-selfing paradigm and beyond. *Philosophical Transactions of the Royal Society London B: Biological Sciences* **358**:991-1004.
- Baskin, C.C. and Baskin, J.M. 1998. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, San Diego, California.
- Blanchard, C. L., and K. A. Tonneson. 1993. Precipitation chemistry measurements from the California Acid Deposition Monitoring Program, 1985-1990. *Atmospheric Environment* **27A**:1755-1763.
- Bytnerowicz, A. and M. Fenn. 1996. Nitrogen deposition in California forests: a review. *Environ. Pollut.*, **92**:127-146.
- California Climate Change Center. 2006. *Our changing climate: assessing the risks to California*. Summary report.
- Cayan, D.R., E.P. Maurer, M.D. Dettinger, M. Tyree, and K. Hayhoe. 2008. Climate change scenarios for the California region. *Climate Change*. **87**(1):S21-S42.
- Corbin, J.D., M.A. Thomsen, T.E. Dawson, and C.M. D'Antonio. 2005. Summer Water Use by California Coastal Prairie Grasses: Fog, Drought, and Community Composition. *Oecologia* **145**(4):511-521
- Crampton B. 1974. *Grasses in California*. University of California Press, Berkeley and Los Angeles.
- Davis, L. H. 1992. The ecology of *Chorizanthe valida* Wats. (Polygonaceae), the rare Sonoma spineflower, at Point Reyes National Seashore, Marin County, California. Masters Thesis. Sonoma State University, California.
- Davis, L. H. and R. J. Sherman. 1992. Ecological study of the rare *Chorizanthe valida* (Polygonaceae) at Point Reyes National Seashore, California. *Madrono*. **39**(4): 271-280.

- Dobson, H.E.M. 1993. Bee fauna associated with shrubs in two California chaparral communities. *Pan-Pacific Entomologist* **69**:77-94.
- Dukes, J.S. and Mooney, H.A. 1999. Does global change increase the success of biological invaders? *Trends in Ecology and Evolution*, 14,135–139. . *in* Alpert, P., E. Bone, and K. Holzapel. 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics*. Vol. 3/1, pp. 52–66.
- Dukes, J.S., Shaw, M.R. 2007. Responses to changing atmosphere and climate. Pages 218-229 in: *Ecology and Management of California Grasslands*, Stromberg, M., Corbin, J., and D'Antonio, C., eds. University of California Press, Berkeley.
- Edwards, Brooke. 1999. *Chorizanthe valida* Management Plan: Draft. Point Reyes National Seashore
- Elzinga, C.L, D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference. 1730-1. BLM/RS/ST-98/005+1730.
- Falk, D.A. 1990. Integrated strategies for conserving plant genetic diversity. *Annals Missouri Botanic Garden* **77**:38-46.
- Falk, D.A., C.I. Millar, and M. Olwell (eds.). 1996. *Restoring Diversity: Strategies for Reintroduction of Endangered Plants*. Island Press, Washington D.C.
- Fenn, M.E., J.S. Baron, E.B. Allen, H.M. Rueth, K.R Nydick, L.Geiser, W.D.Bowman, J.O. Sickman, T. Meixner, D.W. Johnson, and P. Neitlich. 2003. Ecological effects of nitrogen deposition in the Western United States. *BioScience* **53**(4): 404-420
- Fox, L.R., H.N.Steele, K.D.Holl, and M.H. Fusari. 2006. Contrasting demographics and persistence of rare annual plants in highly variable environments. *Plant Ecology* **183**:157-170
- Goulson, D., and J. Stout. 2001. Homing ability of the bumblebee *Bombus terrestris* (Hymenoptera: Apidae). *Apidologie* **32**:105-111.
- Harding Lawson Associates. 2000. Planting and mitigation monitoring plan, Moss Landing Harbor District, North Harbor Property Project No. 49854 004. *in* USFWS. Biological opinion on closure and reuse of Fort Ord, Monterey, California, as it affects Monterey spineflower critical habitat.
- Harvard Kennedy School. 2015. What’s behind bee declines and colony collapse? Latest science on stress from parasites, pesticides, habitat loss. *Journalist’s Resource*. April 24, 2015. Website.
- Hickman, J.C. 1993. *The Jepson Manual, Higher Plants of California*, J.C. Hickman, edit., University of California Press, Berkeley, California.

- Higgins, S.I., Pickett, S.T.A., and Bond, W.J. 2000. Predicting extinction rates for plants: environmental stochasticity can save declining populations. *Trends in Ecology and Evolution* **15**: 516-520.
- Hobbs, R.J. and Mooney, H.A. 1991. Effects of rainfall variability and gopher disturbance on serpentine annuals grassland dynamics. *Ecology*, 72, 59–68. . in Alpert, P., E. Bone, and K. Holzapel. 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics*. Vol. 3/1, pp. 52–66.
- Ingraham, N.L., and R.A. Matthews. 1995. The importance of fog-drip water to vegetation: Point Reyes Peninsula, California. *Journal of Hydrology* **164**: 269-285.
- Jones, C.E., F.M. Shropshire, L.L. Taylor-Taft, S.E. Walker, L.C. Song, Jr., Y.C. Atallah, R.L. Allen, D.R. Sandquist, J. Luttrell, and J.H. Burk. 2009. Reproductive biology of the San Fernando Valley spineflower, *Chorizanthe parryi* var. *fernandina* (Polygonaceae). *Madrono* **56**:23-42.
- Jones, C.E., Youssef C. Atallah, Frances M. Shropshire, Jim Luttrell, Sean E. Walker, Darren R. Sandquist, Robert L. Allen, Jack H. Burk, and Leo C. Song Jr. 2010. Do Native Ants Play a Significant Role in the Reproductive Success of the Rare San Fernando Valley Spineflower, *Chorizanthe parryi* var. *fernandina* (Polygonaceae)? *Madroño* 57(3):161-169. doi: <http://dx.doi.org/10.3120/0024-9637-57.3.161>
- Johnstone, J.A. and T.E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. *Proc. Nat. Acad. Sci.* Early Edition, February 16, 2010. www.pnas.org/cgi/doi/10.1073/pnas.0915062107
- Karoly, K. 1992. Pollinator limitation in the facultatively autogamous annual, *Lupinus nanus* (Leguminosae). *American Journal of Botany* **79**:49-56.
- Karron, J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 in D. Falk and K. Holsinger, eds. *Genetics and conservation of rare plants*. Oxford University Press, Oxford.
- Kershner, K.M. undated. *Scientists: Honeybees in the Wild Nearly Gone in North America*. Ohio State University publication. <http://researchnews.osu.edu/archives/bees.htm>
- Kluse, J., and D.F. Doak. 1999. Demographic performance of a rare California endemic, *Chorizanthe pungens* var. *hartwegiana* (Polygonaceae). *American Midland Naturalist* **142**:244-256.
- Lamarque, J.F., *et al.* 2005. Assessing future nitrogen deposition and carbon cycle feedback using a multimodel approach: Analysis of nitrogen deposition, *J. Geophys. Res.* **110**. D19303, doi:10.1029/2005JD005825.

- Larsson, M. 2005. Higher pollinator effectiveness by specialist than generalist flower-visitors of unspecialized *Knautia arvensis* (Dipsacaceae). *Oecologia*. 146:394-403. DOI 10.1007/s00442-005-0217-y
- Levine, J. M. and M. Rees. 2004. Effects of temporal variability on rare plant persistence in annual systems. *American Naturalist*. **164**: 350-363
- Levine, J. M., A. K. McEachern, and C. Cowan. 2008. Rainfall effects on rare annual plants. *Journal of Ecology*. **96**:795-806.
- Livingston, D.S. 1993. Ranching on the Point Reyes Peninsula: a history of the dairy and beef ranches within Point Reyes National Seashore, 1834-1992. National Park Service, Point Reyes Station, California.
- Loarie, S.R., B.E. Carter, K. Hayhoe, S. McMahon, R. Moe, C.A. Knight, and D.D. Ackerly. 2008. Climate Change and the Future of California's Endemic Flora. *PLoS ONE* **3**(6): e2502.
- Mallery, J.C. 1877. Appendix T.T: Annual report of Lieutenant J.C. Mallery, Corps of Engineers, for the fiscal year ending June 30, 1877. 1441-1443 in United States Army Corps of Engineers. Report of the Chief of Engineers U.S. army, Part 2. Mississippi River Commission. Government Printing Office, Washington, D.C.
- Maron, J.L. and P.G. Connors. 1996. A native nitrogen-fixing shrub facilitates weed invasion. *Oecologia* **105**:302-312.
- McGraw, J.M., and A.L. Levin. 1998. The roles of soil type and shade intolerance in limiting the distribution of the edaphic endemic *Chorizanthe pungens* var. *hartwegiana* (Polygonaceae). *Madrono* **45**:119-127.
- McLaren, J. 1899. Reclamation of drifting sand dunes. *The Forester* **5**:222 -223.
- Milchunas, D.G. & Lauenroth, W.K. (1995) Inertia in plant community structure: state changes after cessation of nutrient-enrichment stress. *Ecological Applications*, **5**, 452-458. in Alpert, P., E. Bone, and K. Holzapfel. 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics*. Vol. 3/1, pp. 52-66.
- Moldenke, A.R. 1975. Niche specialization and species diversity along a California transect. *Oecologia* **21**:210-242.
- Moldenke, A.R. 1976. California pollination ecology and vegetation types. *Phytologia* **34**:305-361.
- Moldenke, A.R. 1979. Pollination ecology as an assay for ecosystemic organization: convergent evolution in Chile and California. *Phytologia* **42**:415-454.

- Mosseler, A. 1992. Life history and genetic diversity in red pine: implications for gene conservation in forestry. *The Forestry Chronicle* **68**:701-707.
- Murphy, K.A. 2003. Endangered plant conservation: do pollinators matter to the robust spineflower? Master's Thesis. San Jose State University. 123 pp.
- NPS. 2006. Management Policies 2006. National Park Service. Washington, D.C.
- NRCS. 2007. Soil Survey Geographic (SSURGO) database for Sonoma County, California. U.S. Department of Agriculture, Natural Resources Conservation Service. Fort Worth, Texas
- Pitt, M. D., and H. F. Heady. 1978. *Responses of Annual Vegetation to Temperature and Rainfall Patterns in Northern California*. *Ecology* **59** (2): 336-350.
- Parsons, L., and J.B. Zedler. 1997. Factors affecting reestablishment of an endangered annual plant at a California salt marsh. *Ecological Applications* **7**:253-267.
- Parsons, S.L., and A.W. Whelchel. 2000. The effect of climatic variability on growth, reproduction, and population viability of a sensitive salt marsh plant species. *Lasthenia glabrata* subsp. *coulteri* (Asteracea). *Madrono* **47**:174-188.
- Pickart, A.J., L.M. Miller, and T.E. Duebendorfer. 1998. Yellow bush lupine invasion in northern California coastal dunes: I Ecology and manual restoration techniques. *Restoration Ecology*. **6**: 59-68.
- Rancho Santa Ana Botanical Garden (RSABG). 2000. Summary Report and Recommendations: Conservation Seed Collection of *Chorizanthe valida*. RSABG accession # 20462. April 12, 2000.
- Reveal, J.L., and C.B. Hardham. 1989. *Chorizanthe valida*. *Phytologia* **66**:83-88.
- Reveal, J.L. 2001. Scientific review questions. Prepared for the California Department of Fish and Game. Sacramento, CA. in Murphy, K.A. 2003
- Richards, A.J. 1986. Plant Breeding Systems. Unwin Hyman, London, UK.
- Ryan, A. and L. Parsons. 2011. Preventing Extinction of Sonoma Spineflower (*Chorizanthe valida*). Report to U.S. Fish and Wildlife Service. March 2011.
- Ryan, A. and L. Parsons. 2015. Sonoma Spineflower (*Chorizanthe valida*) TE018180-4 Annual Report 2014-2015. Report to U.S. Fish and Wildlife Service.
- Soil Conservation Service (SCS). 1985. *Soil survey of Marin County California*. United States Department of Agriculture, Soil Conservation Service. United States Department of Agriculture.

Snyder, M. 2008. Future changes in surface winds in the western U.S. due to climate change. Poster. American Geophysical Union conference. San Francisco, CA.

Stebbins, G.L. 1957. Self fertilization and population variability in the higher plants. *American Naturalist* **91**:337-354.

Thorp, R.W., and D.M. Gordon. 1992. Biodiversity and pollination ecology of bees in coastal nature preserves. Pages 105-111 *in* R.R. Harris, D.C. Erman, and H.M. Kerner, eds. Proceedings of the Symposium on biodiversity in northwestern California. Oct. 28-30, 1991. Santa Rosa, CA. Wildland Resources Center Report 29, University of California, Berkeley.

U.S. Fish and Wildlife Service (USFWS). 1998. Seven coastal plants and the Myrtle's silverspot butterfly recovery plan. (USFWS), Portland, Oregon.

U.S. Fish and Wildlife Service. 2001. Reopening of public comment period and notice of availability of draft economic analysis of proposed critical habitat determination for the *Chorizanthe robusta* var. *hartwegii* (Scotts Valley spineflower). Federal Register **66**:48227-48228.

U.S. Fish and Wildlife Service. 2002. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for *Chorizanthe pungens* var. *pungens* (Monterey Spineflower). Final rule. Federal Register / Vol. 67, No. 103 / Wednesday, May 29, 2002 / Rules and Regulations. Federal Register **66**:48227-48228.

Vogler, D.W., and S. Kalisz. 2001. Sex among the flowers: the distribution of plant mating systems. *Evolution* **55**:202-264.

Weiss, S. B. 1999. Cars, cows, and checkerspot butterflies: nitrogen deposition and management of nutrient-poor grasslands for a threatened species. *Conservation Biology* **13**:1476-1486.

