



Native Component Grasslands of the Marin Headlands

Natural Resource Technical Report NPS/SFAN/NRTR—2013/832





ON THIS PAGE

A Mission Blue Butterfly (*Aricia icarioides* ssp. *missionensis*) visiting a California plantain (*Plantago erecta*) in a Marin Headlands grassland.

Photograph by: Jessica Weinberg, NPS.

ON THE COVER

Grassland sampled in this study (Stand 1).

Photograph by: Robert Steers, NPS.

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Natural Resource Technical Report NPS/SFAN/NRTR—2013/832

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Abstract

Grassland vegetation in the Marin Headlands, Golden Gate National Recreation Area, was sampled in 2011. Stands previously mapped approximately a decade prior by the National Park Service as containing a significant native species component were targeted. The methods utilized were based on those outlined in the San Francisco Bay Area Network, Inventory and Monitoring program's draft plant community monitoring protocol. The purpose of this sampling effort was fourfold: 1) to field-test the methods outlined in the draft protocol, 2) to refine the classification of these grasslands from the base vegetation map that was used to select the stands sampled, 3) to better understand these grasslands in a regional context, and 4) to examine relationships between vegetative and environmental parameters at the sampling unit scale. Nine grassland stands were randomly chosen from the 71 previously mapped stands in the Marin Headlands study area. Species richness in the nine grassland stands was high and found to be similar to other California coastal prairies. The sample design, specifically the number of sample units per stand and the number of stands sampled, appeared to capture the majority of grassland species in the study area based on species accumulation curves. Using the data collected, all stands were classified as coastal prairie with two stands fitting within the *Festuca idahoensis* alliance and six fitting the *Stipa pulchra* alliance. All stands contained significant cover of native perennial grasses and forbs, including *F. idahoensis* and *S. pulchra*. However, exotic grasses were the most abundant group of plants in every stand surveyed. Correlations of vegetation and environmental parameters revealed that litter depth was negatively correlated with native annual species richness. Also, the density of fossorial mammal disturbances was positively correlated with total herbaceous species richness and also to the abundance of two common exotic plant species. At the landscape scale, the grasslands sampled in the Marin Headlands form a consistent and repeatable vegetation type that appears to be closely associated with soil derived from Franciscan complex chert, which is relatively uncommon elsewhere in the San Francisco Bay Area.

Acknowledgments

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Introduction

The Marin Headlands in Golden Gate National Recreation Area (GOGA) contains many grassland types; notably, coastal prairies with high abundance of native perennial forbs and grasses (this study). Most of California's coastal prairies, which are renowned for their high biodiversity and endemism, have been displaced by development or have been severely altered by exotic species (Holland and Keil 1995, Stromberg et al. 2001, Jantz et al. 2007). Coastal prairie is defined here as grassland located in close proximity to the shoreline, with frequent exposure to oceanic fog, and typically situated on a terrace, bluff, or coastal headland in central or northern California (Sawyer et al. 2009).

In developing a vegetation monitoring protocol for the San Francisco Bay Area Network (SFAN) of national parks, it was determined that additional information about the coastal grasslands in the Marin Headlands was needed prior to selecting study sites for long-term monitoring. These grasslands were mostly mapped as "Native Component" grasslands by Schirokauer et al. (2003), which was a moniker used for numerous grasslands up and down the coastal slopes of the Bay Area that were difficult to classify based on aerial imagery. Recent field observations suggested these grasslands were unique from the other native component stands that had been mapped elsewhere (Robert Steers, personal observation).

A floristic survey of the Marin Headlands stands mapped as native component grasslands were undertaken to address four purposes. First, we wanted to field-test methods being considered in a draft protocol to monitor vegetation types in SFAN. Second, we wanted to refine the classification of these native component grassland stands. Third, we wanted to better understand these grasslands in a regional context to determine if they should be included for monitoring under the SFAN plant community monitoring protocol; and fourth, we wanted to demonstrate how these data could be used to examine relationships between vegetative and environmental parameters at the sample unit scale.

A seemingly unlimited number of factors can influence the structure and composition of grassland vegetation. In this study, the relationship between floristic elements and several environmental parameters were investigated. Specifically, plant litter depth and fossorial mammal activity were evaluated in relation to herbaceous vegetation parameters. Litter can be negatively correlated with native herbaceous species abundance and richness in California grasslands (Hayes and Holl 2003, Coleman and Levine 2007). Small mammals, like Botta's pocket gopher (*Thomomys bottae*), can be ecosystem engineers (Reichman and Seabloom 2002) that are also positively correlated with exotic annual plant abundance (Steers 2010). In this study, litter depth was hypothesized to have a negative relationship with native species richness. Also, fossorial mammal activity, as measured by the density of burrows, sunken plugs, and other disturbances to the soil by small mammals, was hypothesized to be positively associated with exotic plant abundance.

Methods

Study Area

The Marin Headlands are a peninsula forming the southern tip of Marin County, California. The city of Sausalito occupies the northeastern shore of the headlands while lands to the south and west are within GOGA (Figure 1). The Marin Headlands has a long history of livestock grazing that may have begun as early as 1817 with Spanish colonizers (Auwaerter and Curry 2012). After 1836, the entire study area was grazed by cattle and other livestock associated with the Mexican land grant, *Rancho del Sausalito* (Toogood 1980). Later, multiple dairies were established and cattle grazing persisted here for many decades.

As early as 1867, grazing was excluded from small portions of the most southern ridge of hills in the headlands that were part of Lime Point Military Reservation (Point Bonita to Cavallo Point). However, other parts of the military reservation remained open to cattle (Auwaerter and Curry 2012). Livestock grazing associated with dairy operations continued into the 20th century but began to cease at various points in time and in various localized areas as additional lands converted to military bases and were closed off. For example, grazing ceased in Fort Cronkhite in 1939 when this area converted to military use. All of the dairy ranches found north of the military lands ceased operating in the decades following World War II. Grazing by livestock could have occurred in parts of the study area as late as the 1960s (Auwaerter and Curry 2012), but ceased before this land became part of the National Park Service in 1972. Thus, at the time of this study, the sampled grasslands had not been grazed by livestock for at least 40 years.

Since the 1950s, fire occurrence in the Marin Headlands has been very low (four fires) and most fires have been small (≤ 1 km²; CDF 2012). The most recent fire that potentially overlapped a sampled stand was in the 1960s. However, these data are known to exclude small fires (Keeley et al. 2011), so it is possible that more of the study area could have burned in the last 60 years. Also, not all experimental or controlled burns performed by the National Park Service were included in this data set. Nevertheless, it appears that the vast majority of the Marin Headlands has no modern record of being burned.

Other landscape-scale factors affecting the vegetation of the study area entail species-specific management by the National Park Service and Golden Gate National Parks Conservancy, who remove various invasive plants (e.g., *Cotoneaster* spp., *Cytisus scoparius*, *Genista monspessulana*, *Pinus radiata*, etc...), plus replant native species in highly disturbed sites. Some of the grasslands sampled in this study have likely been treated for invasive plants, but none have been the focus of replanting efforts to our knowledge.

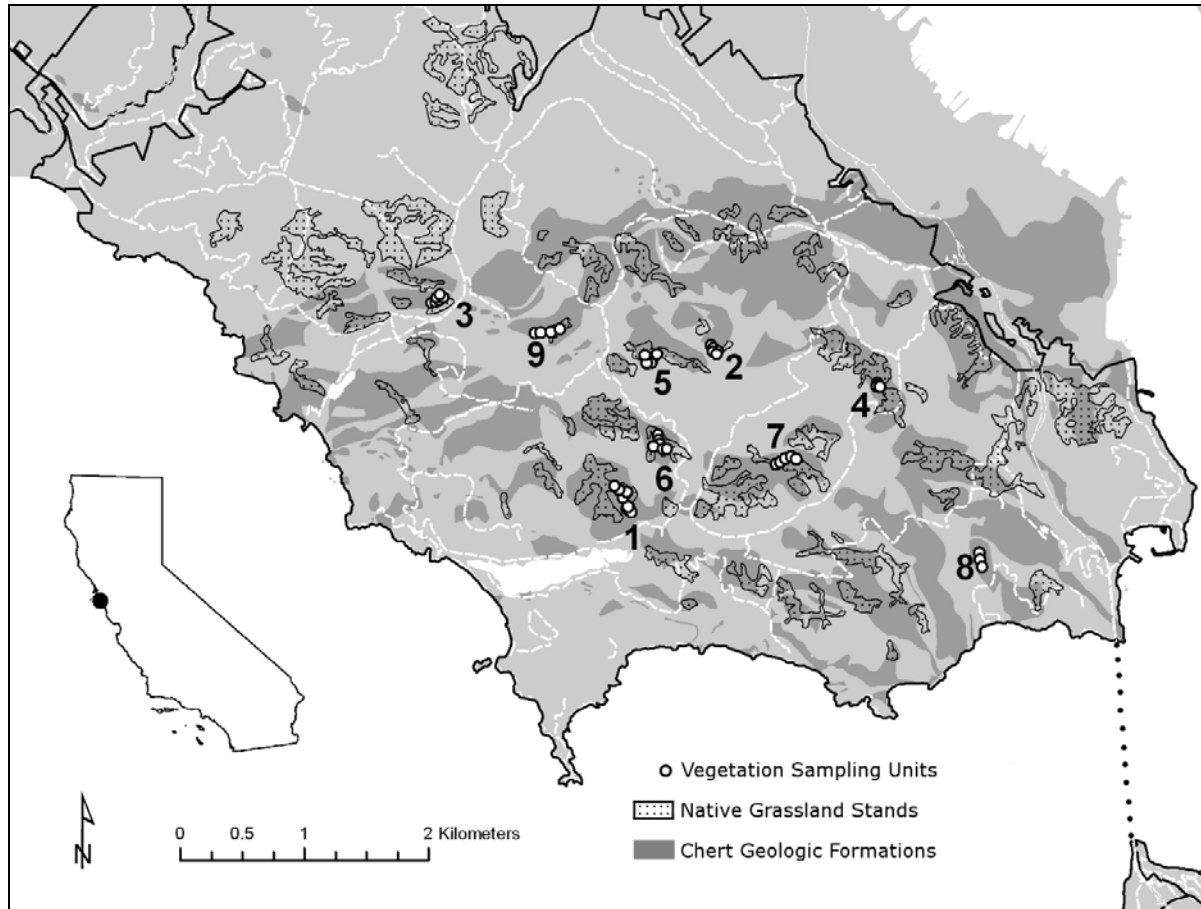


Figure 1. Map of Marin Headlands study area in southern Marin County showing vegetation sampling units at each stand sampled (numbered one through nine). Maps of the chert geologic formations and the native grassland stands are based on Niven et al. (2009) and Schirokauer et al. (2003), respectively.