White, T.A., Campbell, B.D. & Kemp, P.D. 1997. Invasion of temperate grassland by a subtropical annual grass across an experimental matrix of water stress and disturbance. *Journal of Vegetation Science*, 8, 847–854. *in* Alpert, P., E. Bone, and K. Holzapfel. 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics*. Vol. 3/1, pp. 52–66.

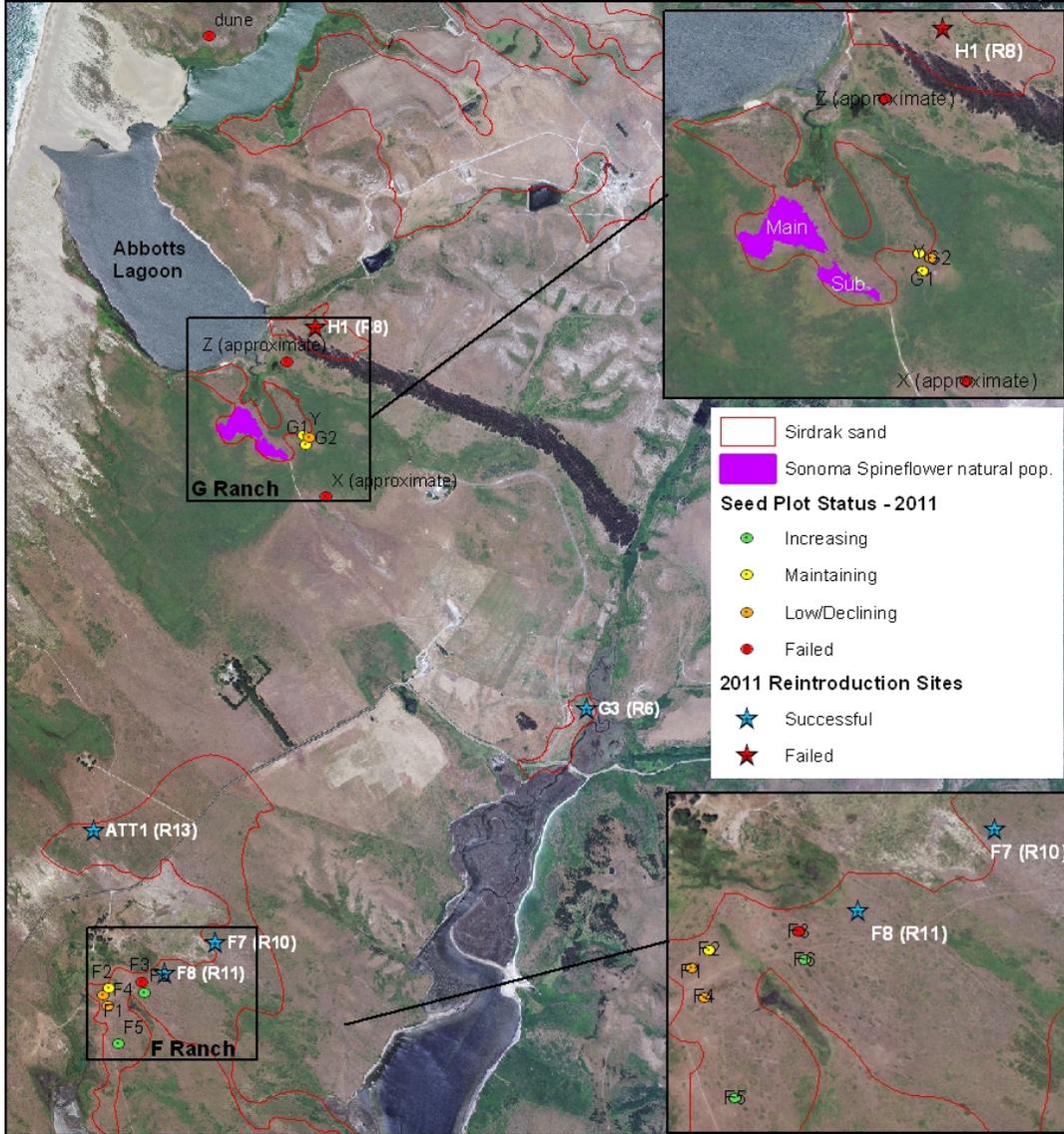
Wyatt, R. 1988. Phylogenetic aspects of the evolution of self-pollination. Pages 109-131 *in* S.K. Jain and L.D. Gottlieb, eds. *Plant evolutionary biology*. Chapman and Hall, New York, NY.

Personal Communications

Kelley, Brad. 2015. Email message to Lorraine Parsons summarizing observations and time-lapse photography of insect visitors to Sonoma spineflower in 2015. Dated Dec. 14, 2015.

Appendix A: Sonoma spineflower maps

Reintroduction plots in relation to the main population

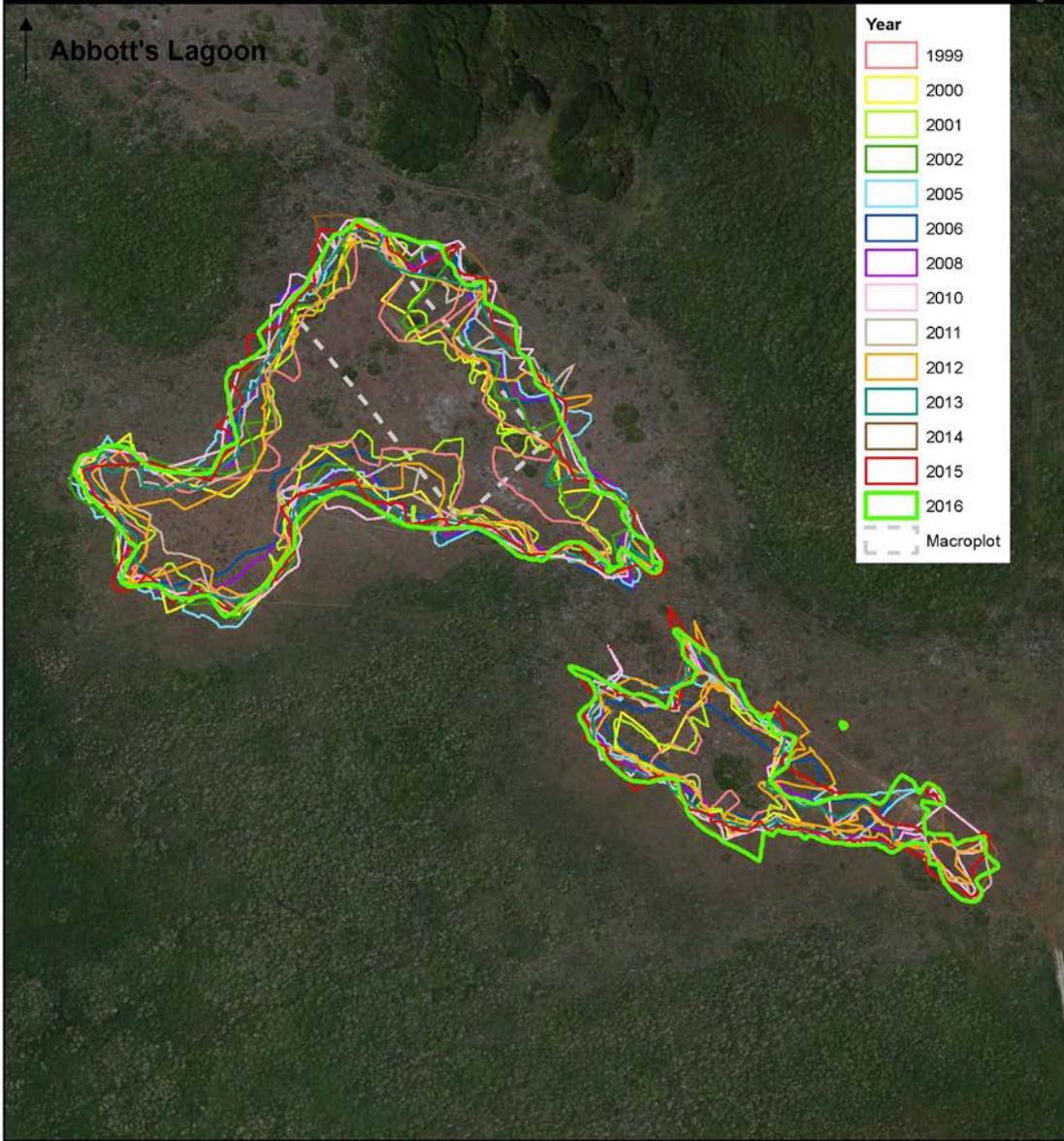


National Park Service
Point Reyes National Seashore
Marin County, CA

0 0.2 0.4 0.6 0.8 Miles

Map 1
Main population and
reintroduction seed plot
spatial relation and status

Sonoma spineflower main population



Year	
[Red box]	1999
[Yellow box]	2000
[Light Green box]	2001
[Green box]	2002
[Light Blue box]	2005
[Blue box]	2006
[Purple box]	2008
[Pink box]	2010
[Light Orange box]	2011
[Orange box]	2012
[Teal box]	2013
[Light Brown box]	2014
[Red box]	2015
[Green box]	2016
[Dashed white box]	Macroplot

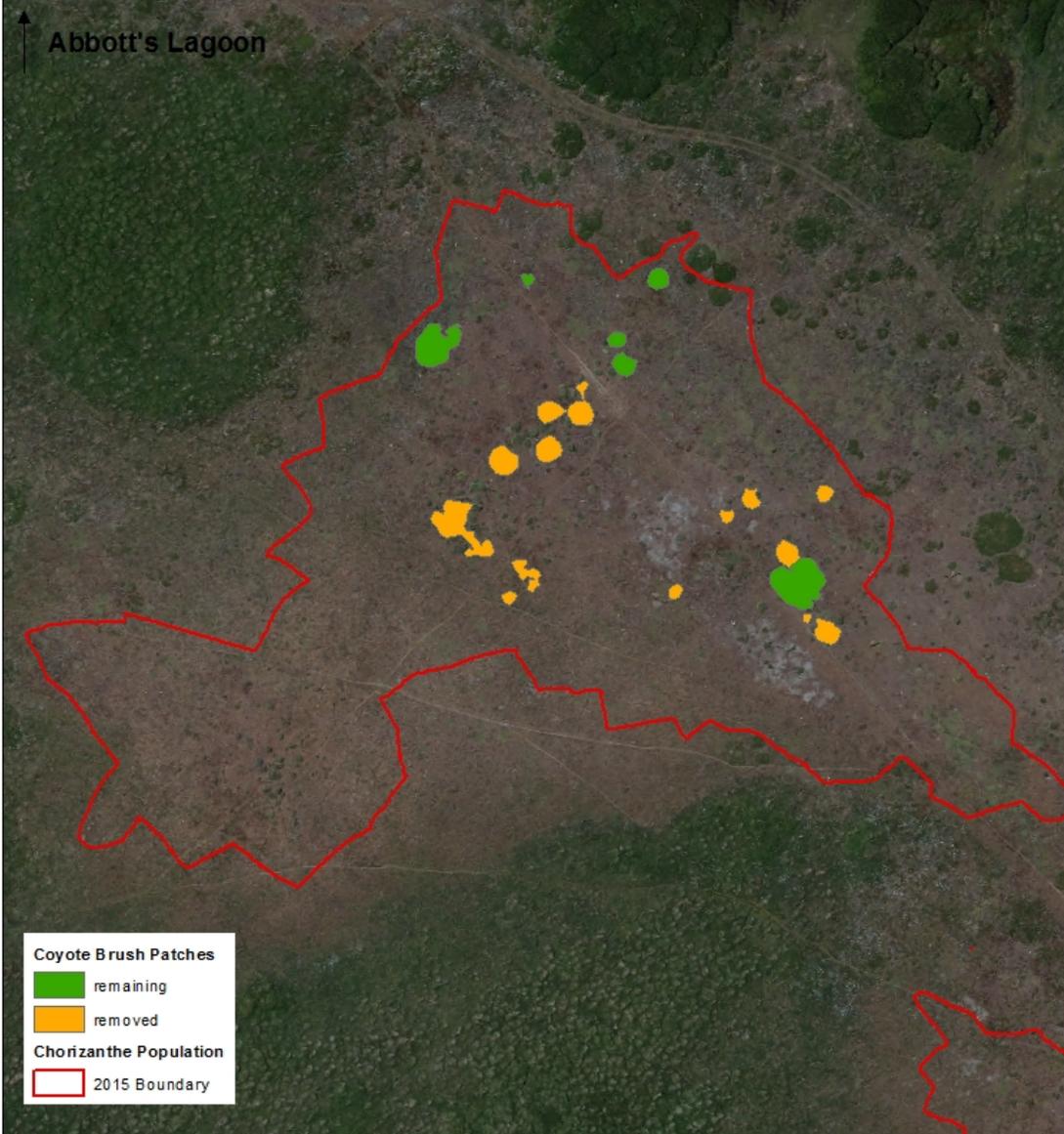


National Park Service
Point Reyes National Seashore
Marin County, CA

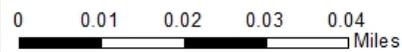
Map 2
Sonoma Spineflower population boundaries in relation to the macroplot and to encroachment from velvetgrass.

Plot date: July 2016 S:\GIS\projects1\veg\CHVA Protocol Figures\CHVA and HOLA boundaries.mxd

Sonoma spineflower main population



National Park Service
Point Reyes National Seashore
Marin County, CA



Map 1
Coyote Brush patches
in relation to Sonoma
Spineflower population.

Appendix B: Plant Community Monitoring Data – 2010-2016

Appendix Table. Plant community composition in terms of percent vegetation cover in wild Sonoma spineflower population. Species marked with asterisks are non-native.