The terrain of the study area is hilly with numerous ridges and valleys (Figure 2). Elevation ranges from sea-level to approximately 340 m. Soils in the study area are derived primarily from greenstone, greywacke, and diatomaceous chert (Cretaceous – Jurassic Franciscan Complex), the latter of which is one of the most abundant geologic types present (Figure 1). The chert of the Marin Headlands is high in silica and iron oxides, and it is characteristically resistant to weathering (Elder 2001), forming reddish or orange colored balds on many of the ridgelines. The chemical composition of these chert-derived soils have not been studied but the chert soils appear relatively less productive than other soil types since bare, mineral soil and rock cover can be high and vegetation coverage is often sparse. The climate in Marin County is Mediterranean, with almost all measured precipitation occurring from October through May, although input from fog during the summer months is unquantified but potentially significant (Corbin et al. 2005). Mean annual precipitation is assumed to be approximately 50 cm per year, based on a weather station that is located 5.4 km to the south of the headlands in San Francisco (WRCC 2011).

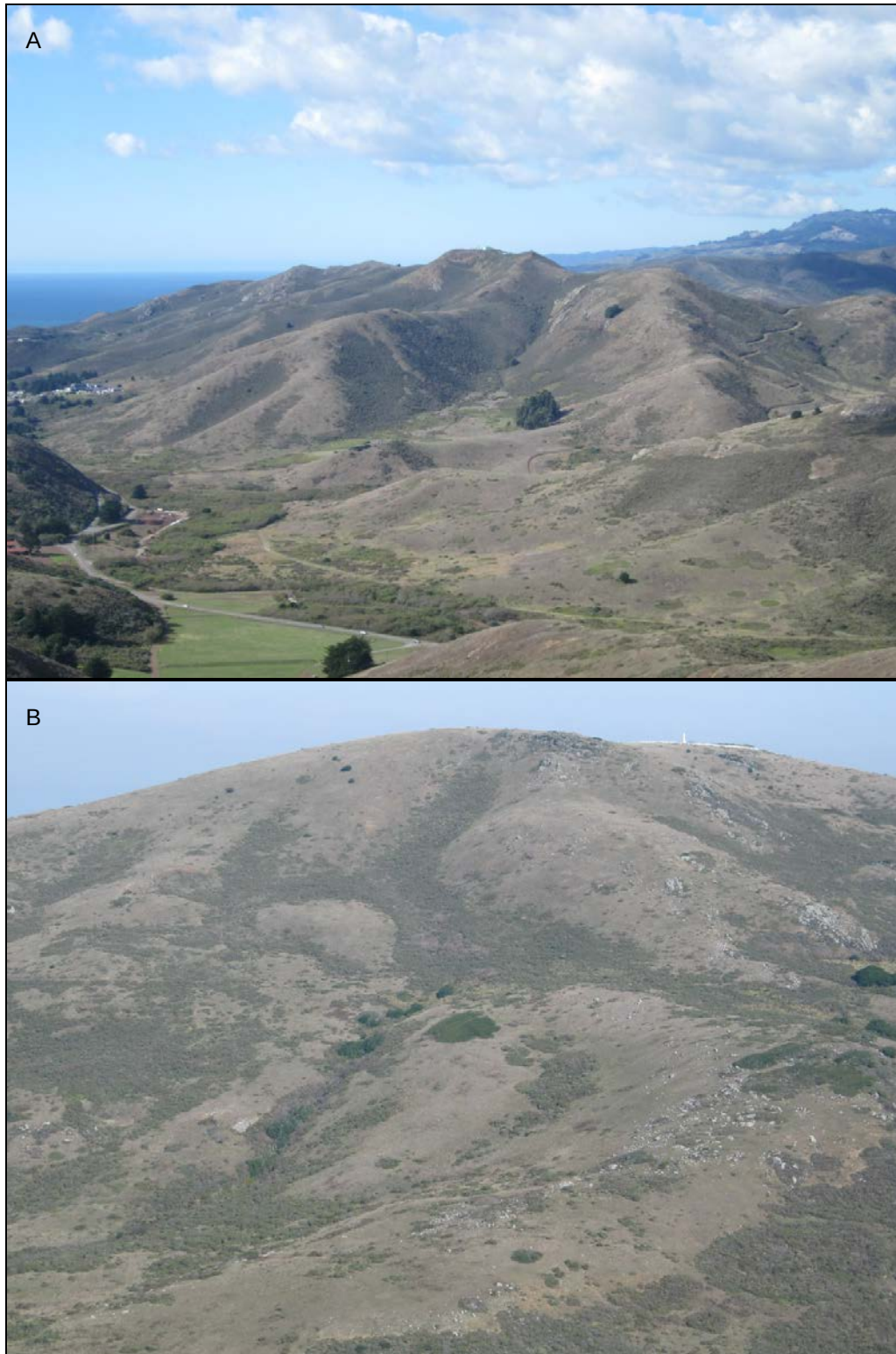


Figure 2. Vegetation patterning typical of the Marin Headlands on Wolf Ridge, taken from Hawk Hill (A) and on a hillside traversed by the Old Springs Trail, taken from Hill 88 (B).

Study Site Selection

To sample grasslands in the Marin Headlands, nine stands were randomly selected using a pre-existing vegetation map of the study area (Schirokauer et al. 2003). Sampling was focused on mapped grassland stands with the highest amount of native herbaceous plant cover; thus, the California Annual Grassland with Native Component Mapping Unit and Purple Needlegrass mapped types were utilized among the other mapped grasslands (i.e., California Annual Grassland Mapping Unit, Introduced Coastal Perennial Grassland Alliance, and Active Pasture or Agriculture).

Using 1994 aerial imagery, Schirokauer et al. (2003) mapped 64 stands of California Annual Grassland with Native Component Mapping Unit and 7 stands of Purple Needlegrass. Nine clusters of these target grasslands were created using nearest neighbor analyses so that each cluster consisted of 7-8 stands that were in the closest proximity with one another. Then, within each of the nine clusters, the stands were assigned a number from 1 to 7(8) and a random number table was used to designate the priority for sampling each stand. If a stand that was selected as the top priority was found to be unsuitable because it was too small to fit at least three sampling units within its boundary or it was no longer grassland (e.g., converted to a shrubland), then the next stand in order of priority in that cluster was visited until a suitable stand was found. The only exception was with stand number 8, which was in a cluster where suitable mapped grasslands classified as having a significant native component were difficult to find. In this cluster, grasslands mapped as California Annual Grassland Mapping Unit were included in the draw and one of those grasslands was utilized. Only one stand per cluster was selected, resulting in nine grasslands sampled.

Within each selected stand, the ecotone with neighboring vegetation types was delineated based on methods found in Steers et al. (2008) and then discarded from further use, leaving only the discrete portion of the stand that represented the target vegetation type. Within this discrete portion, 17.95 m radius circular sampling units were established using a restricted random sample design following Elzinga et al. (1998). This entailed dividing each stand into equal subsections and then placing one sampling plot randomly within each subsection. A table showing the number of sampling units per grassland stand and their geographic coordinates are presented in Appendix A.

Vegetation Sampling

The 17.95 m radius, circular sampling unit was a modified USDA Forest Service (USFS) Forest Inventory and Analysis (FIA) program sample unit (USFS 2011) that included a 7.32 m radius, circular subplot identical to the North American Weed Management Association (NAWMA) standards sampling plot (Stohlgren et al. 2003). Inside the NAWMA sampling plot are three 1 m² quadrats where all plant cover was recorded using a point quadrat method with 50 evenly spaced points (Figure 3). At each point, all species that overlapped were recorded. Bareground, bryophytes, lichens, litter, or rock were recorded if no vascular plants were above them. Vascular plant species richness, the density of fossorial mammal burrows and holes, and litter depth were also recorded within each quadrat. Litter depth was recorded in five equidistant locations within each quadrat. The three 1 m² point quadrats were placed 4.57 m from plot center along the following compass bearings: 30, 150, and 270 degrees. Within the 7.32 m circular subplot, vascular plant species richness was recorded. Surrounding each of the 1 m² quadrats were larger 3 x 3 m quadrats where the density of

woody plants and vines was recorded by species (Figure 3). The cover of woody plants and vines was also sampled along three 10 m line intercept transects that radiated out from the center of the plot along the same axis used to line-up the quadrats. Cover along these transects was recorded from the 3 m through the 13 m mark on each line. Lastly, tree density and diameter at breast height were recorded within the larger 17.95 m sampling unit.

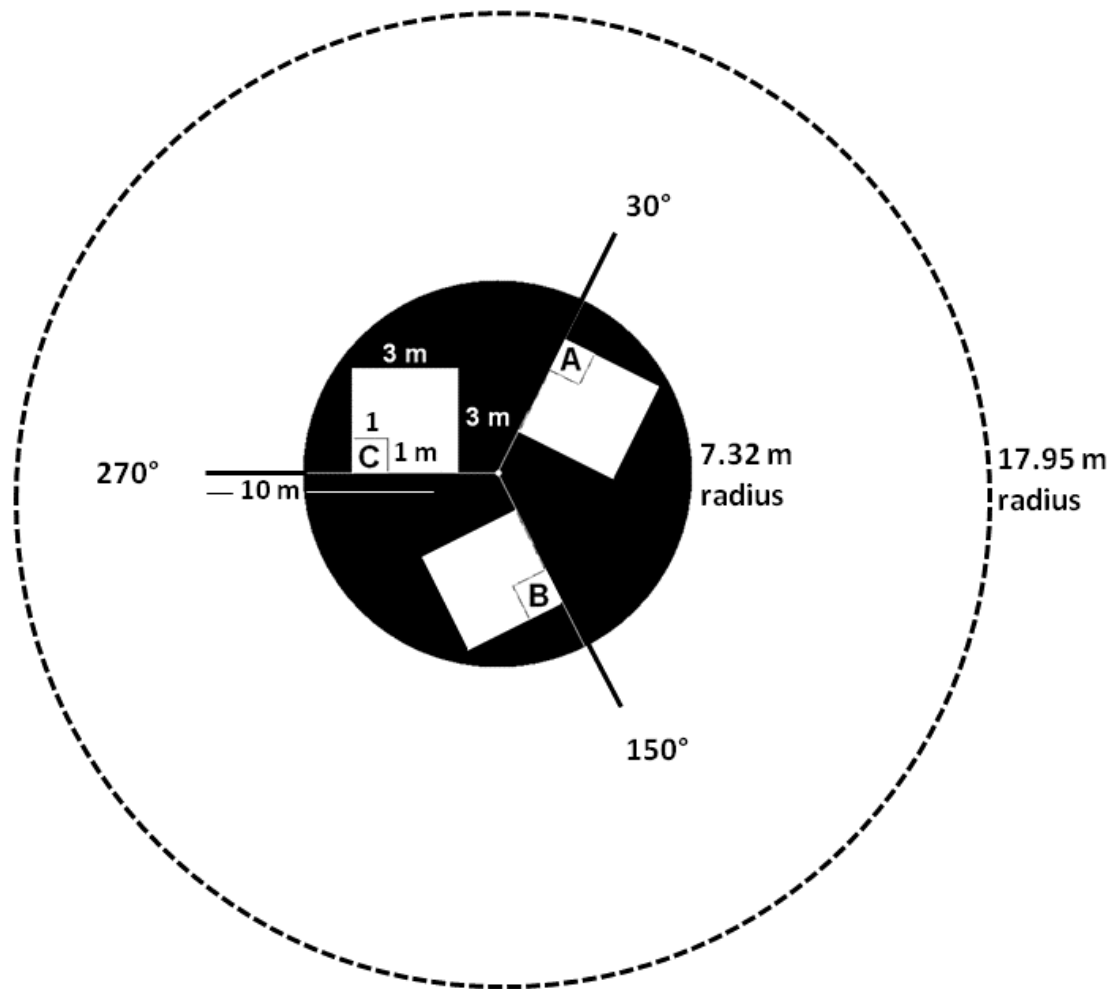


Figure 3. Sample unit used for vegetation sampling.