7 Year Top 28 species absolute cover			Current Monitoring Plots in Wild Population												Davis Plots			
Average	Species Name	Code	2016	Rank	2015	Rank	2014	Rank	2013	Rank	2012	Rank	2011	Rank	2010	Rank	1989	Rank
26.8%	<i>Vulpia bromoides</i> *	VUBR	38.9%	1	13.2%	2	8.2%	7	24.6%	1	44.5%	1	43.3%	1	14.9%	5	25.5%	1
20.0%	<i>Rumex acetosella</i> *	RUAC	26.1%	2	12.1%	3	11.5%	3	8.8%	9	24.6%	2	36.7%	2	20.1%	1	6.0%	6
13.2%	<i>Cardionema ramosissimum</i>	CARA	12.7%	6	15.9%	1	14.8%	1	15.1%	4	10.5%	7	12.0%	7	11.8%	8	8.5%	4
12.6%	<i>Leontodon taraxacoides</i> *	LETA	6.5%	13	5.3%	7	2.2%	19	14.9%	5	22.2%	3	18.4%	5	18.4%	3	0.0%	
11.9%	<i>Cynosurus echinatus</i> *	CYEC	4.4%	19	2.6%	21	1.5%	23	9.4%	8	12.7%	5	34.5%	3	18.0%	4	1.0%	13
11.7%	<i>Danthonia californica</i>	DACA	3.1%	22	4.0%	12	10.6%	4	19.4%	2	18.6%	4	13.3%	6	13.3%	7	0.5%	16
10.9%	<i>Bromus diandrus</i> *	BRDI	15.4%	4	8.2%	4	8.7%	5	15.9%	3	8.6%	8	11.3%	9	8.0%	11	0.0%	
10.7%	<i>Bromus hordeaceus</i> *	BRHO	4.9%	17	3.3%	16	3.9%	13	11.9%	7	12.7%	5	23.9%	4	14.4%	6	11.5%	2
8.5%	<i>Lupinus varicolor</i>	LUVA	3.8%	21	4.2%	10	13.2%	2	14.9%	5	7.6%	9	5.9%	14	5.5%	16	0.0%	
7.9%	<i>Hypochaeris glabra</i> *	HYGL	5.3%	16	6.6%	5	3.1%	16	4.0%	14	3.4%	15	5.1%	16	20.0%	2	0.0%	
6.8%	<i>Aira praecox</i> *	AIPR	12.9%	5	3.2%	19	0.9%	26	4.0%	14	1.1%	23	12.0%	7	10.7%	9	0.0%	
6.4%	<i>Spergula arvensis</i> *	SPAR	23.2%	3	3.3%	16	8.7%	5	3.1%	21	0.0%	27	1.2%	27	3.8%	20	0.0%	
6.2%	<i>Horkelia marinensis</i>	HOMA	7.3%	11	5.8%	6	4.9%	9	4.4%	13	6.1%	10	7.1%	13	5.6%	15	0.0%	
5.5%	<i>Layia platyglossa</i>	LAPL	6.5%	13	2.8%	20	2.4%	17	1.9%	24	2.8%	18	7.8%	12	9.5%	10	0.5%	16
4.8%	<i>Aira caryophylla</i> *	AICA	8.1%	9	2.2%	23	0.6%	27	1.4%	25	1.2%	22	8.7%	11	7.9%	12	11.5%	2
4.3%	<i>Hypochaeris radicata</i> *	HYRA	9.5%	7	2.5%	22	3.5%	15	3.9%	16	4.0%	14	3.8%	20	2.7%	23	5.0%	7
4.3%	<i>Hordeum brachyantherum</i>	HOBR	2.9%	23	4.2%	10	4.0%	12	3.2%	19	3.1%	17	5.9%	14	6.1%	14	0.0%	
4.2%	<i>Baccharis pilularis</i>	BAPI	5.4%	15	4.8%	9	4.8%	10	4.9%	11	3.4%	15	3.1%	22	2.6%	24	0.0%	
4.2%	<i>Lolium perenne</i> *	LOPE	1.4%	27	1.5%	24	3.6%	14	3.3%	18	4.7%	13	9.6%	10	3.5%	21	2.0%	10
4.0%	<i>Briza maxima</i> *	BRMA	4.8%	18	3.3%	16	1.9%	22	6.0%	10	5.2%	12	4.4%	17	1.2%	27	0.0%	
3.8%	<i>Chorizanthe valida</i>	CHVA	4.1%	20	3.5%	13	4.8%	10	2.4%	23	0.7%	24	4.2%	18	6.7%	13	7.0%	5
3.8%	<i>Achillea millifolium</i>	ACMI	1.9%	26	3.5%	13	6.6%	8	3.6%	17	2.2%	20	3.6%	21	2.6%	24	1.0%	13
3.4%	<i>Silene gallica</i> *	SIGA	6.6%	12	3.5%	13	2.0%	21	2.9%	22	0.0%	27	1.6%	26	4.7%	17	0.0%	
3.1%	<i>Chorizanthe cuspidata</i> var. <i>villosa</i>	CHCUv	9.2%	8	4.9%	8	2.2%	19	0.7%	26	0.4%	25	1.2%	27	2.1%	26	1.0%	13
3.0%	<i>Holcus lanatus</i> *	HOLA	2.4%	24	0.6%	26	1.4%	24	4.5%	12	6.0%	11	3.9%	19	0.5%	28	0.0%	
2.7%	<i>Briza minor</i> *	BRMI	8.1%	9	1.5%	24	0.2%	28	0.1%	28	0.2%	26	2.5%	23	4.2%	19	0.0%	
2.4%	<i>Lupinus arboreus</i> (x <i>chamissonis</i>)	LUAR	2.1%	25	0.2%	27	2.4%	17	3.2%	19	2.4%	19	1.8%	25	3.5%	21	1.5%	11
2.2%	<i>Eryngium armatum</i>	ERAR	0.5%	28	0.2%	27	1.3%	25	0.6%	27	1.3%	21	2.4%	24	4.4%	18	0.0%	
T-test p-value: Top 28 spp. relative to 2010			0.805		0.001		0.011		0.300		0.685		0.144		N/A		0.012	
Bare Ground			2.2%		9.9%		16.5%		1.6%		2.4%		1.1%		4.7%		6.5%	
Total absolute percent cover for all species			265%		138%		147%		204%		224%		310%		249%			
Total absolute percent cover of natives			80.2%		63.8%		83.5%		83.1%		70.9%		83.6%		93.1%			

Table 2. Plant community composition in terms of percent vegetation cover in wild Sonoma spineflower population. Species marked with asterisks are non-native.

	Current Monitoring Plots in Wild Population							Davis Plots	
	2016	2015	2014	2013	2012	2011	2010	1989	Rank
Total absolute cover of non-natives	183.3%	73.3%	63.2%	120.4%	152.5%	224.2%	155.8%		
Total absolute cover of non-native grasses	102.4%	39.6%	31.2%	81.4%	97.4%	155.6%	83.5%		
Total relative percent cover of natives	29.8%	41.9%	47.6%	40.2%	31.0%	26.9%	35.6%	28.5%	
Total relative cover of non-natives	68.0%	48.2%	36.0%	58.2%	66.6%	72.1%	59.7%	65.0%	
Total relative cover of non-native grasses	30.0%	22.1%	18.2%	18.8%	24.1%	22.0%	27.7%	50.5%	

Appendix C: Pollinator Surveys Report – 2015

GRANT FINAL REPORT

U.S. Fish and Wildlife Service
Report to the U.S. Fish and Wildlife Service
Agreement No. 4500067955

Chorizanthe valida habitat restoration, introductions, seedbank and pollinator studies

Lorraine Parsons and Amelia Ryan
Point Reyes National Seashore
Marin County, California

February 2016

INTRODUCTION

The "health" of the pollinator population can affect the viability of a species such as Sonoma spineflower (*Chorizanthe valida*; FE): without adequate pollination, not enough seed may be produced, which could adversely impact a species' reproductive success and lead eventually to extinction of individual populations or even an entire species. Inadequate pollination can also limit the success of new introductions by reducing seed output. Adequate pollination relies not only on the number of pollinators present, but the number of effective pollinators. Ultimately, inadequate or ineffective pollination can have potentially adverse consequences for genetic diversity within special status plant species by eliminating reproduction within obligatory outcrossing species or forcing self-compatible species to self-pollinate more, which has strong implications for heterozygosity.

Sonoma spineflower is somewhat of an anomalous species. Despite its name, it no longer occurs in Sonoma County, and it's unclear whether it ever actually did occur there. It was believed extinct until members of the California Native Plant Society (CNPS) found a single population at G Ranch within Point Reyes National Seashore (Seashore) in the 1980s. Needless to say, existence of only a single population has broad implications for the long-term viability for this species, with the spineflower being much more vulnerable than its more common congeners such as San Francisco Bay spineflower (*Chorizanthe cuspidata* var. *cuspidata*; CNPS 1B.2) to threats from environmental degradation, stochastic events, genetic issues, and changes in climate related to global warming. Extremely limited species' distribution can also wreak havoc on pollinator-plant relationships, particularly for pollinators that may "specialize" on particular plant species, with low plant numbers resulting in sharp declines in pollen and nectar supply that then may encourage pollinators to shift to other plant species or possibly even cause localized extinction of specialized pollinators.

While little information has been collected on pollination ecology of Sonoma spineflower since the G Ranch was found, some studies have been conducted on other spineflower species. Wasps, bees, flies, and butterflies constituted the principal insect visitors to *Chorizanthe pungens* var. *hartwegiana* (Ben Lomond spineflower; USFWS 2001). Moldenke (1976) observed several different types of insects visiting *Chorizanthe* flowers, including wasps, bee flies, unspecified tiny species of insects, and generalist bees.

A large diversity of insects visited robust spineflower (*Chorizanthe robusta* var. *robusta*) both at a coastal scrub population (Sunset Beach) and a more inland woodland-chaparral location (Pogonip) in Santa Cruz County, with bees, beetles, flies, wasps, and moths observed (Murphy 2003). Within the larger taxonomic orders, there was also a lot of diversity, with 14 insect families at Sunset Beach and 13 families at Pogonip considered “frequent” visitors to robust spineflower. Bees or hymenoptera accounted 40% of all flower visits at the more coastal Sunset Beach site and 61% of all visits to the more inland population (Murphy 2003). Halictine or metallic bees accounted for a large proportion of the bee visitors observed at the coastal site, with far fewer visits by honeybees and bumblebees (*Bombus*; Murphy 2003). While Hymenoptera represented a larger proportion of the total visitors at the inland population, most of the visitors actually were wasps, not bees, with halictine and bumblebees relatively low in number comparatively (Murphy 2003).

Recent studies completed on a southern California species, *Chorizanthe parryi* var. *fernandina* (San Fernando Valley spineflower), indicated that five insect species accounted for about 75% of the visitors at one population (Newhall; *Apis mellifera*; two species of ants; two species of beetle), while another species, the small red ant, alone constituted almost 40% of the visitors to the other population (Newhall; Jones *et al.* 2009). Native bees were observed infrequently at either site during the study (Jones *et al.* 2009).

In 2009, Point Reyes National Seashore received a grant from the USFWS to take steps to prevent possible extinction of Sonoma spineflower by improving habitat and establishing new introduction sites (Improvement of Habitat and Reintroduction of Sonoma spineflower at Point Reyes National Seashore, Agreement NO: 81420-9-H535). This project included five components, one of which involved a detailed study of biotic and abiotic variables for the different natural and introduced populations to improve evaluation of potential future introduction sites. One of the biotic variables studied was pollination ecology of Sonoma spineflower.

During this study year, the primary insect visitors to spineflower at both the natural and introduced observation sites were bumblebees (Hymenoptera; Apidae; Anthophoridae; *Bombus*); honeybees (Hymenoptera; Apidae; Anthophoridae; *Apis mellifera*); beeflies (Bombyliidae); and ants (Hymenoptera; Formicidae; Ryan and Parsons 2011). This list corresponds well with the list of visitors observed by Davis (1992), a former Seashore employee who characterized the insect visitors during his study on the effect of grazing on Sonoma spineflower. In that particular year, *Bembix americana comata* (solitary ground nesting wasp), *Bombus vosnesenkii* (yellow-faced bumblebee), and *Apis mellifera* represented the most common insect visitors to the natural or “wild” spineflower population (Davis 1992).

The pollinator studies conducted as part of the Preventing Extinction Grant study primarily identified species to functional groups (bee, fly, ant, etc). In 2013, the Seashore issued a research permit to Brad Kelly of CNPS to conduct a more detailed survey of pollinators of Sonoma spineflower in the wild population and introduced populations. His survey efforts found that a variety of insects, including a number of bumblebee species, ants, tiny beetles, flies, solitary bees, and wasps. Bee visitors included species in the genera *Bombus*, *Melissodes*, *Colletes*, and *Lasioglossum*. Five species of *Bombus* were observed: *B. vosnesenskii*, *B. caliginosus*, *B. bifarius*, *B. melanopygus*, and *B. californicus*. In addition,

solitary wasps such as *Bembix* were often observed nectaring on Sonoma spineflower. Other visitors to Sonoma spineflower included some flies (Diptera), possibly in the Bombyliidae (beefly) family, and butterflies such as *Plebejus icarioides parapheres*.

Though *Bombus* are very numerous and probably the most frequent visitor to Sonoma spineflower, it is unclear that they are the prime pollinator in all cases (Kelly, unpub. data). *Bombus* are recognized as especially effective pollinators of “buzz-pollinated” plants like tomatoes, manzanita, and shooting star, where the morphology of the bee and the flower contribute to pollination (ibid). In those cases, the bee hangs under the flower and buzzes the pollen onto its ventral surface where the stigma can pick up pollen from visits to other flowers (ibid). When visiting Sonoma spineflower, they often already have full pollen loads from lupine and are mostly nectaring (ibid).

Smaller bees that crawl across the surface collecting pollen and nectar might prove more effective at pollinating this flower (Kelly, unpub. data). It might be that the continued expansion of the introduced population at Coast Guard Road/Schooner Creek -- at a time when other spineflower populations appear to have been severely impacted by the drought -- is partially due to higher numbers of more effective pollinators. Two species of small *Lasioglossum* bees were observed on Sonoma spineflower at the main G Ranch site (wild population) and at one of the new introduction sites at the Coast Guard Road or Schooner Creek site (ibid). At the Coast Guard Road/Schooner Creek site, they were observed in large numbers on the flowers when the temperature warmed up and appeared to be collecting both nectar and pollen (ibid). Kelly noted that these small bees might be a very effective pollinator of Sonoma spineflower (ibid). If that is the case, it might be possible to encourage nesting in the area of other populations.