Statistical Analyses

Species Composition

Species richness of vascular plants was collected at two spatial scales: within 1 x1 m quadrats and within 7.32 m radius circles. All data was then summarized to the stand level so that $n = 9$ for all analyses. Total unique species encountered per stand was determined using data from both scales. The relationship between species richness found at the two scales was evaluated with linear regression. Also, the relationship between sampling effort (number of sample units per stand) and total unique species found at the stand-level was determined. Lastly, paired t-tests compared mean

richness between the two scales used. Analyses were conducted using JMP 10.0.0 (©SAS Institute, Inc. 2012).

Species accumulation curves were constructed for the whole study area where the number of new species detected was a function of additional stands sampled. Curves were constructed based on actual data and Sobs (Mao Tau) estimates computed using EstimateS, Version 8.2 (Colwell 2011) at both the 7.32 m radius and 1 m² scales. Sobs (Mao Tau) estimates were constructed using 50 runs of randomizations without replacement. Species accumulation curves were also constructed for each stand where the number of new species detected was a function of increasing the number of sample units within each stand. These latter species accumulation curves were only performed with actual data and only at the 7.32 m radius scale.

Vegetation Structure

Cover values were derived from 1 m² point quadrat frames plus line intercept transects for herbaceous and woody plants, respectively. Density data were based on 3 x 3 m quadrats. Each sampling plot contained three point quadrat frames, three line intercept transects, and three 3 x 3 m woody plant density quadrats. Data were averaged per sampling plot. Then, data from each sampling plot were averaged to the stand level for all tables or appendices reporting mean and standard error values for structural parameters.

Community Classification

All stands were classified using the field key to the plant communities of Point Reyes National Seashore, Golden Gate National Recreation Area, and neighboring lands (Keeler-Wolf et al. 2003) and keyed to the alliance level using National Vegetation Classification Standards following keys to herbaceous vegetation in the Manual of California Vegetation, 2nd Edition (Sawyer et al. 2009). Data used to key the vegetation types was mean cover of species per stand based on point quadrat data.

Ordinations

Ordinations of multivariate data were used to assess the similarity of sampling plots and stands amongst each other. First, data was summarized by sampling plot ($n = 44$). Then, Nonmetric Multidimensional Scaling (NMS) was performed three times for the following variables: cover by species (all species $\geq 5\%$ in at least one sampling unit), cover by life form (native shrub, native grass, native rush and sedge, native perennial forb [including ferns], native annual forb, exotic perennial and annual grass, exotic perennial forb, and exotic annual forb), and presence-absence. The first two NMS analyses used cover data collected in the point quadrats and were based on Euclidean distance and the third analysis examining presence-absence utilized the Sorenson distance metric, which was based on values of 0 or 1 to represent if a species was present or absent within each sampling plot at the 7.32 m radius scale. For each ordination, a random starting configuration with 50 runs of real data was used in the autopilot mode with medium speed. Then, a Multi Response Permutation Procedure (MRPP) was used, post hoc, to examine if sampling plots from the same stand were unique from sampling plots measured in other stands at $\alpha = 0.05$ and also with a Bonferroni correction of $\alpha = 0.001389$. In the MRPP, groups were weighted by: $n/\text{sum}(n)$. PC-ORD version 5.31 was used for the NMS and MRPP analyses (McCune and Mefford 2006).

Correlations

Based on the resulting NMS ordination using species cover, the top three species with the strongest correlations to Axis 1 (one-dimensional solution) were evaluated to assess how they related to other biotic and abiotic parameters. However, only one species, *Brachypodium distachyon*, was frequent enough to be used in these analyses. Also, litter depth and density of fossorial mammal disturbances were examined for relationships with parameters like species richness and the abundance of exotic plants. All relationships were explored using linear regression with data averaged to the sampling unit ($n = 44$). Correlations were analyzed using JMP 10.0.0 (©SAS Institute, Inc. 2012).

Results

Species Composition

Vegetation samples were taken from nine grasslands in the Marin Headlands. The number of vegetation sampling units measured in each grassland ranged from 3 to 6, with larger stands accommodating more sampling units than smaller stands. For all sampling units ($n = 44$), the slope at center ranged from 13 to 30 degrees with a mean of 21.7 ± 0.6 . Also for all sampling units, aspect at center ranged from 128 to 265 degrees with a mean of 183.7 ± 5.2 (Appendix A). A total of 113 taxa were recorded, of which one was an unidentifiable seedling and 5 were identified to the genus only, although three of these were conferred (cf) a specific epithet (Appendix B). Lastly, all native perennial *Festuca* plants encountered were determined to be *F. idahoensis* although it is possible that some specimens were actually *F. rubra* since this latter species can be difficult to distinguish from the former depending on available plant material.

Species Richness

Species richness of vascular plants was collected at two spatial scales: within 7.32 m radius circles and within 1 m² quadrats. Total unique species encountered per stand ranged from 50 (Stand 4) to 68 (Stand 5) using the 7.32 m radius plots and from 31 (Stand 8) to 52 (Stand 5) using 1 m² quadrats. As expected, the number of unique species was always greater in the larger 7.32 m radius compared to the three 1 m² quadrats per sampling unit. Furthermore, stands with more unique species recorded at the larger scale also had more species recorded using the smaller spatial scale ($R^2 = 0.65107$, $df = 8$, $p = 0.0053$). Not all stands experienced the same sampling effort since larger stands accommodated more sampling units. However, there was no significant relationship between the number of sampling units per stand and the total number of unique species found per stand at the 7.32 m radius scale ($R^2 = 0.2997$, $df = 8$, $p = 0.1271$) or at the 1 m² quadrat scale ($R^2 = 0.3672$, $df = 8$, $p = 0.08369$); although the latter correlation was nearly significant.

Mean species richness per stand ranged from 32.8 ± 3.4 (Stand 2) to 44.25 ± 2.56 (Stand 9) based on 7.32 m radius plots (Table 1). Based on the 1 m² quadrats, mean species richness per stand ranged from 13.27 ± 2.37 (Stand 2) to 20.58 ± 1.75 (Stand 9) (Table 2). At both scales, herbaceous species exhibited much greater species richness than woody species. Based on paired t-tests using data from the 7.32 m radius scale, mean native herbaceous plant richness was greater than mean exotic herbaceous plant richness ($t = -2.5152$, $df = 8$, $p = 0.0360$). However, at the 1 m² scale, the opposite was true and mean exotic herbaceous species richness was greater than mean native herbaceous species richness ($t = -6.847$, $df = 8$, $p = 0.0001314$).

Species Accumulation Curves

Species accumulation curves based on new unique species encountered as a function of increasing stands sampled leveled-off sooner using actual data compared to estimates calculated from Sobs (Mao Tau) at both the 7.32 m radius and 1 m² scales (Figure 4). In other words, species accumulation curves using Sobs (Mao Tau) calculations under-valued the number of species in the study area at both spatial scales (Figure 4).

Species accumulation curves based on new unique species encountered as a function of increasing the number of sampling units per stand revealed that the sampling design captured most of the species present in each stand at the 7.32 m radius scale (Figure 5). At the 1 m² scale, the number of new species found as a function of increasing the number of sampling units leveled off sooner and resulted in fewer species per stand (data not shown).

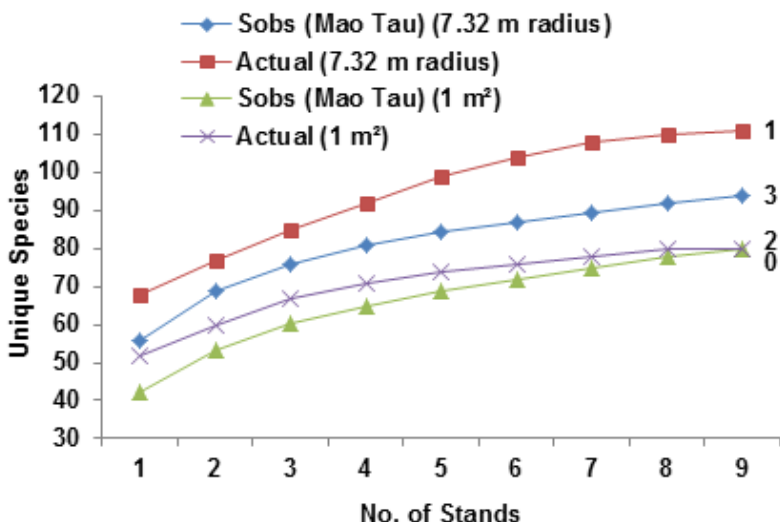


Figure 4. Species accumulation curves for the study area based on the incremental addition of grassland stands sampled. Curves are based on Sobs (Mao Tau) plus actual numbers using data collected with 7.32 m radius plots and with 1 m² plots. Numbers at end of curves indicate how many new species were added with the addition of the last stand.

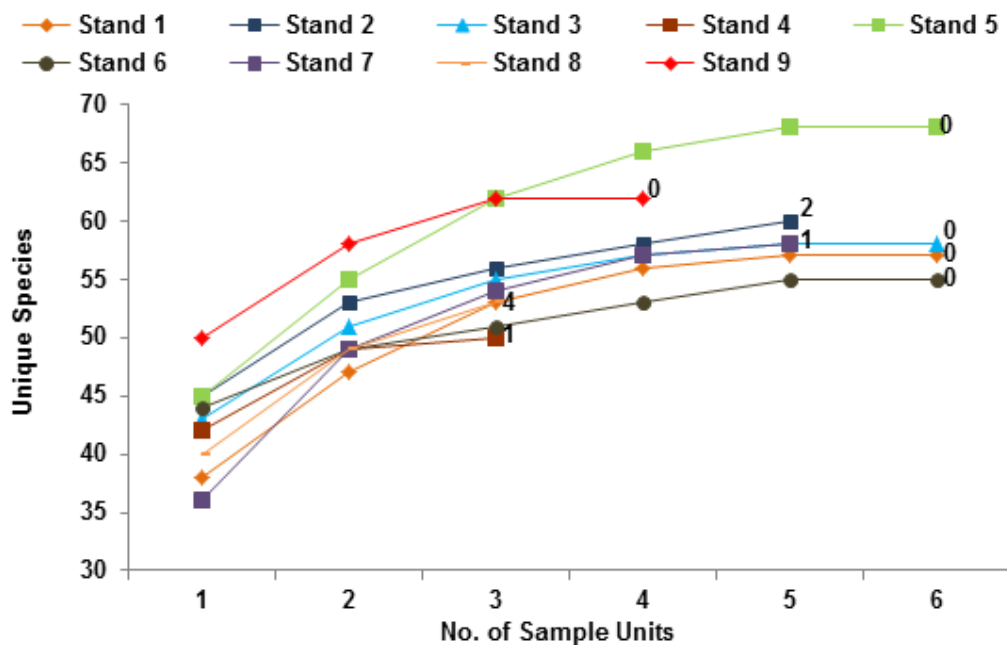


Figure 5. Species accumulation curves for each stand sampled based on the incremental addition of sampling units utilized per stand. Curves for each stand are based on actual numbers using data collected inside 7.32 m radius plots.

Table 1. Mean plant species richness and standard errors based on 7.32 m radius plots.

Plant Richness	1	2	3	4	5	6	7	8	9
Total (All Spp.)	34.33 ± 0.95	32.8 ± 3.4	39.67 ± 0.95	35.67 ± 4.91	33.83 ± 3.81	37.33 ± 1.98	38 ± 1.76	36 ± 2	44.25 ± 2.56
Herbaceous	31.67 ± 0.76	31.8 ± 3.38	38.17 ± 1.11	33 ± 4.16	32.83 ± 3.66	33.33 ± 1.76	35.2 ± 1.83	30 ± 1.53	42.75 ± 2.84
Woody	2.67 ± 0.42	1 ± 0.32	1.5 ± 0.43	2.67 ± 0.88	1 ± 0.26	4 ± 0.37	2.8 ± 0.37	6 ± 0.58	1.5 ± 0.29
Native	22.67 ± 0.95	18.2 ± 2.52	23.5 ± 0.96	18.33 ± 3.28	19.67 ± 2.81	22.17 ± 1.62	22.8 ± 1.28	22.33 ± 1.45	25.5 ± 2.1
Exotic	14.5 ± 1.91	15.6 ± 0.98	17.17 ± 0.6	18.33 ± 1.67	15.17 ± 1.4	16.17 ± 0.6	16.2 ± 0.92	14.67 ± 0.88	19.75 ± 1.65
Native Herbaceous	19 ± 0.73	16.2 ± 2.48	21 ± 1	15 ± 2.65	18 ± 2.58	17.17 ± 1.45	19 ± 1.18	15.67 ± 0.67	23.25 ± 2.25
Exotic Herbaceous	12.67 ± 0.21	15.6 ± 0.98	17.17 ± 0.6	18 ± 1.53	14.83 ± 1.45	16.17 ± 0.6	16.2 ± 0.92	14.33 ± 0.88	19.5 ± 1.44

Table 2. Mean plant species richness and standard errors based on 1 m² quadrats.

Plant Richness	1	2	3	4	5	6	7	8	9
Total (All Spp.)	15.83 ± 0.41	13.27 ± 2.37	19.17 ± 0.5	18.78 ± 0.95	15.06 ± 1.2	16.11 ± 0.73	19.13 ± 0.67	15.56 ± 2.3	20.58 ± 1.75
Herbaceous	15.06 ± 0.47	13.2 ± 2.35	19.11 ± 0.48	18.56 ± 0.91	15 ± 1.17	15.72 ± 0.76	18.67 ± 0.61	14.78 ± 1.89	20.5 ± 1.75
Woody	0.78 ± 0.28	0.07 ± 0.07	0.06 ± 0.06	0.22 ± 0.11	0.06 ± 0.06	0.39 ± 0.1	0.47 ± 0.13	0.78 ± 0.48	0.08 ± 0.08
Native	8.67 ± 0.29	5.47 ± 0.85	8.39 ± 0.51	6.67 ± 0.58	7.22 ± 0.94	7.78 ± 0.87	8.6 ± 0.34	7.22 ± 1.28	8.67 ± 1.19
Exotic	8.67 ± 0.63	8.8 ± 1.62	11.78 ± 0.38	13.11 ± 0.59	8.83 ± 1.23	9.33 ± 0.62	11.53 ± 0.58	9.33 ± 1.02	12.92 ± 0.83
Native Herbaceous	6.89 ± 0.31	4.4 ± 0.83	7.33 ± 0.49	5.44 ± 0.48	6.17 ± 0.97	6.39 ± 0.92	7.13 ± 0.39	5.44 ± 0.91	7.58 ± 1.22
Exotic Herbaceous	8.17 ± 0.22	8.8 ± 1.62	11.78 ± 0.38	13.11 ± 0.59	8.83 ± 1.23	9.33 ± 0.62	11.53 ± 0.58	9.33 ± 1.02	12.92 ± 0.83

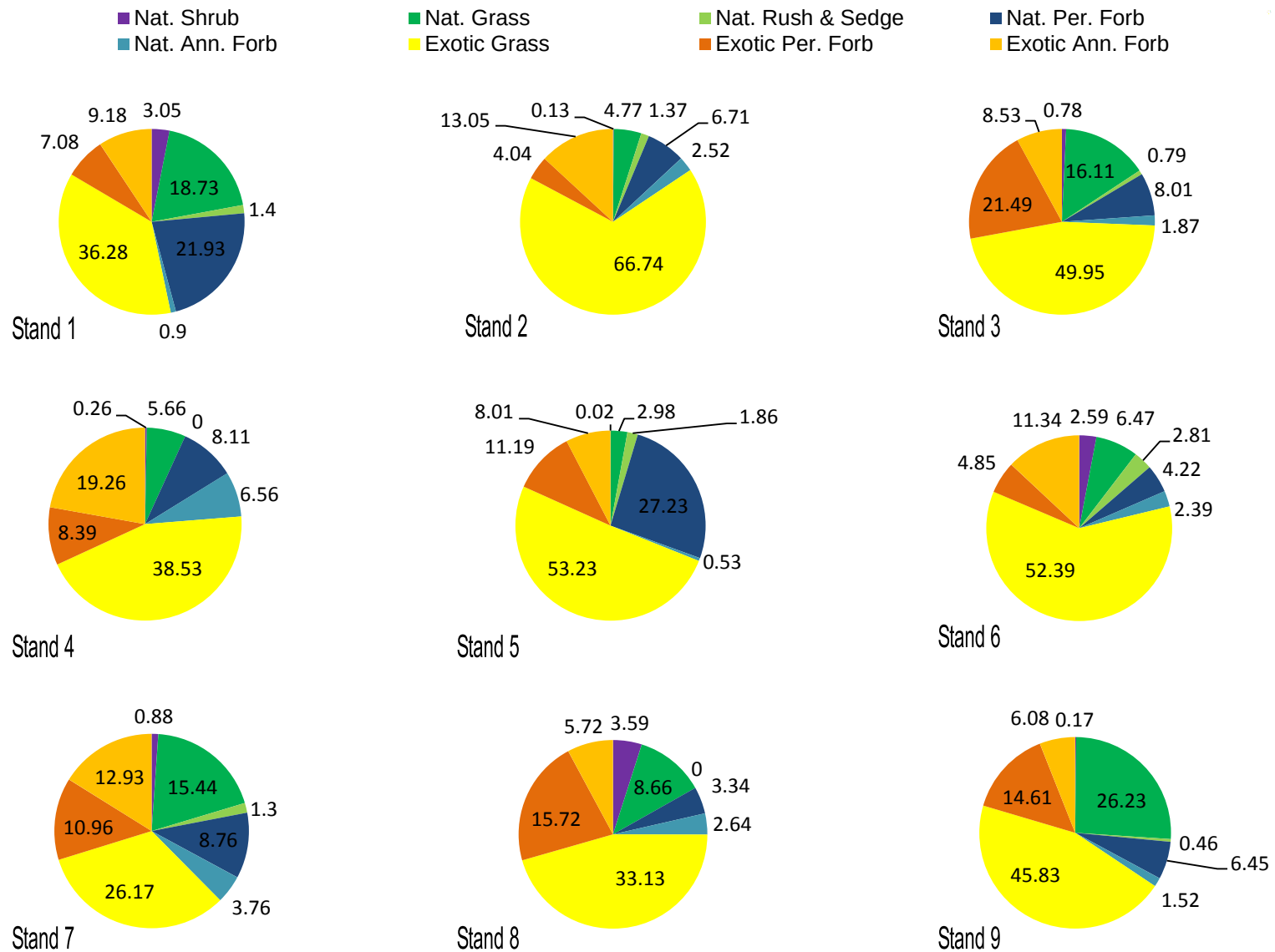


Figure 6. Mean cover of plant life forms for each stand based on the point quadrat technique using 1 m² quadrats.

Vegetation Structure

Cover

Plant cover at all stands was primarily represented by exotic grasses (Figure 6). Exotic grass composition was almost entirely made up of annual species (Appendix C). Native grasses, which were exclusively perennials, were also abundant in many of the grasslands as were native perennial forbs (Figure 6). Shrub cover was low for all stands and only included native species when based on the point quadrat method (Figure 6). Shrub cover calculated from line intercept transects was also low for the stands sampled (Table 3) but detected two exotic species, *Cotoneaster pannosus* and *Genista monspessulana* (Appendix D).

Density

Density of live and dead adult shrubs, and shrub seedlings were low across all stands (Table 3). Most of the shrub density was attributed to two species, *Acmispon glaber* var. *glaber* and *Eriogonum latifolium*, although many more species that are common to the surrounding coastal scrub were also recorded (Appendix E). The density and cover of vines was very low (Appendices E and D, respectively) and only attributable to two species, *Calystegia purpurata* ssp. *purpurata* and *Lathyrus vestitus*.

Table 3. Means and standard errors of shrub cover and shrub density per stand.