The Seashore received funding from USFWS in 2014 to conduct further pollinator studies in 2015. The study was intended to build upon the information collected by previous National Park Service studies and more recent surveys by Kelly by determining whether there were differences in the suite of pollinators present at each of the existing spineflower sites and whether the presence of certain pollinators may be associated with better reproductive performance. If so, these differences would need to be taken into account when selecting introduction sites. Monies from the USFWS funded hiring of a contractor with a background in entomology to conduct more quantitative pollinator watches that assessed the number of visits by individual insect species. In addition, in 2014-2015, Mr. Kelly continued to survey insects present at the G Ranch, F Ranch, and Schooner Creek sites.

MATERIALS AND METHODS

Survey Methods

Pollinator observations were conducted at the G Ranch, F Ranch, Schooner Creek, and AT&T wild and introduced populations (Figure 1). Ten (10) locations or patches measuring 1X1 m in size were selected randomly within the natural or wild population for surveys – eight (8) at the main population and two (2) in the sub-population. Survey sites were also established in the two (2) Y and G1 introduction locations at G Ranch, as well as at the F Ranch (four sites), Schooner Creek (four sites), and AT&T (two sites) introduced populations.

The number and type of insect visitors to survey patches was recorded for a period of three (3) days during the prime flowering period (June 3 – June 20, 2015) by Seth Bunnell, a biologist contractor from Tomales, Calif., with expertise in entomology. During each pollinator observation period, observation sites were observed for 15 minutes, with observation times rotated so that each patch was observed at least once in the first half of each survey day (9:20 a.m. to 12:00 p.m.) and once in the last half of the day (12:30 – 3:45 p.m.). Schedules took into account transit time between observation sites. Mr. Bunnell attempted to identify insects to the lowest possible taxonomic level using his expertise, along with consultations with Brad Kelly.

For the purpose of this assessment, an insect “visit” was defined as an insect landing or being on a flower. During each observation period, the total number of insect visitors within the 1X1 m sampling plot was counted, even if they did not land on any spineflower plants. Other insects in the area, but outside the plot, were also noted. In addition, the total number of spineflower and non-spineflower plants visited in the observation site was counted. During the survey period, the observer listed all flowering species within the patch. At least once during the survey period, Seashore and Point Reyes National Seashore Association (PRNSA) biologists and interns (Lorraine Parsons, Amelia Ryan, Kelsey Cox, and Cody Ender) assessed the total density of flowering Sonoma spineflower, as well as other flowering species, within the patches, as well as qualitative assessments of percent vegetation cover.

Data Analysis

Most of the data collected was analyzed using General Linear Method (GLM) tests (MiniTab, Version 17), with some data logarithmically transformed to meet assumptions of normality and/or homogeneity of variance. If data were unable to meet assumptions even with transformation, they were analyzed using a Linear Permutation test (LPm) in the R statistical package program. Chi-Square analyses were also performed for some of the frequency-oriented data (MiniTab, Version 17). Community composition was evaluated using several multivariate techniques, including Non-Metric Multi-Dimensional Scaling (NMS), Multi-Response Permutation Procedure (MRPP), and Indicator Analysis (PC-Ord Version 5).

RESULTS/DISCUSSION

Our efforts to better understand pollination ecology of this species were hindered, to some degree, by climate-related factors. At the time of the surveys in summer 2015, California was considered to be in the fourth – and seemingly driest – year of a four-year drought. While rainfall totals for 2012 and 2013 appeared average, both years were considered much drier than normal from a statewide perspective. Conditions became even drier in 2014 and 2015. While rainfall totals seemingly increased in 2015 relative to 2014, most of this increase came from torrential rains in December 2014, and the late winter/early spring was one of the driest periods on record, with the state of California declaring a Drought State of Emergency in January 2015.

Dry conditions, however, did not necessarily equate to hot conditions, at least in the Point Reyes Peninsula area. During the previous year (2014), Kelly noted that the bloom period remained cooler in temperature than in the previous survey year (2013; Kelly, unpub. data). A similar weather trend was seemingly observed in 2015, at least in June, with conditions often being cool, windy, and overcast.

Weather data from the nearby Point Reyes RCA monitoring station did not show any clear evidence of strong inter-annual differences in average temperature or wind speed during the bloom period (June) between 2010 and 2015, but it did appear that maximum temperatures recorded were perhaps lower in 2014 (64 degrees Fahrenheit/°F) than between 2011 and 2013 (67 to 69 °F). No maximum temperature data was available for 2015.

Both drought and cold can affect pollinator dynamics. Drought may reduce the number and diversity of flowering plant species that are available for pollinators to forage on, while cold may reduce the number and diversity of pollinators. Some insects tolerate cooler temperatures better than others (Kelly, unpub. data). Given this, it is not surprising that the number of pollinator species is, in general, much lower along California's coast, which is typically much cooler than inland areas due to the strong influences of wind and fog. Based on surveys of bees abundance and diversity by Dobson (1993), the diversity of bee species along the cool, foggy, and windy Marin County coast is literally half that found in more inland chaparral sites. Moldenke (1976) also found that coastal scrub in northern California supported about 50% less pollinator diversity than inland sites, with some of the more common coastal species other than bees being muscoid flies and beeflies.

The cool, foggy, and windy conditions that are prevalent along the coast limit flight time for small bees and metallic bees, which cannot regulate internal temperature, which is why bumblebees, which can, to some degree, regulate their body temperatures, are more common in foggy coastal climates (Dobson 1993). According to Moldenke (1975), bumblebee abundance increases with severity of environment, with numbers in his survey being highest at the Point Reyes coastal site. Bumblebees represented 80% of the bee fauna observed during Moldenke's study (1975). The other family, halictids, represents the dominant pollinator for about 25% of the bee-pollinated flora (Moldenke 1979). The Anthophoridae and Halictidae families have been classified as two of the most important pollinator groups in California (Moldenke 1976).

Most of the bee species along the coast tend to act as generalist pollinators, visiting many plant species, rather than specialists. A survey of a coastal dune site at the Seashore found that only 5% of the plant species supported specialist bee pollinators (Moldenke 1979), with 95% being considered "super-generalists" (Moldenke 1975). Dobson (1993) also found that Anthophoridae and Halictidae pollinators at a northern California coastal site acted as generalists, not specialists. In general, California's Mediterranean climate, with its large variability in temperature and rainfall, may favor generalist strategies among pollinators (Jones *et al.* 2009). With most species in this spineflower genus occupying xerophytic



Bumblebee visiting Sonoma spineflower (Chorizanthe valida; photo courtesy of A. Ryan, NPS.)

habitats, it is perhaps not surprising that any pollination ecology study that has been conducted on *Chorizanthe* has found a generalist strategy among the principal pollinators (Reveal and Hardham 1989; Bauder 2000 in Jones et al. 2009; USFWS 2001; Murphy 2003; Jones et al. 2009).

There were some striking similarities – and dissimilarities – between surveys conducted in 2010 and 2015. In 2010, the majority of insect visits within the Sonoma spineflower pollinator observation sites came from bumblebees, which also accounted for a disproportionate number of the spineflower plants visited within the plot (Ryan and Parsons 2011). Of the total visits to observation sites in 2010, bumblebees totaled 51 visits; honeybees, 14 visits; beeflies, 6 visits; and ants, 2 visits (ibid). The numbers become even more disproportionate when looking at total number of spineflower plants visited by different species, with bumblebees visiting a total of 475 spineflower plants at all observation sites; honeybees, 62 plants; and beeflies, 6 plants (ibid). Of the two visits by ants, neither of those insects visited Sonoma spineflower, but rather another *Chorizanthe* species, *Chorizanthe cuspidata* var. *cuspidata*, and other non-*Chorizanthe* species (ibid). However, ants had been observed on Sonoma spineflower during the study period (A. Ryan, NPS, pers. obs.). In general, bumblebees and honeybees focused most of their foraging efforts at least within the patches on spineflower (>56%), while approximately 14% - 23% visited a mix of spineflower and other plant species within a patch: based on our data, tidy tips accounted for most of the visits to other species, with other members of the Asteraceae family at F Ranch also being visited (Ryan and Parsons 2011). This data suggests that the suite of pollinators in 2010 were primarily generalists that may occasionally focus foraging efforts on certain plant species.

In 2015, the diversity of visitors to spineflower expanded dramatically relative to 2010. In 2010 surveys, only four species were observed visiting Sonoma spineflower: in 2015, that number jumped to 28 (Table 1a-1b; Figure 2). The number of insect species visiting per plot averaged 3.7 ± 0.6 (S.E.) in 2015, compared to 1.5 ± 0.6 (S.E.) in 2010 (GLM, df=1, F=7.2, P=0.011; log-transformed). This change may relate, in part, to the fact that the number of monitoring sites expanded in 2015 to include Schooner Creek, AT&T, and the G Ranch Introduction sites as well as F Ranch and G Ranch Main/Sub-Population, but other factors probably played a role, as well, including doubling of the observation time (from 45 to 90 min) and hiring of a more highly trained person to conduct surveys in 2015. In contrast, the mean number of visitors per plot remained equivalent (GLM, df=1, F=0.2, P=0.63, log-transformed). On average, 4.5 ± 1.0 (S.E.) insects visited spineflower plants in plots in 2010, while 4.1 ± 0.9 (S.E.) visited plants in plots in 2015: visitor numbers were adjusted in this analysis to account for differences in observation time between years. When total number of visitors for each year is adjusted for both increased observation time and the increased number of plots or monitoring locations in 2015, the totals remain roughly equivalent, with 72 visitors in 2010 and 65 visitors in 2015. In essence, then, in 2010, there were fewer species visiting spineflower, but, on average, more of those four taxa than of all the 28 taxa observed visiting in 2015.

Visitors to Sonoma spineflower in 2015 spanned a very broad number of taxonomic orders, including Hymenoptera (bees, wasps, and ants), Diptera (flies), Coleoptera (beetles), and Lepidoptera (butterflies; Table 1a-1b; Figure 3). Much of this variety was captured by Brad Kelley using time-lapse photography at some of the spineflower sites. Mr. Kelley took 1,600 photos and 125 videos: Some representative

photos are included in Appendix A. The mix of taxonomic groups varied considerably among both between groups (populations or Areas; Figure 3) and among groups (patches/plots; Figure 4), but was more similar among groups. This is strongly evident in the multivariate Non-Metric Multidimensional Scaling (NMS) analysis, which show fairly strong grouping of most plots/patches of Areas, with little to no overlap with plots from other Areas (NMS, Stress=13.22, 73 iter.; Figure 5). There were a few exceptions. G Ranch Main and Sub-Population plots did overlap, which is not too surprising considering their proximity. Plots 3D from Schooner Creek and 3 from the G Ranch Main population strayed somewhat far from their groups, with the former being more closely allied with the G Ranch Introduction sites and the latter, the ATT sites. F Ranch sites defied grouping altogether, with plots dispersed throughout multivariate space. Axis 1 of the NMS analysis largely separated the G Ranch Introduction group from the ones at Schooner Creek/ATT, with G Ranch Main and Sub-Population being somewhat intermediate (NMS $R^2=0.227$; LM Perm, $df=5$, $P=0.05$). However, Axis 2 accounted for more of the data variability (NMS $R^2=0.379$) and was focused more on separation of natural or “wild” population sites from introduced ones (LM Perm, $df=5$, $P=0.04$).

Other multivariate analyses also pointed to dissimilarities between insect visitor community assemblages between groups or Areas (MRPP, $T=-3.52$, $P=0.002$). Based on summary statistics (Figure 3) and results from NMS and Indicator Species analyses, certain insect taxa were more closely associated with particular plots or Areas. Listed below in Table 2 are some of the stronger visitor taxa-Area associations. G Ranch Main appeared to support the largest numbers of the genus, *Bombus*, with *Bombus vosnesenskii* being the most common species. Melyridae (Dasytinae) or “flower beetles” also visited large numbers of spineflower plants, along with black ants (*Formica* sp.), which were much more common to spineflower at all sites in 2015 than in 2010. *Bombus* and black ants were also common at F Ranch. At Schooner Creek, bumblebees represented a fairly common visitor, but other species seemed more key to the species assemblage such as solitary bee species (*Anthophora*, *Ceratina*), bee fly species (*Chrysanthrax*, *Villa*), and other Diptera species such as *Paracosmus*. ATT had few visitors, but many of those were fairly distinct such as *Megachile* and, to a lesser degree, *Agapostemon*.

Table 2. List of insect visitor taxa strongly associated with particular Areas or Sonoma spineflower populations based on results of multivariate analyses and summary statistics.					
Area/Popln	Taxa1	Taxa2	Taxa3	Taxa4	Taxa5
G Ranch Main/SP	<i>Bombus</i> ^{1,3}	Melyridae (Dasytinae) ^{1,3}	Melyridae ^{1,3}	<i>Formica</i> ¹	Sphericidae ¹
F Ranch	<i>Bombus</i> ³	<i>Formica</i> ³			
Schooner Creek	<i>Anthophora</i> ^{1,2}	<i>Ceratina</i> ^{1,3}	<i>Villa</i> ^{1,3}	<i>Paracosmus</i> ²	<i>Chrysanthrax</i> ²
ATT	<i>Megachile</i> ^{1,2}	<i>Agapostemon</i> ²			

¹ = NMS; ² = Indicator Species; ³ = Summary Statistics

The total number of visitors for each area shown in Figure 6 and in Figure 4 showed strong dissimilarities in the number of total visitors per area, even when totals were adjusted for difference in observation times (Chi-Square, $df=5$, Chi-Square=21.5, $P=0.001$): Schooner Creek and G Ranch Sub-Population had higher numbers of total visitors than G Ranch Main and F Ranch, which had more visitors than G Ranch Introduction sites and AT&T. However, despite this, average visitors per area remained roughly

equivalent (LMPerm, df=5, P=0.92; Figure 6). Means ranged from approximately 4 visitors/area at ATT and G Ranch Introduction areas to 12 visitors/area at G Ranch Sub-Population area, with F Ranch, G Ranch Main, and Schooner Creek averaging approximately 7, 9, and 10 visitors/area, respectively. No differences existed, either, among areas in the average number of taxa visiting (LMPerm, df=5, P=0.75). Mean taxa richness ranged from a low of approximately 2 taxa at the G Ranch Introduction area to a high of 5 at G Ranch Main, with most other sites averaging 4 (ATT, F Ranch, and Schooner Creek).

The suite of insect visitors represents only part of the story. Insects may facilitate pollination, but they may also rob nectar resources without effecting pollination or be only present to feed on leaves, floral parts, or developing or developed seeds. In addition, certain insects may be capable of transferring pollen, but only within plant due to the insects' limited mobility (e.g., ants). These visitors may be completely ineffective as pollinators if the plant species is an obligate "outcrosser."

Spineflower species appear to share very similar characteristics in terms of their breeding systems. Several spineflower species, including the San Fernando Valley spineflower (*Chorizanthe parryi* var. *fernandina*; SE) and Monterey spineflower (*Chorizanthe pungens* var. *pungens*; FT), have been described as protandrous, in which the anthers shed pollen before the style of the flower is developed (USFWS 2002; Jones *et al.* 2009). As noted at least for Monterey spineflower, this protandrous condition is relatively fleeting, lasting only a day or two before the style is also fertile (USFWS 2002): If cross-pollination does not occur within 1 or 2 days, self-pollination may occur, as the flower closes at the end of the day (Reveal 2001 *in* USFWS 2002).

Many spineflower species have been shown to be self-compatible. Even when bagged, the San Fernando Valley spineflower produced 30% of its fruits with viable seed, which suggests that this species can self when pollinators are limiting and when insects induce selfing by visiting primarily flowers on the same plant (i.e. ants; Jones *et al.* 2009). The robust spineflower also turned out to be self-compatible, although seed set rates were lower than for its southern California congener (mean=5.7%; Murphy 2003). Reveal (2001 *in* Murphy 2003) discussed greenhouse studies that showed that selfing occurs in several other annual *Chorizanthe* species, as well.

In the 2010 Preventing Extinction study, approximately $8.7\% \pm 2.5\%$ (S.E.) of the "bagged" flowers of the Sonoma spineflower plants from which pollinators were excluded set fruit, with most – but not all – fruit appearing viable, although viability was not formally evaluated (Ryan and Parsons 2011). The Seashore's study, however, was confounded by mammals such as cows, rabbits, and rodents knocking inflorescence mesh enclosures off plants, leaving only 33 of the original 60 enclosures intact (Ryan and Parsons 2011). Only 22% of Sonoma spineflower plants grown in a greenhouse from seed accessioned at Rancho Santa Ana Botanic Garden set seed unlike some of the other *Chorizanthe* species that they have propagated (M. Walls, RSABG, *pers. comm.*). The greenhouse eliminates not only the potential for insect pollination, but wind pollination, as well, which may be a factor for plants growing along California's extremely windy coastline. As much as an estimated 30% of coastal dune scrub species were self-compatible or habitually self-fertilizing, with higher percentages exhibited by annuals (Moldenke 1976).

Self-compatibility is believed to be common in geographically restricted species (Stebbins 1957), annual plants of California and other Mediterranean regions (Stebbins 1957), and rare plants (Karron 1991, Barrett 2002). Restricted outcrossing and selfing can be genetically problematic for obligate outbreeding species. However, quite a few outbreeding plant species have adjusted to increased inbreeding with no ill effects on fitness parameters such as fecundity and viability, and some have even developed mating systems that favor inbreeding (Falk 1990; Mosseler 1992). Indeed, some obligately outcrossing plant species have developed mechanisms for autogamy (self-fertility) as insurance against the uncertainties of pollinator availability (Karoly 1992, Richards 1986, Barrett 1988; Wyatt 1988).

While a number of *Chorizanthe* species are self-compatible and show varying capabilities for self-pollination, most of the studies conducted show higher fruit and seed set rates when pollinators have access. *Chorizanthe pungens* var. *pungens*, a Monterey County threatened spineflower, suffered decreases in seed set and even germination when pollinators had limited access to plants (Harding Lawson Associates 2000 in Murphy 2003). Fruit set was also lower for the San Fernando Valley spineflower when pollinators were excluded: open inflorescences set 50-60% seed compared to 30% for closed ones (Jones *et al.* 2009). Robust spineflower flowers from which insects were excluded set only 19% as many seeds as did flowers that had open pollination, with open inflorescences setting 29.9% seed compared to 5.7% for closed inflorescences (Murphy 2003).

In our 2010 study, Sonoma spineflower plants that were open to pollination set 44.4% seed, compared to $8.7\% \pm 2.5\%$ (S.E.) for enclosed inflorescences (Ryan and Parsons 2011). Plants that primarily rely on insect- or other types of pollination vectors, but that can self-pollinate, are often considered to have adopted a mixed mating strategy (Vogler and Kalisz 2001), which provides additional assurance of reproductive output every year for plants found in habitats with extreme variability in climatic conditions (Barrett 2002, 2003; Jones *et al.* 2009). It appears that, to some degree, Sonoma spineflower has also adopted this strategy, which is important because of the inherently lower number of insect pollinators along the California coast, which strongly points to most coastal plant species probably being pollinator-limited (Thorp and Gordon 1992).

Given all this information, what we can assume is that flying insects that tend to specialize, at least primarily, on Sonoma spineflower will represent the “best” pollinators, because they move between spineflower plants and possibly patches, promoting outcrossing, and are less likely to “pollute” the stigmas of spineflower plants with pollen from other plant species. However, the greater effectiveness of specialist pollinator species can be negated, to some degree, if generalist pollinators are more abundant and contribute more to pollen flow, even if some of that pollen comes from other plant species (Larsson 2005). While bumblebees are generalists, bumblebees are known to repeatedly visit the same plant species (Moldenke 1976) and show strong degrees of floral constancy in that they visit a high number of flowers of the same species in succession (Proctor *et al.* 1996 in Murphy 2003). In terms of sheer numbers, *Bombus* spp. represented the most common flying insect genera visiting spineflower in both 2015 and 2010, with *Bombus vosnesenskii* the most common bumblebee species (Ryan and Parsons 2011; Figure 2).

The 2015 study year differed from 2010 in that the plants also supported a fair number of crawling or preferentially crawling insect species such as Coleoptera spp. (non-flying beetles) and Formica spp. (ants), which actually surpassed flying insects considerably in number in 2015 (Figure 3). Ants were one of the few crawling insect orders found in both study years, but numbers appeared to be dramatically higher in 2015. Crawling species are obviously less likely to move pollen from plant to plant, much less between spineflower patches, however, as spineflower is probably only slightly protandrous, ants could effect self-pollination once both stigmas and styles are fully developed. Ants appear to be an important pollinator for the San Fernando Valley spineflower: Fruit set was 57% in flowers exposed to ant visitation, compared to 27% in flowers in which ants were excluded, and the germination rate for seeds produced from flowers where ant visitation occurred reached as high as 61%, compared to 25.7% for seeds produced from flowers in which ants were excluded (Jones *et al.* 2010).

The authors concluded that ant pollination may be more prevalent in drier climates (Jones *et al.* 2010). The San Fernando Valley, which is located in southern California, definitely has a drier climate than the Seashore, which is located in the northern portion of central California. However, as we discussed in detail at the outset of this discussion, intra- and inter-annual variation in rainfall can produce “drought” conditions even seemingly in the wettest areas. The prolonged drought in California that persisted through 2015 definitely appeared to impact the target species and its pollinator populations, as well as some of the associated plant species that may serve to help support pollinator species both before and after the limited spineflower bloom. Estimated population size for the main or “wild” population of Sonoma spineflower fell far below historic highs between 2012 and 2014 – the start of the drought – but rebounded surprisingly in 2015 even though rainfall levels remained low, particularly spring rainfall levels (Ryan and Parsons 2015). More variable plant estimate numbers were found for the introduced populations (Ryan and Parsons 2015).

In terms of pollinators, the drought can affect floral and other biotic and abiotic resources, which can drive short-term and long-term population dynamics. The dry spring in 2015 meant that flowers of many plant species tended to bloom earlier and for a shorter period of time (B. Kelley, *pers. comm.*). While spineflower produced a decent amount of flowers, many of the flowers of other species dried up, resulting less pollen and nectar for provisioning nests (B. Kelley, *pers. comm.*). Once resources become scarce, many pollinators go off to die to set up for the next generation, therefore, for most species, any year’s total population is based on the previous year’s provision availability, creating at least a one year lag in population recovery (B. Kelley, *pers. comm.*). While *Bombus* numbers were also down this year, this genus does not have same restriction as some of the other bee pollinators: the colony just produces more workers, as conditions improve (B. Kelley, *pers. comm.*).

One glaring difference between 2010 and 2015 in terms of insect visitors to spineflower is the utter absence of honeybees in 2015, which represented the second highest visitor to this species in 2010 (Ryan and Parsons 2011). These results are particularly interesting, given what has been occurring with the collapse of managed honeybee populations across the United States in recent years due to factors such as parasites, fungi, viruses, pesticides, declining plant diversity, and interaction between some or all of these factors (Harvard Kennedy School 2015). While most of the research has been focused on managed honeybee populations, wild populations also appear to be on the decline: one Ohio State

University researcher, Dr. James Tew, proclaimed that honeybees in the wild in North America have been virtually wiped out by recent climatic conditions and two parasitic mites (Kershner, Ohio State University, no date). Kelley notes that it's possible that honeybee populations near Sonoma spineflower may have succumbed to the drought or to some of the other factors affecting other managed and wild honeybee populations in North America.

Ultimately, factors affecting reproductive success of this species may prove to be quite complicated. As with other California coastal species such as *Cordylanthus maritimus* ssp. *maritimus* (salt marsh bird's beak; Parsons and Zedler 1997), Sonoma spineflower may be alternately pollen- and resource-limited both on temporal and spatial scales.

Implications for Reintroduction Strategies and Long-Term Species Conservation

Results of the self-pollination analysis from 2011 (Ryan and Parsons 2011) suggested that, while spineflower can set seed without insect vectors, seed set is more successful when insects, particularly bees, are present. While there is no conclusive evidence from either 2010 or 2015 data, it does seem that introduction patches or sites that have had consistently higher plant numbers over the years were the ones supporting a number of Hymenopteran visitors in 2010 and/or 2015, particularly *Bombus* or bumblebees. The same is true of the main or wild population of spineflower.

The 2015 study demonstrated, however, that hymenopterans are not the only insect visitor that may be capable of effecting pollination. In decided contrast to 2010, the diversity of insect visitors was much greater in 2015, spanning a number of different insect orders. While the contribution of these visitors to plant pollination is difficult to determine, the fact that the plant can successfully self-pollinate means that even crawling insects that do not transfer pollen between plants could play some role in plant pollination, although self-pollination may impact the genetic integrity and, thereby, the viability of this species. Without genetic studies, it is impossible to determine how robust this species is to potential inbreeding issues. However, it goes without saying that, in most cases, outbreeding is a safer and more evolutionarily beneficial reproductive strategy.

With that in mind, in terms of long-term viability of Sonoma spineflower, the Seashore needs to ensure that it conserves not only natural and reintroduced spineflower habitat, but the habitat of its pollinators. Conservation of pollinator habitat will require a better understanding of nesting and foraging needs of the primary pollinator species within the Seashore. Not much is known of the nest locations for Hymenopterans at the Seashore. One very large bumblebee nesting area was found in a large sandstone formation along the coast only a few miles from the natural population: Certain species of bumblebees are believed to fly up to several miles from the nest in search of nectar and pollen (Goulson and Stout 2001).

However, for reintroduction purposes, perhaps, the best evidence of pollinator presence may be the abundance of other bee-pollinated plants such as members of the Asteraceae family (e.g., tidy tips) and other wildflowers. While these species may compete to some degree for pollinator services, their abundance points to pollinators consistently visiting these areas on a year-to-year basis, and these flowers provide nectar and pollen "insurance" for pollinators, supporting them when spineflower is not

in flower, or numbers in a particular year are low. Factors such as nest proximity and presence of other floral resources should be incorporated into evaluation of potential reintroduction sites. Ultimately, successful recovery of certain threatened and endangered plant species may require “enhancement” of pollinator activity through sowing seed of other plant species known to attract specific pollinators and even creating nesting areas within the vicinity of plant populations.

BUDGET

The Seashore staff decided that it would better to hire a contractor with a strong entomological background rather than to conduct insect visitors surveys in-house, as it would improve the quality and quantity of information. For this reason, the total amount spent on this project increased, so funds at Point Reyes National Seashore Association were used to pay for a final round of potential pollinator surveys. The park’s match to this project was time spent by the Vegetation Ecologist (GS-11) and Wetland/Rare Plant Ecologist (GS-9) setting up the contract, working through the logistics of the surveys and survey schedule, monumenting the plots, orienting the contractor, analyzing the data, and writing this report. The park also used funds to buy rebar for monumenting plots and to pay for one month of a GSA vehicle lease.

Budget Item	Est. Cost	Actual Cost
Biologist-(GS-9-Term STF) – Pollinator obs.	\$3,200.00	\$ 0
Contractor-Pollinator observations	\$ 0	\$3,013.00
Vehicle (GSA Lease)	\$ 0	\$ 338.30
Supplies (rebar-plot marking)		\$ 35.42
Project Total	\$3,200.00	\$3,386.64

LITERATURE CITED

Barrett, S.C. 1988. The evolution, maintenance, and loss of self-incompatibility systems. Pages 98-124 in J. Lovett Doust and L. Lovett Doust, eds. Plant reproductive ecology. Oxford University Press, New York, NY.