Stand	Shrub Cover (10 m line intercept)		Shrub Density (3 x 3 m quadrat)		
	Live	Dead	Live Adults	Live Seedlings	Dead Adult
1	2.06 ± 1.34	0 ± 0	6.5 ± 2.1	0.9 ± 0.5	0.1 ± 0.1
2	0.63 ± 0.63	0 ± 0	0.4 ± 0.2	0.1 ± 0.1	0 ± 0
3	0.22 ± 0.11	0.59 ± 0.59	0.6 ± 0.4	0 ± 0	0 ± 0
4	6.43 ± 0.70	0.03 ± 0.03	0.7 ± 0.5	0.1 ± 0.1	0 ± 0
5	0.82 ± 0.80	0.07 ± 0.05	0.1 ± 0.1	0 ± 0	0 ± 0
6	3.96 ± 1.21	0 ± 0	4.6 ± 1.0	0.1 ± 0.1	0.1 ± 0.1
7	0.91 ± 0.60	0.35 ± 0.35	2.9 ± 0.8	0.9 ± 0.5	0.2 ± 0.1
8	12.22 ± 6.95	0 ± 0	8.9 ± 3.4	3.4 ± 2.2	0 ± 0
9	0.05 ± 0.05	0 ± 0	0.3 ± 0.1	0 ± 0	0 ± 0

Community Classification

In all stands sampled, exotic grasses were the most abundant species as a group (Figure 6), mostly attributable to annuals like *Brachypodium distachyon*, *Briza maxima*, and *Festuca bromoides* (Appendix C). Exotic perennial grasses such as *Festuca arundinacea* and *Stipa purpurata* were more abundant than any native perennial grass species in two of the nine stands but never more abundant than any exotic annual grass species. Among all stands, the most abundant native perennial grasses were *Stipa pulchra*, *Festuca idahoensis*, and *Danthonia californica*, respectively. *Stipa pulchra* was the most abundant native grass in six out of the nine stands sampled. Also, native perennial forbs such as *Calystegia purpurata*, *Carex brevicaulis*, *Chlorogalum pomeridianum*, *Heterotheca sessiliflora*, and *Wyethia angustifolia* were the most abundant native species in one stand each. However, no stand contained a native species that was more abundant than an exotic species

(Appendix C). Based on the key to vegetation types in Keeler-Wolf et al. (2003), four of the nine stands sampled were native grasslands (either CA Annual Grassland with Native Component Mapping Unit or *Stipa pulchra* Alliance), one stand keyed out to the *Brachypodium distachyon* association, and four of the nine stands did not key out to any of the grassland types in their key (Table 4). These four stands that could not be keyed out exhibited less than 10 percent relative cover of native grasses but greater than 15 percent relative cover of native perennial species since forb cover was substantial.

Based on Sawyer et al. (2009), all nine of the grasslands sampled would qualify as coastal prairie with diagnostic native perennials present and >10% relative cover of native plants situated on a coastal headland. Since *Stipa pulchra* was relatively abundant (Figure 7), many stands could be classified under the *Stipa pulchra* alliance. The *Stipa pulchra* alliance, however, is not listed as a coastal prairie vegetation type (e.g., *Calamagrostis nutkaensis*, *Danthonia californica*, *Deschampsia caespitosa*, *Festuca idahoensis*, and *Festuca rubra* alliances, among others) in the key to herbaceous vegetation (Sawyer et al. 2009), but is instead listed in a group of alliances that represent cool coastal to dry interior climates of cismontane California (e.g., *Aristida purpurea*, *Elymus multisetus*, *Elymus glaucus*, and *Festuca idahoensis* alliances, among others). It is unclear if Sawyer et al. (2009) intended for *Stipa pulchra* dominated grasslands to be considered as coastal prairies. This alliance is excluded from the list of coastal prairie types in their key yet stands of this alliance in very coastal prairie-like settings (i.e. PORE) are mentioned in the alliance's profile. We consider the *Stipa pulchra* stands in this study to be coastal prairie because of their location and the presence of other indicative native perennial forbs and grasses (Appendix C).



Figure 7. A patch of *Stipa pulchra* within stand 8.

Table 4. The grassland stands sampled in this study as classified and mapped by Schirokauer et al. (2003) in addition to their classification using current data (this study) with the following keys: 1) the original field key to the plant communities in PORE, GOGA, and surrounding lands (Keeler-Wolf et al. 2003); 2) the Manual of California Vegetation, 2nd edition (Sawyer et al. 2009).

Stand Number	Schirokauer et al. (2003): Plant Community Classification and Mapping of GOGA, PORE, etc...	Keeler-Wolf et al. (2003): Field Key to the Plant Communities Classified and Mapped in Schirokauer et al. (2003).			Sawyer et al. (2009): Manual of California Vegetation, 2 nd Edition	
		>15% Rel. Cover of Native Perennial Grasses [^]	≤15% Rel. Cover of Native Perennial Species [†]	Finest Classification Possible based on Key to Herbaceous Vegetation	>10% Rel. Cover of Diagnostic Native Plants*	Finest Classification Possible based on Key to Herbaceous Vegetation
1	CA Annual Grassland w/ Native Component Mapping Unit	Yes	No	<i>Stipa pulchra</i> Alliance	Yes	<i>Stipa pulchra</i>
2	CA Annual Grassland w/ Native Component Mapping Unit	No	Yes	<i>Brachypodium distachyon</i> Association	Yes	<i>Stipa pulchra</i>
3	Purple Needlegrass Alliance	Yes	No	CA Annual Grassland w/ Native Component Mapping Unit	Yes	<i>Coastal prairie</i>
4	CA Annual Grassland w/ Native Component Mapping Unit	No	No	Herbaceous Vegetation	Yes	<i>Stipa pulchra</i>
5	CA Annual Grassland w/ Native Component Mapping Unit	No	No	Herbaceous Vegetation	Yes	<i>Stipa pulchra</i>
6	CA Annual Grassland w/ Native Component Mapping Unit	No	No	Herbaceous Vegetation	Yes	<i>Stipa pulchra</i>
7	CA Annual Grassland w/ Native Component Mapping Unit	Yes	No	CA Annual Grassland w/ Native Component Mapping Unit	Yes	<i>Stipa pulchra</i>
8	California Annual Grassland Mapping Unit	No	No	Herbaceous Vegetation	Yes	<i>Festuca idahoensis</i>
9	CA Annual Grassland w/ Native Component Mapping Unit	Yes	No	CA Annual Grassland w/ Native Component Mapping Unit	Yes	<i>Festuca idahoensis</i>

[^] Greater than 15% relative cover of native perennial grass species is required to key out to “California Annual Grassland with Native Component Mapping unit.”

[†] No more than 15% relative cover of native perennial species is required to key out to “California Annual Grassland Mapping Unit.”

* Native plants diagnostically present with >10% relative cover; non-native annual plants may be present at high cover is required to key out to “Perennial grasslands and herblands.”

Ordinations

Three NMS ordinations and MRPPs were performed on three different sets of compositional or structural vegetation data. The first NMS ordination utilized species cover data and resulted in a 1-dimensional solution with a final stress of 35.44722 and instability of 0.00000 after 42 iterations (Figures 8 and 9). The MRPP on this same data also revealed significant differences between the nine stands sampled using a p -value of 0.05 but not when using a Bonferroni corrected p -value (Table 5). Sampling units from some stands, like stands 7 and 4, formed distinct groupings while sampling units from other stands did not (Figure 8). *Brachypodium distachyon*, *Stipa purpurata*, and *Wyethia angustifolia* had the strongest correlations with Axis 1 (Figure 9).

The second NMS ordination utilized life form (native grass, exotic grass, etc.) cover data and resulted in a 3-dimensional solution with a final stress of 6.42097 and instability of 0.00000 after 61 iterations (Figures 10 and 11). The MRPP on the life form cover data also revealed a significant difference between the nine stands sampled using a p -value of 0.05 but not when using a Bonferroni corrected p -value (Table 5). Most of the sampling units belonging to Stand 5 clustered together and apart from the other stands (Figure 10). The distinctive grouping of sampling units from stand 5 was attributable to high native perennial forb cover (Figure 11), notably from *W. angustifolia* (Appendix C). Sampling unit F from stand 5 had zero cover of *W. angustifolia* and thus, much lower native perennial forb cover than the other sampling units from that stand and did not group with them. Sampling units from stand 2 formed a group that was influenced by exotic grass cover (Figures 10 and 11).

The third NMS ordination utilized presence-absence data for all species and resulted in a 2-dimensional solution with a final stress of 19.88684 and instability of 0.00303 after 200 iterations (Figure 12). The MRPP on the presence-absence data brought out the strongest difference among the nine stands (Table 5). Sampling units from stands 2, 4, 5, and 8 all made distinct clusters with little overlap with sampling units from other stands (Figure 12). Relatively uncommon species, like *Festuca arundinacea*, *Gastridium phleoides*, *Genista monspessulana*, and *Melica torreyana* had positive correlations with Axis 1 and influenced the separation of stands 2, 4, 5, and 8 from the others. *Castilleja subinclusa* ssp. *franciscana*, *Iris macrosiphon*, *Oxalis pillosa*, and *Pyracantha* sp., were also rare, found only in sample units from stand 5, which pulled this stand apart from the others mostly along Axis 2 (Figure 12).

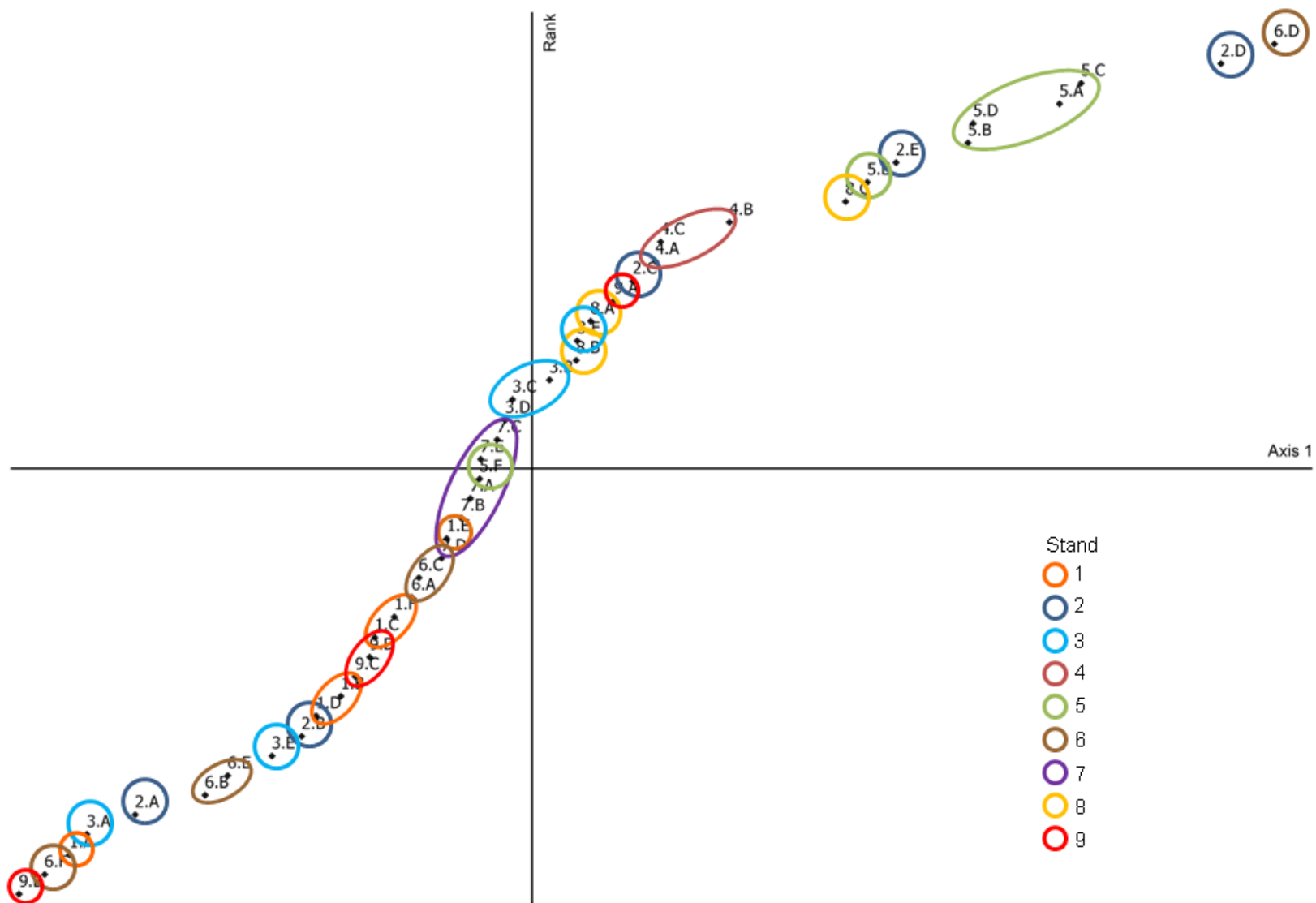


Figure 8. Nonmetric Multidimensional Scaling ordination showing plot scores based on data that included the cover of all species and non-plant variables (e.g., bare soil, lichen, etc.) that exhibited $\geq 5\%$ cover in at least one sampling plot. Plots are named by the stand they occur within followed by a period and then a letter.