Barrett, S.C.H. 2002. The evolution of plant sexual diversity. Nature.com **3**:274-284.

Barrett, S.C.H. 2003. Mating strategies in flowering plants: the outcrossing-selfing paradigm and beyond. Philosophical Transactions of the Royal Society London B: Biological Sciences **358**:991-1004.

Davis, L.H. 1992. The ecology of *Chorizanthe valida* Wats. (Polygonaceae), the rare Sonoma spineflower, at Point Reyes National Seashore, Marin County, California. Master’s Thesis. Sonoma State University, CA, 37 pp.

- Davis, L. H. and R. J. Sherman. 1992. Ecological study of the rare *Chorizanthe valida* (Polygonaceae) at Point Reyes National Seashore, California. *Madrono* **39**:271-280.
- Dobson, H.E.M. 1993. Bee fauna associated with shrubs in two California chaparral communities. *Pan-Pacific Entomologist* **69**:77-94.
- Falk, D.A. 1990. Integrated strategies for conserving plant genetic diversity. *Annals Missouri Botanic Garden* **77**:38-46.
- Falk, D.A., C.I. Millar, and M. Olwell (eds.). 1996. *Restoring Diversity: Strategies for Reintroduction of Endangered Plants*. Island Press, Washington D.C.
- Goulson, D., and J. Stout. 2001. Homing ability of the bumblebee *Bombus terrestris* (Hymenoptera: Apidae). *Apidologie* **32**:105-111.
- Harding Lawson Associates. 2000. Planting and mitigation monitoring plan, Moss Landing Harbor District, North Harbor Property Project No. 49854 004. *in* USFWS. Biological opinion on closure and reuse of Fort Ord, Monterey, California, as it affects Monterey spineflower critical habitat.
- Harvard Kennedy School. 2015. What's behind bee declines and colony collapse? Latest science on stress from parasites, pesticides, habitat loss. *Journalist's Resource*. April 24, 2015. Website.
- Jones, C.E., F.M. Shropshire, L.L. Taylor-Taft, S.E. Walker, L.C. Song, Jr., Y.C. Atallah, R.L. Allen, D.R. Sandquist, J. Luttrell, and J.H. Burk. 2009. Reproductive biology of the San Fernando Valley spineflower, *Chorizanthe parryi* var. *fernandina* (Polygonaceae). *Madrono* **56**:23-42.
- Jones, C.E., Youssef C. Atallah, Frances M. Shropshire, Jim Luttrell, Sean E. Walker, Darren R. Sandquist, Robert L. Allen, Jack H. Burk, and Leo C. Song Jr. 2010. Do Native Ants Play a Significant Role in the Reproductive Success of the Rare San Fernando Valley Spineflower, *Chorizanthe parryi* var. *fernandina* (Polygonaceae)? *Madroño* 57(3):161-169. doi: <http://dx.doi.org/10.3120/0024-9637-57.3.161>
- Karoly, K. 1992. Pollinator limitation in the facultatively autogamous annual, *Lupinus nanus* (Leguminosae). *American Journal of Botany* **79**:49-56.
- Karron, J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 *in* D. Falk and K. Holsinger, eds. *Genetics and conservation of rare plants*. Oxford University Press, Oxford.
- Kershner, K.M. undated. Scientists: Honeybees in the Wild Nearly Gone in North America. Ohio State University publication. <http://researchnews.osu.edu/archives/bees.htm>
- Larsson, M. 2005. Higher pollinator effectiveness by specialist than generalist flower-visitors of unspecialized *Knautia arvensis* (Dipsacaceae). *Oecologia*. 146:394-403. DOI 10.1007/s00442-005-0217-y

- Moldenke, AR. 1975. Niche specialization and species diversity along a California transect. *Oecologia* **21**:210-242.
- Moldenke, A.R. 1976. California pollination ecology and vegetation types. *Phytologia* **34**:305-361.
- Moldenke, A.R. 1979. Pollination ecology as an assay for ecosystemic organization: convergent evolution in Chile and California. *Phytologia* **42**:415-454.
- Mosseler, A. 1992. Life history and genetic diversity in red pine: implications for gene conservation in forestry. *The Forestry Chronicle* **68**:701-707.
- Murphy, K.A. 2003. Endangered plant conservation: do pollinators matter to the robust spineflower? Master's Thesis. San Jose State University. 123 pp.
- Parsons, L., and J.B. Zedler. 1997. Factors affecting reestablishment of an endangered annual plant at a California salt marsh. *Ecological Applications* **7**:253-267.
- Reveal, J.L., and C.B. Hardham. 1989. *Chorizanthe valida*. *Phytologia* **66**:83-88.
- Reveal, J.L. 2001. Scientific review questions. Prepared for the California Department of Fish and Game. Sacramento, CA. in Murphy, K.A. 2003
- Richards, A.J. 1986. *Plant Breeding Systems*. Unwin Hyman, London, UK.
- Ryan, A. and L. Parsons. 2011. Preventing Extinction of Sonoma Spineflower (*Chorizanthe valida*). Report to U.S. Fish and Wildlife Service. March 2011.
- Ryan, A. and L. Parsons. 2015. Sonoma Spineflower (*Chorizanthe valida*) TE018180-4 Annual Report 2014-2015. Report to U.S. Fish and Wildlife Service.
- Stebbins, G.L. 1957. Self fertilization and population variability in the higher plants. *American Naturalist* **91**:337-354.
- Thorp, R.W., and D.M. Gordon. 1992. Biodiversity and pollination ecology of bees in coastal nature preserves. Pages 105-111 in R.R. Harris, D.C. Erman, and H.M. Kerner, eds. Proceedings of the Symposium on biodiversity in northwestern California. Oct. 28-30, 1991. Santa Rosa, CA. Wildland Resources Center Report 29, University of California, Berkeley.
- U.S. Fish and Wildlife Service. 2001. Reopening of public comment period and notice of availability of draft economic analysis of proposed critical habitat determination for the *Chorizanthe robusta* var. *hartwegii* (Scotts Valley spineflower). *Federal Register* **66**:48227-48228.
- U.S. Fish and Wildlife Service. 2002. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for *Chorizanthe pungens* var. *pungens* (Monterey Spineflower). Final rule. *Federal Register* / Vol. 67, No. 103 / Wednesday, May 29, 2002 / Rules and Regulations. *Federal Register* **66**:48227-48228.

Vogler, D.W., and S. Kalisz. 2001. Sex among the flowers: the distribution of plant mating systems. *Evolution* **55**:202-264.

Wyatt, R. 1988. Phylogenetic aspects of the evolution of self-pollination. Pages 109-131 in S.K. Jain and L.D. Gottlieb, eds. *Plant evolutionary biology*. Chapman and Hall, New York, NY.

Personal Communications

Kelley, Brad. 2015. Email message to Lorraine Parsons summarizing observations and time-lapse photography of insect visitors to Sonoma spineflower in 2015. Dated Dec. 14, 2015.

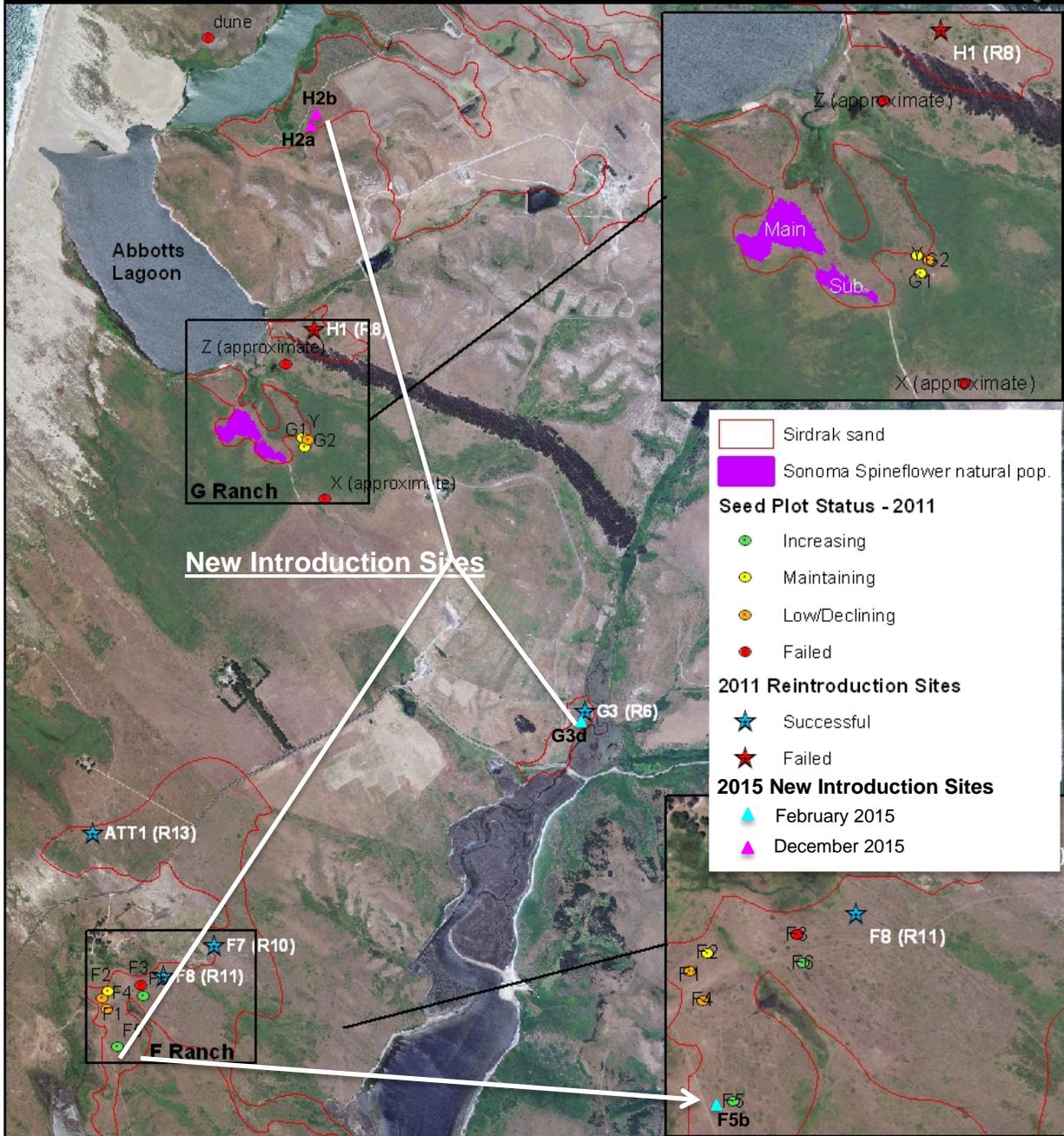
Table 1a. Insect visitors observed during 2015 surveys at Sonoma spineflower sites in Point Reyes National Seashore.

	F Ranch				Schooner Creek				G Ranch Introd.	
	F2	F4	F5	F6	G3A	G3B	G3C	G3D	Y	G1
<u>HYMENOPTERA - APOIDEA</u>										
<u>APINAE</u>										
<u>BOMBINI</u>										
Bombus vosnesenskii *	4		1		9					
Bombus caliginosus *										
Bombus bifarius *			1							
Bombus californicus			1							
<u>ANTHOPHORINI</u>										
Anthophora spp.					1	1				
<u>XYLOCOPINAE</u>										
<u>CERATININI</u>										
Ceratina spp.	3				8	4				
<u>EUCERINI</u>										
Melissodes spp.										
<u>HALICTIDAE</u>										
Lasioglossum sp.				1						
Agapostemon sp.						1	1			
Halictus spp.					1					
Unk Halictidae										
<u>MEGACHILIDAE</u>										
Megachile sp.										
<u>SPHECIDAE</u>										
Bembix sp.	1		1						3	
Sphecidae					1					
<u>VESPOIDEA</u>										
<u>FORMICIDAE</u>										
Formica spp.	7			1	2	1		3	5	1
<u>DIPTERA</u>										
Chrysanthrax spp.					1	2				
Villa spp.	1		1		1	7				
Diptera spp.										
Callephoridae	3									
Tachinidae					3	1				
Paracosmus					6	1		3		
Calliphoridae										
<i>Lucilia</i> spp.										
<u>COLEOPTERA</u>										
Melyridae (Malachiinae)										
Melyridae (Dasytinae)		1								
Melyridae										
Chrysomelidae										
<u>LEPIDOPTERA</u>										
<i>Pyrgus communis</i>				1						
<i>Celastrina</i> sp.					1					
TOTAL INSECT VISITORS	19	1	4	3	34	18	1	6	8	1
TOTAL CHVA DENSITY	41	1	137	28	1139	138	20	13	41	107
TOTAL INSECT VISITORS/AREA	27				59				9	
TOTAL CHVA DENSITY/AREA	207				1310				148	

Table 1b. Insect visitors observed during 2015 surveys at Sonoma spineflower sites in Point Reyes National Seashore.