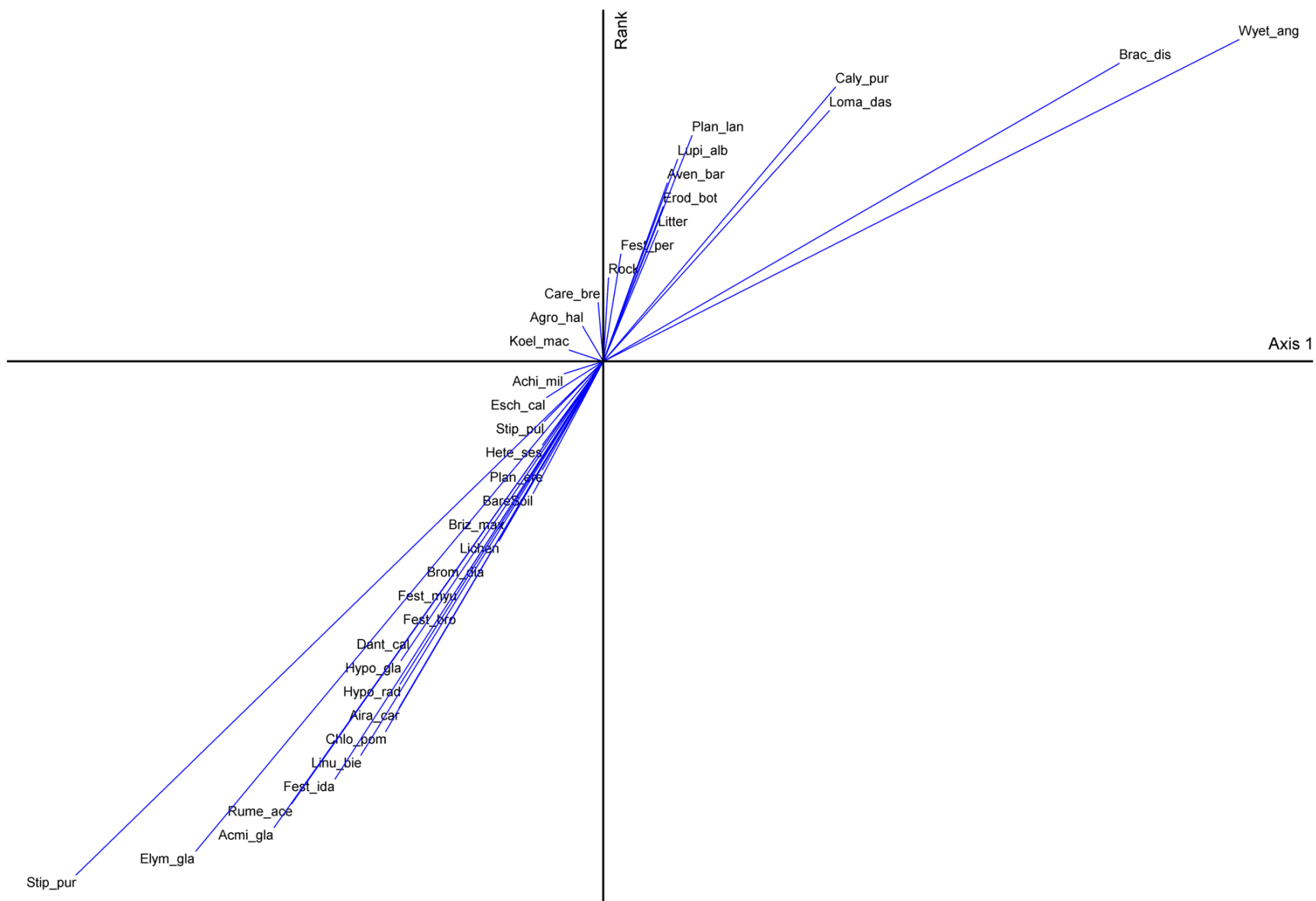


Figure 9. Species scores based on the Nonmetric Multidimensional Scaling ordination in Figure 7.

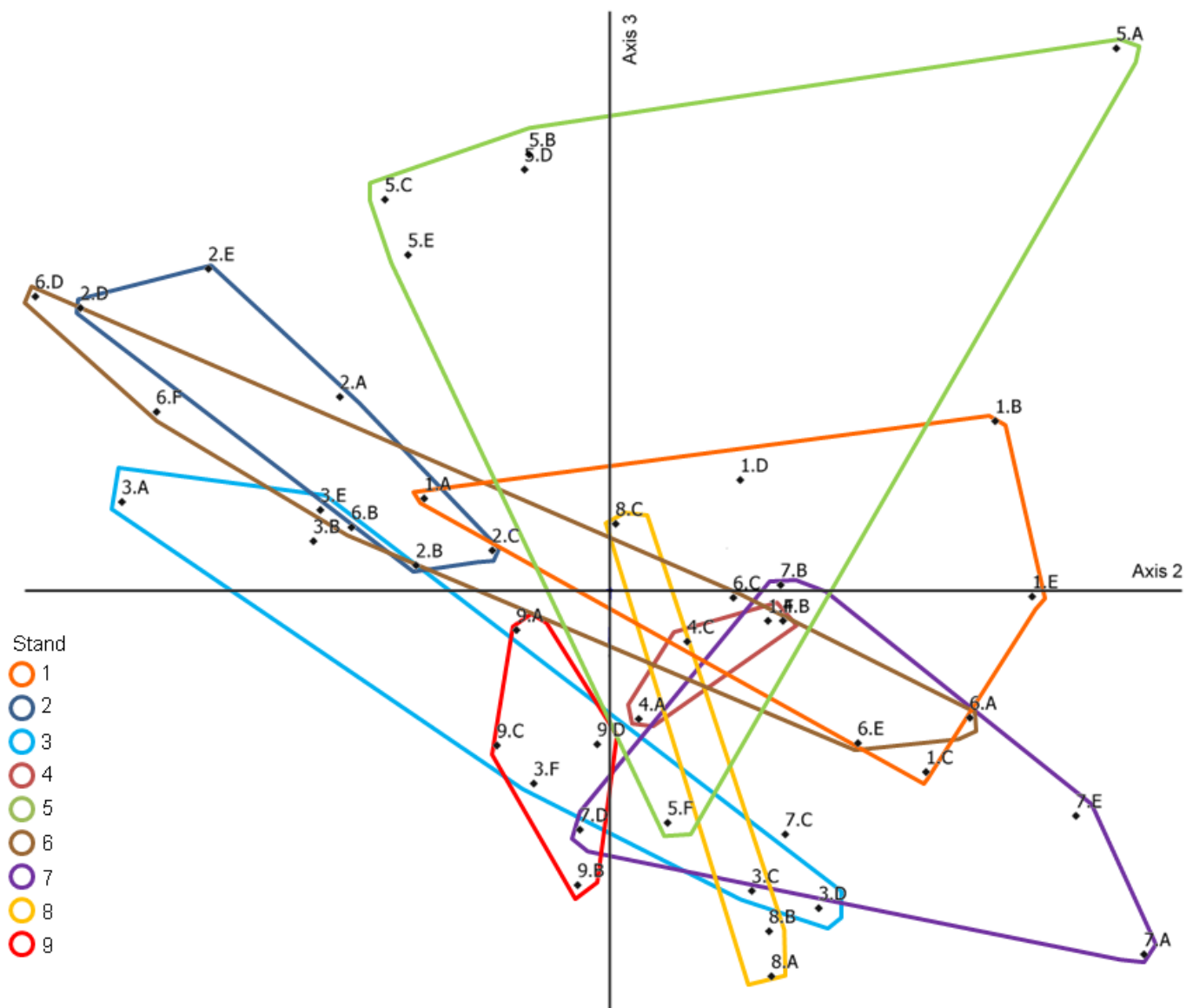


Figure 10. Nonmetric Multidimensional Scaling ordination showing plot scores based on the cover of plant life forms. Plots are named by the stand they occur within followed by a period and then a letter.