	G-Ranch Main Population										AT&T	
	Sub-Pop1	Sub-Pop2	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	1a	1b
HYMENOPTERA - APOIDEA												
APINAE												
BOMBINI												
Bombus vosnesenskii *			6	3		3	2	1	1	1		
Bombus caliginosus *												
Bombus bifarius *		3				1						
Bombus californicus												
ANTHOPHORINI												
Anthophora spp.												
XYLOCOPINAE												
CERATININI												
Ceratina spp.												1
EUCERINI												
Melissodes spp.												
HALICTIDAE												
Lasioglossum sp.					1							2
Agapostemon sp.								1			1	1
Halictus spp.				1								1
Unk Halictidae												
MEGACHILIDAE												
Megachile sp.											1	
SPHECIDAE												
Bembix sp.			3		1							
Sphecidae				1								
VESPOIDEA												
FORMICIDAE												
Formica spp.		8	2	1		6	2	1	1	1		
DIPTERA												
Chrysanthrax spp.												
Villa spp.												
Diptera spp.												
Callephoridae					1							
Tachinidae					2							
Paracosmus												1
Calliphoridae		1										
Lucilia spp.		1										
COLEOPTERA												
Melyridae (Malachiinae)						1	1					
Melyridae (Dasytinae)		11		1		5	7	1	1	1		
Melyridae							1	1	1	2		
Chrysomelidae			1									
LEPIDOPTERA												
<i>Pyrgus communis</i>								1				
<i>Celastrina</i> sp.												
TOTAL INSECT VISITORS	0	24	12	7	5	16	13	6	4	5	2	6
TOTAL CHVA DENSITY	62	216	140	296	325	140	132	102	49	81	NS	NS
TOTAL INSECT VISITORS/AREA					92							8
TOTAL CHVA DENSITY/AREA					1543							

Reintroduction plots in relation to the main population



National Park Service
Point Reyes National Seashore
Marin County, CA



0 0.2 0.4 0.6 0.8
Miles

Figure 1.
Main population and reintroduction seed plot spatial relation and status

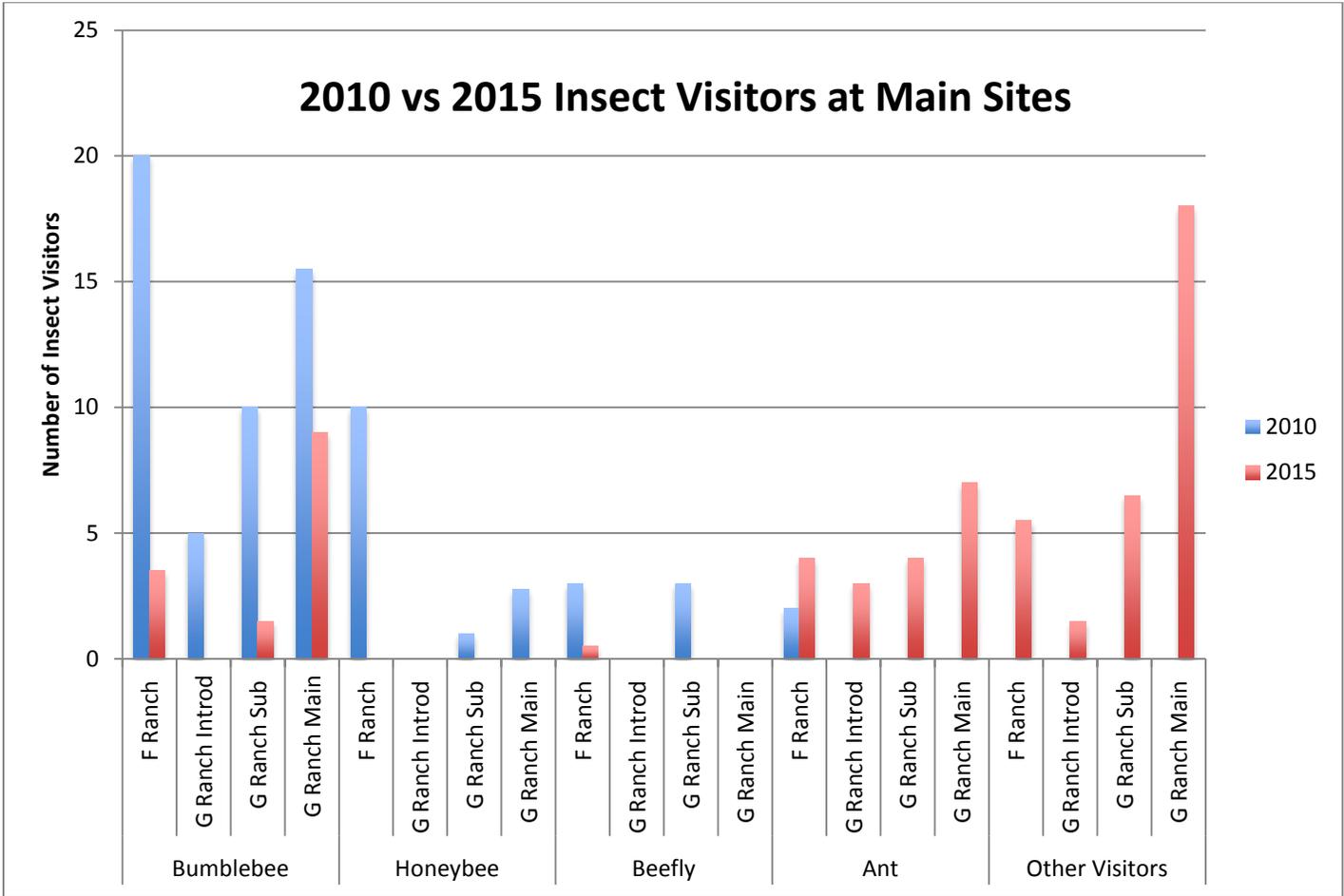


Figure 2.

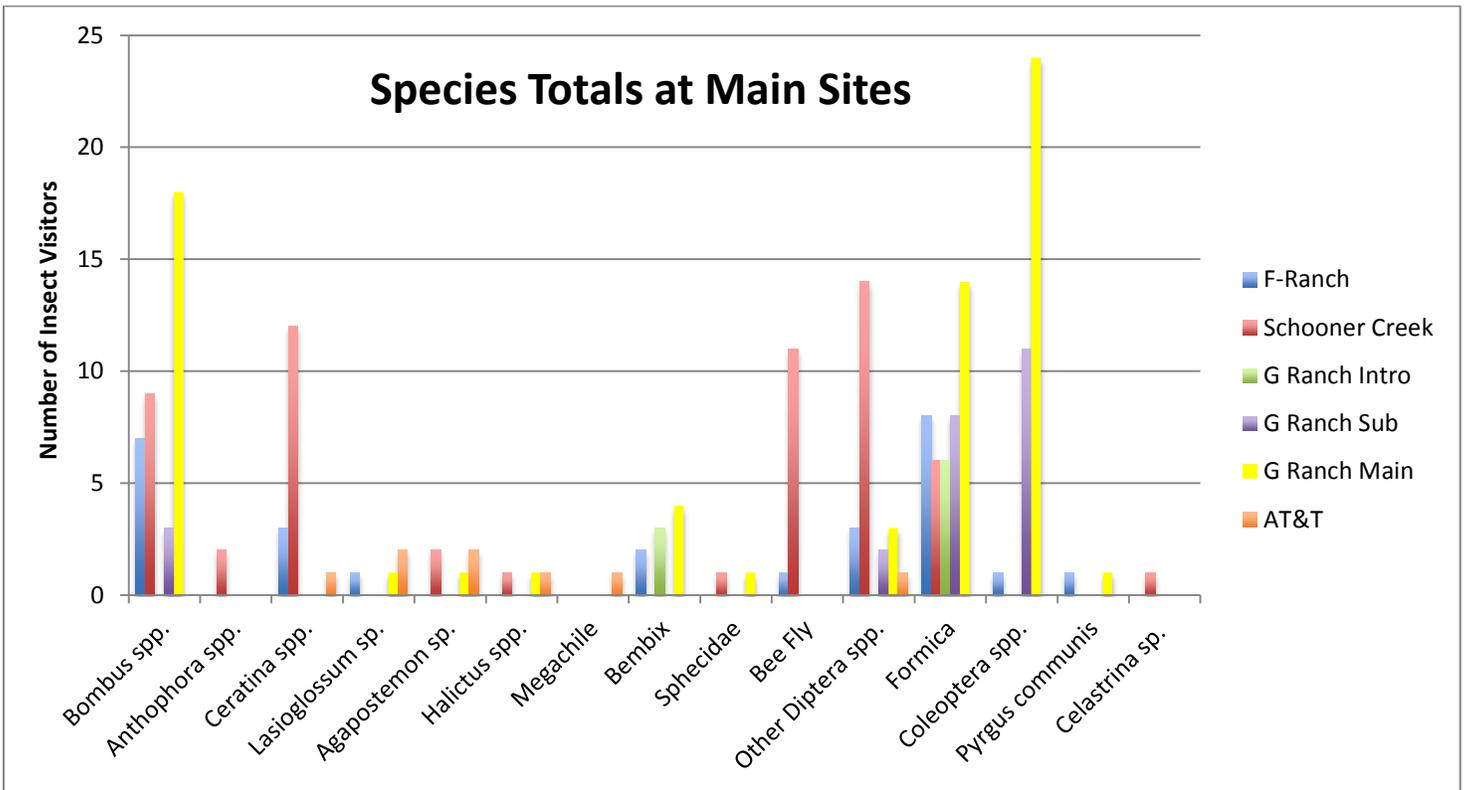


Figure 3.

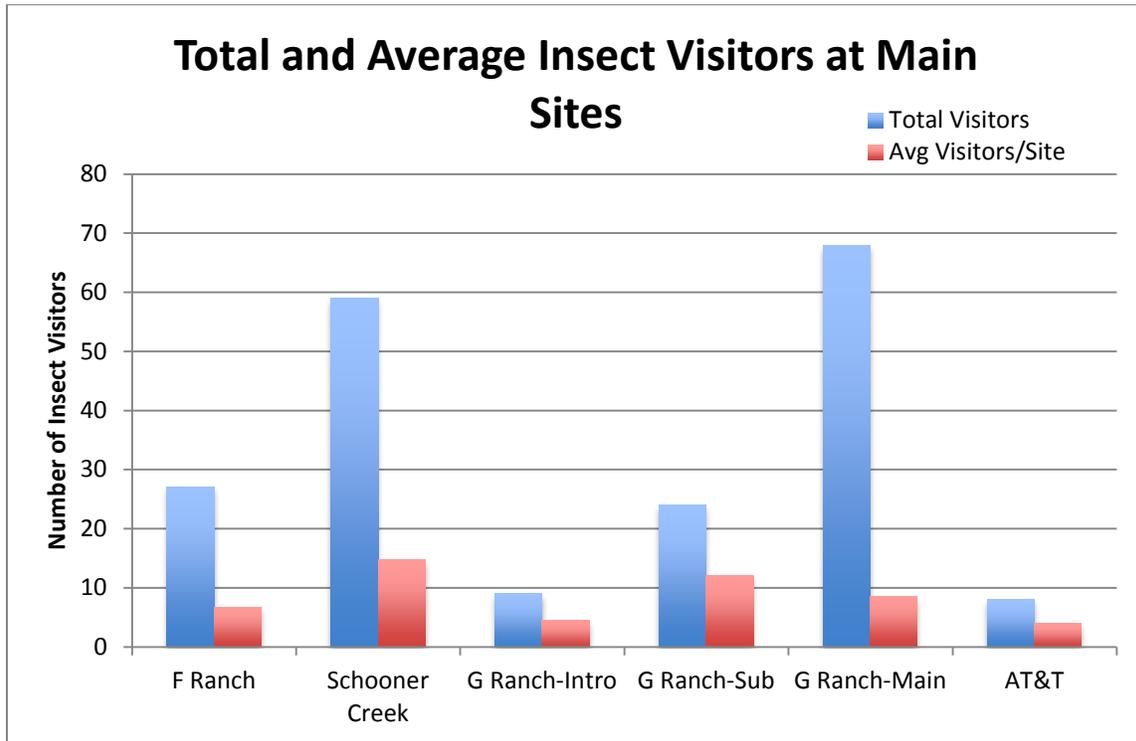


Figure 6.

APPENDIX A. Photographs of *Chorizanthe valida* insect visitors taken by Brad Kelley using time lapse photography.

All identifications courtesy of Brad Kelley unless otherwise noted.



ID: Hymenoptera:Formicidae:*Formica neogates* Det. James C. Trager(IMG_5397)



ID: Hymenoptera:Ichneumonidae:*Anomalon* sp. Det. Ross Hill (IMG_5467)



ID: Hymenoptera:Formicidae: *Formica neogates* (IMG_13(26))



ID: Hymenoptera:Apidae: *Ceratina* sp. (IMG_12(2))



ID: Hymenoptera:Formicidae: *Formica neogates* (IMG_19(27))



ID: Hymenoptera:Apidae:*Ceratina* spp. (IMG_26_80)



ID: (2) Hymenoptera:Formicidae and Ichneumonidae: *Anomalon* sp. (Det. Ross Hill) (IMG_5468)



ID: Hymenoptera:Apidae:*Ceratina* spp. (IMG_26_276))



ID: Hymenoptera:Apidae: *Bombus vosnesenskii* (IMG_5424)



ID: Diptera:Syrphidae: *Paragus haemorrhous*
Det. Kelsey J.R.P. Byers (IMG_12(22))



ID: Hymenoptera:Apidae:*Bombus vosnesenskii* (IMG_14(24))



ID: Diptera:Tachinidae (IMG_13_50)



ID: Diptera: Bombyliidae:*Exoprosopa* sp.
(IMG_5200)



ID: Coleoptera: Melyridae: Dasytinae
(IMG_18(90))



ID: Diptera: Bombyliidae: *Paracosmus* spp. Det. Martin Hauser (IMG_12(17))



ID: Coleoptera: Melyridae: Dasytinae and
Hymenoptera:Apidae:*Ceratina* sp.
(IMG_26(136))



ID: Coleoptera: Chrysomelidae:
Pachybrachis sp. Det. Blaine Mathison
(IMG_19(90))



ID: Lepidoptera: Crambidae: Det. Paul da
Silva (IMG_13(57)):



ID: Lepidoptera: Lycaenidae: *Plebejus*
icarioides (IMG_12(93))

Appendix D: Seedbank Dynamics Report – 2015

Sonoma spineflower (*Chorizanthe valida*) Seedbank Study
Amelia Ryan
January 2016

Report to the U.S. Fish and Wildlife Service
Agreement No. 4500067955

Chorizanthe valida habitat restoration, introductions, seedbank and pollinator studies

Introduction

Prior to the Preventing Extinction project (Ryan and Parsons 2011), very little was known about the life cycle of Sonoma spineflower (*Chorizanthe valida*). Demographic studies were conducted as a part of that project which followed the plant species from seedling to seed-set, with one of the major study locations being the one wild or natural population at Point Reyes National Seashore (Seashore). One component missing from that study was the characterization of the seed bank of Sonoma spineflower. Prior introduction efforts have revealed that this species can live for at least two years in the soil and that seeds kept in cold storage germinate readily even after 20 years (Ryan and Parsons 2011). Collecting seed bank information is a key component in performing a population viability analysis and gives us a better understanding of the species as a whole.