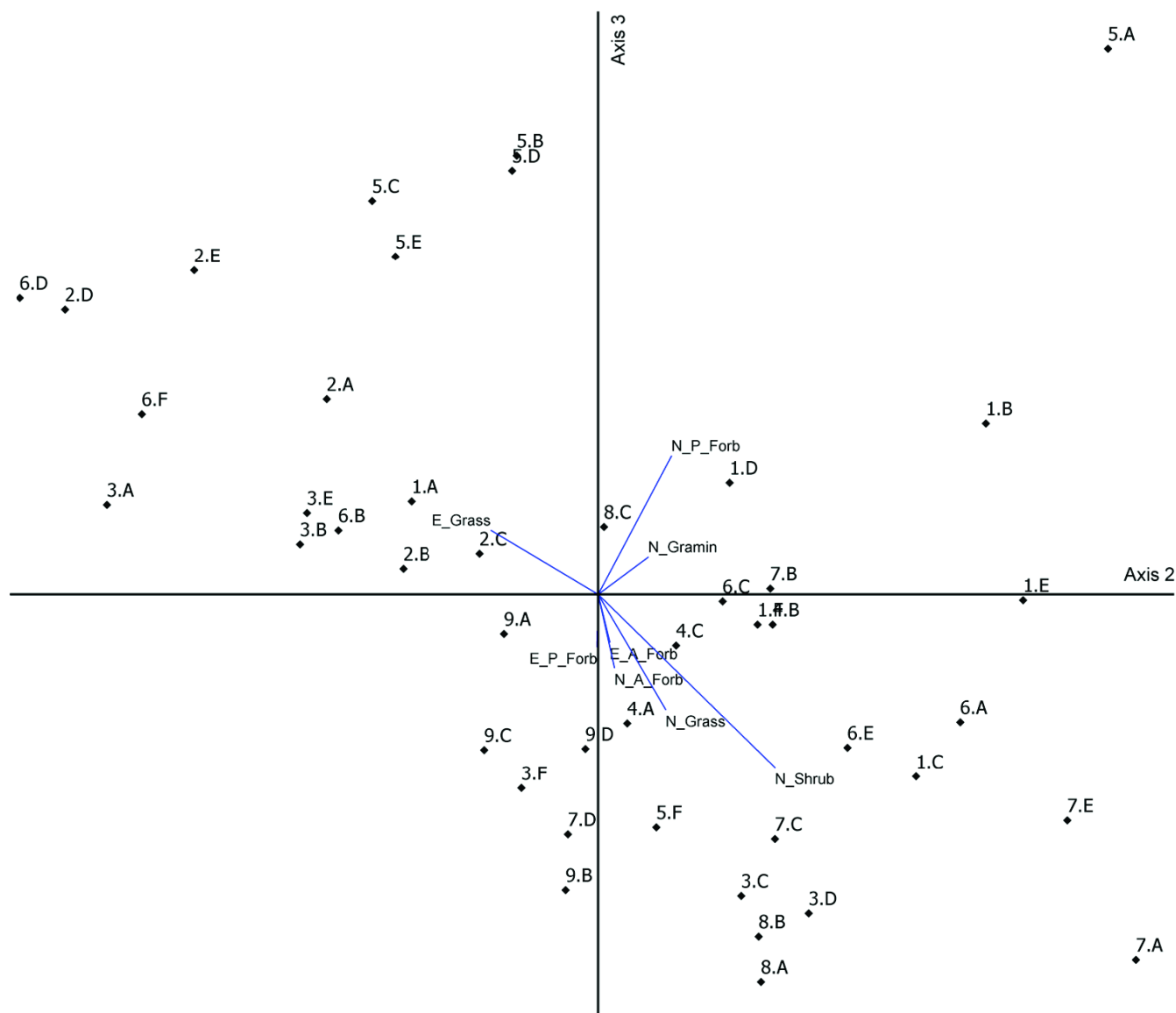


Figure 11. Species scores (using cover of life forms) derived from the Nonmetric Multidimensional Scaling ordination in Figure 9. Symbols to represent the different life forms include the following: E = Exotic, N = Native, A = Annual, P= Perennial.

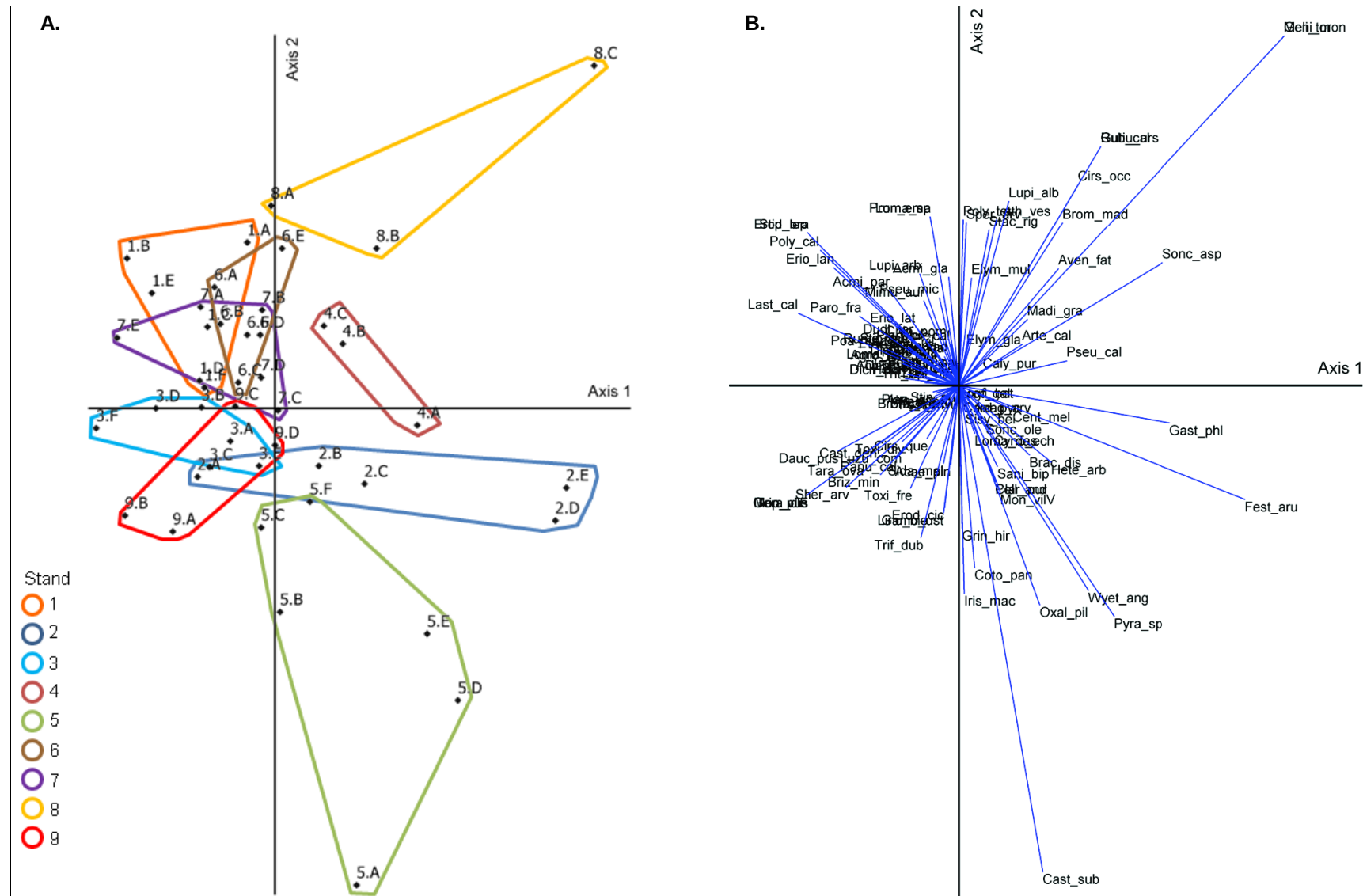


Figure 12. Nonmetric Multidimensional Scaling ordination showing plot scores (A) and species scores (B) based on presence-absence data of all plant species. Plots are named by the stand they occur within followed by a period and then a letter.

Table 5. Multiresponse Permutation Procedure results showing differences between stands based on cover of species, cover of life forms, and species composition at $\alpha = 0.05$ and $\alpha = 0.001389$ (Bonferroni correction). Sharing of a letter between stands indicates no significant difference.

Ordination	Stand Identity								
	1	2	3	4	5	6	7	8	9
<u>Cover of Species ($\geq 5\%$)</u>									
$\alpha = 0.05$	c	abd	ef	a	d	bc	g	ea	fb
$\alpha = 0.001389$	a	a	a	a	a	a	a	a	a
<u>Cover of Life Forms</u>									
$\alpha = 0.05$	e	d	a	abc	c	abcd	be	ab	a
$\alpha = 0.001389$	a	a	a	a	a	a	a	a	a
<u>Presence-Absence</u>									
$\alpha = 0.05$	a	b	c	d	e	f	g	h	i
$\alpha = 0.001389$	b	ac	c	ab	a	bd	ab	ab	ad

Correlations

Linear regression revealed that *Brachypodium distachyon*, an exotic annual grass, was negatively correlated with native annual plant species richness across all sample units ($R^2 = 0.1974$ df = 43, $p = 0.002516$). This exotic grass also was positively correlated with litter depth across all sample units ($R^2 = 0.1718$ df = 43, $p = 0.005147$). Had these regression analyses been restricted to only sample units that contained *B. distachyon*, the correlations would have been stronger (data not shown). Correlations using other species, like *Stipa purpurata* and *Wyethia angustifolia*, which exhibited a strong influence on the ordination of sampling units (see Figure 8), were not performed because of low frequency.

Besides the positive relationship between litter depth and *B. distachyon*, litter depth was also positively correlated with exotic grass cover as a whole ($R^2 = 0.457473$, df = 43, $p < 0.0001$) but had no relationship with native grass cover ($R^2 = -0.01909$, df = 43, $p = 0.6615$). Litter depth was also negatively correlated with native annual plant richness ($R^2 = 0.077815$, df = 43, $p = 0.0372$), although this relationship was weak.

Density of mammal disturbance was positively correlated with the cover of two plant species, *Hypochaeris radicata* ($R^2 = 0.34015$, df = 43, $p < 0.0001$) and *Festuca bromoides* ($R^2 = 0.132395$, df = 43, $p = 0.0152$). Other species like *Briza maxima* and *Danthonia californica* had positive correlations with mammal disturbance density that were near significant (data not shown). Lastly, density of mammal disturbance was positively correlated with total (native and exotic) herbaceous species richness ($R^2 = 0.096275$, df = 43, $p = 0.0404$) and with native grass cover ($R^2 = 0.140509$, df = 43, $p = 0.0122$), although both of these relationships were weak.

Discussion

Species Composition

Species Richness

Regionally, the grasslands in this study may exhibit relatively high native species richness, although it is difficult to be certain due to limited published data and methodological inconsistencies between studies. Future vegetation sampling by SFAN will allow for comparisons between other grasslands, shrublands, and forested vegetation types in this region. Currently, we know that the richness found in these grasslands at the 7.32 m radius scale is higher than in the coastal scrub of the Marin Headlands. At the 1 m² scale, the grasslands in the study area have similar species richness as coastal prairie grasslands on shallow granite soils of PORE and higher species richness than rocky, *Selaginella bigelovii* dominated vegetation at Pinnacles National Monument (Robert Steers, unpublished data). Also at the 1 m² scale, species richness of these grasslands is between that found in coastal terrace prairies and inland *Stipa pulchra* prairies of the South Coast Range (Stromberg et al. 2001).

Stand size did not have a relationship with the total number of unique species found. This was surprising, given the species–area relationship (Lomolino 2001), but may be due to the following: 1) smaller stands might be more influenced or swamped by propagules from surrounding vegetation types, thus boosting species numbers, 2) not enough variation in stand size was represented in this study, or 3) a sample-size of nine was too low to examine this relationship.

Mean richness of native herbaceous species was greater than mean richness of exotic herbaceous species at the 7.32 m radius scale but the opposite was true at the smaller, 1 m² scale. Competitive displacement of natives by exotic species is likely driving lower native richness at the 1 m² scale. At larger scales, there is more substrate patchiness and soil resource heterogeneity that allows native species to persist despite competitive pressure by exotics (Sarr et al. 2005).

The growing season along the coast is relatively long. Not all species overlap in their flowering phenology. Therefore, it is possible that species richness could have been higher if each sampling plot was visited multiple times during the growing season; however, it is unlikely that richness metrics would have changed substantially since sampling was done from mid-April through mid-May when most species were in flower or near-flowering.