Methods

Before developing a final sample design, a pilot sample was collected at 10 random points within the main population area using a scoop (Figure 1). These samples were used to experiment with different techniques to extract the seed from the soil. Water extraction of seeds and organic material and sieving were attempted.

Sieving proved to be very effective, much quicker to process, and did not require drying time. A set of sieves was borrowed to determine the precise mesh size required to



Figure 1. Field Sampling Techniques.

capture Sonoma spineflower seeds. This proved to be $850\mu\text{m}$ for seeds in an involucre. Mesh size $710\mu\text{m}$ caught seeds even when outside of the involucre (rare). Mesh size 1.18 mm allowed seeds to pass through, but caught larger organic matter. The sand that constitutes the bulk of the soil passed easily through all mesh sizes. Two of the three mesh sizes needed were not in existing supply and had to be purchased.

One hundred seedbank sampling locations were chosen within the main and sub populations of the one wild population. The population boundary used was the maximum population extent over the years 2005-2014 created by merging together the mapped population boundary for each year. The sampling sites were generated randomly using the "Create Random Points" tool in ArcGIS 10.2 (ESRI ©1995-2013).

Each randomly chosen point was navigated to using a handheld GeoXH GPS unit with and flagged. To collect the sample, a sturdy, 14" by 14" plastic planter with the bottom removed was pounded into the ground to a depth of two inches (5 cm, Figure 1). This depth was chosen because a number of studies have shown that the majority of seeds occur in the upper 5 cm of soil (Baskin and Baskin 2014). Total volume extracted was 392 in.^3 (6.4 dm^3). The material with the square was scraped off to a uniform depth and sieved in situ to remove material larger than would pass through 1.18 mm mesh size. Material that would not pass through the mesh was inspected to make sure there were no seeds attached before being discarded. Samples were collected September 20 and October 5, 2015, after seed drop, but before the onset of the rainy season.

In November-December 2014, samples were then further sieved to remove material smaller than $710\mu\text{m}$. This fine material was retained and returned to the field site. The rest of the sample $>710\mu\text{m}$ and $<1.16\text{ mm}$ was stored in a cool dry place for later processing.

Field work and initial sample processing were conducted by Amelia Ryan, Seashore Ecologist, and Ryan O'Dell, BLM Natural Resource Specialist, who also contributed technical expertise to the project.



Figure 2. Sorting seed with red (newer) and black (older) involucres.

In spring 2015, samples were re-sieved to remove any additional fine material and Sonoma spineflower seeds were removed by hand from the sample using forceps and a magnifying glass. Involucres encased 99% of seeds removed from the samples. Involucres varied in color: some were bright red, and some black and a few were gray (Figure 2). Red

involucres appeared to be mostly from the current year, while black and gray ones were presumed to have weathered at least one rainy season. Some involucres were empty because the ovary they had encased was not pollinated, so once involucres were separated into red, black and grey piles, they were tallied according to whether or not the involucres were “filled,” i.e., had a hard seed present within.

The first sample counted took approximately 10 hours to count, so subsequent samples were mixed, weighed, remixed, halved or quartered, and counted. Subsequent samples took ~three (3) to four (4) hours each to separate and count.

Samples that occurred within the macroplot (See Map 1) used for population estimates were given priority for counting, because they were comparable to the estimated population within the macroplot. Because seed extraction took considerably longer than predicted, only the 26 that fell within the macroplot ended up being counted.

Preliminary Population Viability Analysis was explored the RAMAS GIS Software (©2002-2015 by Applied Biomathematics). The model was run with 100 replications for 500 years, with two stages (seedling and adult), density dependence set to exponential, with survival rate affects, and good year/bad year set as catastrophes. Model parameters were set using data from the seedbank study and the 2010-2011 demography data collected as a part of the Preventing Extinction Project (Ryan and Parsons 2011).

Results and Discussion

Samples averaged 600 involucres, but only 41% contained seed (Figure 3). Of those with seed, 56% appeared to be from the same year (red in color), while 44% were black or gray, which was interpreted to mean that they had overwintered (Table 1). Newer seed (red involucre) averaged 1,107 seeds/m² (1,021-1,193 95% C.I.), and older seed averaged 867 seeds/m² (801-933 95% C.I.), with a total of 1,975 mean seeds/m² (Table 1).

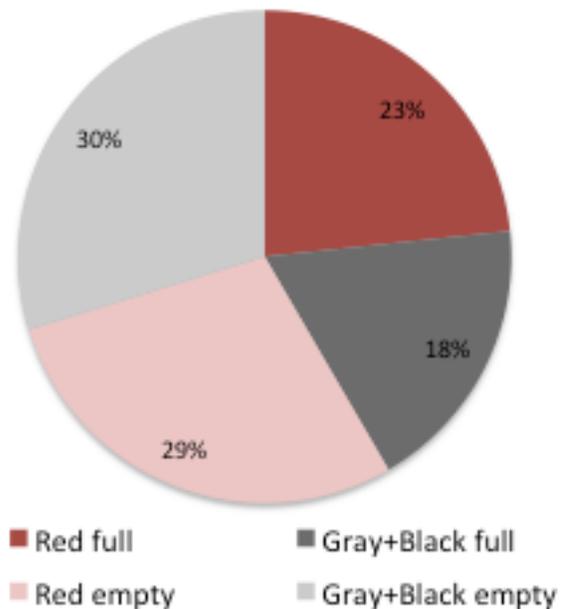


Figure 3. Involucre Tally. Red involucres were assumed to be newer than black/gray involucres. Involucres were also sorted by whether or not they contained seed (full vs. empty).

Table 1. Seedbank Count Results.

	Count/sample	Count/m ²				Range	Percent of Seedbank	Ratio Full:Empty
	Mean	Mean	SD	SE	95% CI			
Red (newer)	140	1,107	1,689	331	1,021-1,193	0-6,769	56.1%	1:1.2
Black (older)	110	867	1,298	254	801-933	0-6,611	43.9%	1:1.6

In 2014, population sampling estimated the density of plants within the macroplot as 59 (42-76 95% C.I.). In 1999, 2010, and 2011, seed output was totaled for 50-150 plants. Mean seed output ranged between 30-33 seeds per plant, averaging 31. Based on these numbers, one might therefore expect a seed density in the macroplot of ~1,828 seeds/m² (1,309-2,347 95% C.I.) This is actually quite a bit higher than the actual density of seeds found in the upper 2 inches (5 cm) and supports the idea that the red seeds could very well represent only the current year's seeds. However, as noted earlier, only the upper 5 cm of soil were sampled as a part of this study. Therefore, the actual seedbank may be a little higher.

A higher proportion of older (black) involucre were empty (1:1.6 black full:empty compared to 1:1.2 for red), which would be expected as some of the filled ones germinated in year past. One might expect even higher proportion to be empty involucre, but some of the seed in the black involucre may be no longer viable, yet persisting in the soil. Seeds associated with black involucre seemed to be more brittle and prone to disintegration (Amelia Ryan, personal observation).

A preliminary look at Population Viability Analysis using the RAMAS Software found that, as the majority of the seedbank is from the year before, the Sonoma spineflower trajectory (population growth or extinction) was extremely sensitive to the percent of seeds that germinate on a given year and the percent of those seeds that remain viable in the seedbank for a second or third year. Changing the percent of seed that germinate on a given year by as little as 1-2% was the difference between population growth and extinction.

Conclusions

The seedbank study illuminated that the majority of seed seems to be from the same year as sampling occurred. Further, older seed often seemed less viable. Preliminary population viability analysis suggests that the continued viability of this population may be very tenuous, depending on seed viability of older and newer seed and the percent of new seed that germinate on a given year. Overall, this study was very useful, as the composition of the seedbank highlights a potentially large obstacle to the long-term viability of this species. Further study on the viability and percent of seeds germinating would allow a full population viability analysis. A list of proposed future studies related to Sonoma spineflower seedbank is below.

Proposed Future Studies

- Density and distribution of Sonoma spineflower seeds below 5 cm
- Viability of same year and older seeds
- Germination trials to determine the percent of seed germinating on a given year
- Full Population Viability Analysis

Budget Justification

Contrary to expectations, a few additional supplies were required to conduct this study because the Seashore did not have all the correct sieve sizes. A total of \$143.90 were spent to purchase a two additional sieves, a sieve pan to collect sieved materials, and a sieve lid to prevent the sample from escaping the sieve when it was agitated. Sample processing prior to counting took considerably longer than expected, and counting took more than three (3) times as long per sample as budgeted, and thus only 26 samples were completed rather than the planned 60-100 and hoped for 100 samples. Some monies (\$784) not used in the introduction component were used to complete this project.

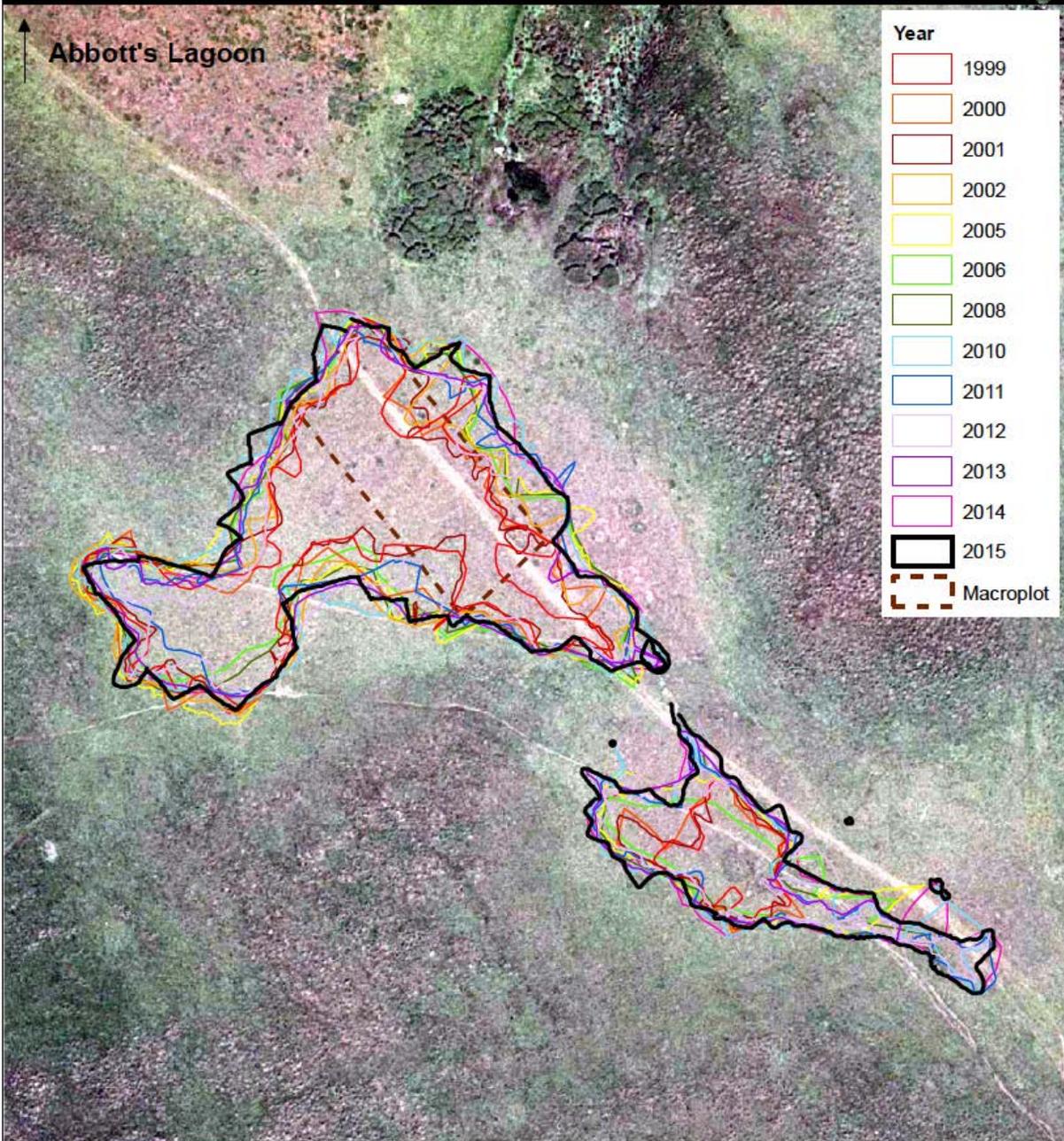
Budget Item	Projected Cost	Actual Cost		
		Year 1	Year 2	Total
Biologist- field collection (GS-9-Term STF)	\$800	\$640	\$0	\$640
Biologist- sieving	\$0	\$800	\$0	\$800
Biologist – counting	\$4,000	\$3,200	\$800	\$4000
Biologist – analysis	\$1,600	\$320	\$1280	\$1600
Supplies	\$0	\$144	\$0	\$144
Project Total	\$6,400	\$5,104	\$2,080	\$7,184

References

Ryan, A. and L. Parsons. 2011. Sonoma Spineflower (*Chorizanthe valida*) TE018180-4 Annual Report 2011. Report to U.S. Fish and Wildlife Service.

Baskin, C.C. and Baskin, J.M. 1998. Seeds: Ecology, Biogeography, and, Evolution of Dormancy and Germination. Academic Press, San Diego, California.

Sonoma spineflower main population



National Park Service
Point Reyes National Seashore
Marin County, CA



0 0.02 0.04 0.06 0.08 Miles

Map 1

Sonoma Spineflower population boundaries in relation to the macroplot and to encroachment from velvetgrass.