Species Accumulation Curves

Actual species accumulation curves and modeled curves based on Sobs (Mao Tau) (Colwell et al. 2004) revealed that that number of species detected as a function of increasing the number of stands sampled began to level-off or become close to leveling-off with the addition of the last one or two stands. This indicates that the number of stands sampled is likely capturing the majority of species found in the grasslands of the study area. Also, adding new stands above the nine that were utilized may not yield benefit in capturing additional taxa compared to the effort required.

Only one stand, which was small, did not have a curve that approached a slope of zero (stand 8). Small stands surrounded by coastal scrub may contain more species associated with that vegetation type, especially since succession from grassland to shrubland is typical in the region (Hsu et al. 2012). In fact, stand 8 had the highest shrub cover of any stand and it might be in the early stages of succeeding to coastal scrub. Stand 8 was the only stand in this study that was located in the original Lime Point Military Reservation, which excluded grazing as early as 1867, well before grazing ceased in the rest of the Marin Headlands. In selecting a stand to sample in the cluster of stands where stand 8 was chosen from, we found that many of its mapped native grasslands had too much shrub cover to be considered grasslands.

Vegetation Structure

Cover

Exotic herbaceous plants were more abundant than native species in the grasslands of the Marin Headlands. However, all stands still contained >10% native herbaceous plant cover, thus qualifying as coastal prairie (Sawyer et al. 2009). Furthermore, these stands were not just occupied by one or two native species. Instead, many native species contributed to grass, rush/sedge, and forb cover.

Within each stand there were small-scale features that produced heterogeneity in species composition and structure, similar to other grasslands (Gea-Izquierdo et al. 2007). It appears that much of this heterogeneity was due to the nature of the chert derived soils, which had patches of extremely shallow, rocky soils intermixed with relatively deep soils that appeared more productive based on greater plant abundance within them. In shallow soil patches, exotic annual grasses were less abundant. For example, in the most shallow, rocky soils it was common to see *Danthonia californica* interspersed among lichen covered mineral soil with sparse cover of other species (Figure 13).

Density

Only the density of woody plants and vines were recorded. No trees were found. Shrub density was mostly attributable to very short-statured sub-shrubs (a prostrate form of *Acmispon glaber* plus *Erigonum latifolia*) that are not dominant components of the coastal scrub in the study area. Their presence does not likely confer an impending conversion to shrubland. However, stand 8 contained several large shrub species that are indicative of coastal scrub.



Figure 13. Images from the sampled grasslands showing patches (bands) of shallow and deep soils, facing up-hill (A), *Festuca idahoensis* bunches growing in shallow soils (B), and an assemblage of *Danthonia californica* and lichen, which was seen throughout the study area on the shallowest soils (C).

Community Classification

The grasslands sampled in this study are coastal prairies. Two stands were classified under the *Festuca idahoensis* alliance based on Sawyer et al. (2009). *Stipa pulchra* was more abundant than any other native grass species in the majority of the stands sampled and six stands were classified under the *Stipa pulchra* alliance; however, this alliance is not listed as a coastal prairie type in the classification scheme presented by Sawyer et al. (2009). Because of the geographic setting and since the *Stipa pulchra* classified grasslands of the Marin Headlands contain a number of diagnostic coastal prairie species, we believe these stands are a coastal prairie form of the *Stipa pulchra* alliance. To avoid confusion, we think that future editions of the Manual of California Vegetation (Sawyer et al. 2009) should include this alliance under both coastal prairie and grasslands of cool coastal to dry interior locations, similar to the *Festuca idahoensis* alliance, which is already under both groupings. Alternatively, coastal prairie alliances could be lumped with alliances found in cool coastal climates.

A separate and recent grassland sampling effort in coastal Marin and Sonoma counties have classified and mapped these same Marin Headlands stands under the *Festuca idahoensis* alliance (Ayzik Solomeshch, UC Davis, personal communication). Future studies of grasslands south and east of the Golden Gate would greatly add to our understanding of how edaphic conditions influence composition and how the grasslands of the Marin Headlands could be placed within a broader spectrum of coastal prairie vegetation in the Bay Area. Currently, the grasslands reported in this study appear to be regionally unique.

Ordinations

The NMS ordinations and MRPPs were helpful in understanding how the sample units within each of the stands were related to one another based on the cover of common species, the cover of life forms, and the presence-absence of species. In general, all three ordinations revealed that most sample plots did not show strict affinity for the stands they belonged to and instead were interspersed amongst each other. This suggests that most stands were not very different, forming repeatable types with consistent floristic composition much in the same way a vegetation association is defined. The ordination based on presence-absence data produced the strongest differences among the stands measured; however, most of this was driven by the presence of uncommon species. Thus, differences between stands based on this latter ordination should not carry as much weight as the other two ordinations that utilized abundance data.

The most noticeable stand that seemed to separate from the others was stand 5. This stand had high native perennial cover, mostly attributed to *Wyethia angustifolia*, which was uncommon or absent in all other stands. Upon close inspection of the geologic map (Niven et al. 2009) it appears that only a small portion of this stand was on chert-derived soils, which could explain why it was different from the other stands.

Correlations

Finding correlations between parameters does not imply causation; however, these relationships can improve our understanding of the mechanisms that shape grasslands. The correlations presented were not corrected for multiplicity (e.g., Bonferroni corrected *p*-values) because they were based on a

priori hypothesis relating to findings from previous research in California herbaceous vegetation; 1) exotic annual grasses produce high amounts of recalcitrant litter that preclude the establishment of native herbaceous species (Hayes and Holl 2003, Coleman and Levine 2007), and 2) fossorial mammal disturbances can promote exotic species (Schiffman 2007, Steers 2010) but also allow for native species to establish in densely packed vegetation (Hobbs and Mooney 1985).

We did observe a negative impact of litter on native annual plant richness. While the identity of the litter was never recorded, it was mostly composed of dead exotic annual grasses from the previous, 2010 field season (Robert Steers personal observation). Notably, *Brachypodium distachyon* appears to produce a relatively high amount of recalcitrant litter and its abundance exhibited a negative relationship with native annual plant richness.

The role of fossorial mammals in shaping grassland vegetation is becoming increasingly recognized (Schiffman 2007). Our data showed that the density of fossorial mammal burrows was positively associated with two abundant and widespread exotic species and with total herbaceous plant species richness. Disturbances are expected to promote invasive species (Hobbs and Huenneke 1992); thus, it is not surprising that *Hypochaeris radicata* and *Festuca bromoides*, both considered invasive plants (Cal-IPC 2013), were positively associated with fossorial mammal disturbances.

The positive increase in herbaceous species richness associated with fossorial mammal disturbances was weak but significant. It is unclear what mechanism may be promoting species richness in places where fossorial mammals are active. Cover of bare ground was high in the grasslands so the role of burrow mounds acting as openings in an otherwise densely packed grassland might not be a viable mechanism. However, the meter square sampling quadrats were much larger than any one burrow, mound, or plug, suggesting that where mammal disturbances were found, there were still other portions of the quadrat with undisturbed soils. Thus, the increase in species richness may be due to higher microhabitat heterogeneity within the quadrat where fossorial mammals are found (Hobbs and Mooney 1985, Lundholm and Larson 2003), or could be related to the intermediate disturbance hypothesis (Connell 1978). Alternatively, the relatively deep soils where fossorial mammals occur in might be more productive and species rich in general (Mittelbach et al. 2001).

Conclusions

The grasslands on chert-derived soils of the Marin Headlands are regionally unique, representing a relatively dry, coastal prairie vegetation type with a high abundance of *Stipa pulchra* and *Festuca idahoensis*. Unlike many other coastal prairie stands elsewhere in California, the Marin Headlands stands contain relatively low exotic perennial abundance, especially of grasses. However, two exotic perennial grass species, *Festuca arundinacea* and *Stipa purpurata*, were noted for their high abundance in two stands. These exotic species, in addition to other exotic perennial grasses that may appear in the future, are threats to habitat quality and should be managed if resources are available.

Coastal grassland vegetation in central California can convert to coastal scrub in the absence of disturbances (Hsu et al. 2012). However, the Marin Headlands grasslands found on chert-derived soils appear relatively resistant to undergoing succession. Succession proceeds more rapidly in productive soils (Prach et al. 1993) and it seems that the chert-derived soils are relatively shallow and less productive; hence, many grasslands in the study area have not type-converted even after decades without disturbances from grazing or fire. Like many portions of the San Francisco Bay Area, the geology of the Marin Headlands is complex and unique. Substrate or soil type has a large effect on the patterning of vegetation and dynamics, and should be the focus of future research in the SFAN.

The sample design functioned well at capturing most of the species that occur within each stand and also in the grasslands of the study area as a whole, at least based on species accumulation curves. Although not presented, power analyses reveal that the sample design is also adequate for detecting changes in various structural parameters over time (Robert Steers, unpublished data).

Through this sampling effort, we have been able to improve the classification of the stands sampled. This resulted in a new vegetation type (*Festuca idahoensis* alliance) that had not been documented in the last vegetation mapping effort (Schirokauer et al. 2003). All stands sampled had a fairly consistent mixture of native perennial grasses and forbs. *Stipa pulchra* and *F. idahoensis* were common in every stand sampled in addition to native forbs like *Heterotheca sessiliflora*, *Eschscholzia californica*, and *Plantago erecta*. Ordinations of the stands based on NMS revealed that, besides stand 5, the other stands sampled are very similar to one another. Monitoring these grasslands as a distinct type (i.e., chert associated *Stipa-Festuca* grasslands) in the SFAN plant community monitoring program would be informative to park managers who are faced with addressing diverse management challenges in the Marin Headlands.

Lastly, our hypothesis that litter depth would be negatively associated with native species richness was supported, although the correlation was very weak. Our other hypothesis that fossorial mammal disturbance would be positively associated with total exotic plant abundance was not supported. Most correlations found were weak, although the relationship between *Brachypodium distachyon* cover and litter depth was convincing, which is consistent with anecdotal observations that this species produces highly recalcitrant litter that appears to preclude the establishment of native plants, like annual wildflowers (Cal-IPC 2013).

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Appendix A. Slope, aspect, and geographical location of all sample units

Stand	Sample Unit	Slope (Degrees)	Aspect (Degrees)	Latitude	Longitude
1	A	20	135	37 50.105	-122 31.400
	B	22	128	37 50.128	-122 31.416
	C	19	168	37 50.166	-122 31.444
	D	18	134	37 50.192	-122 31.456
	E	20	140	37 50.191	-122 31.425
	F	21	134	37 50.217	-122 31.490
2	A	23	245	37 50.831	-122 30.956
	B	21	216	37 50.816	-122 30.942
	C	24	209	37 50.803	-122 30.922
	D			37 50.802	-122 30.948
	E	26	194	37 50.789	-122 30.929
3	A	22	197	37 51.021	-122 32.491
	B	25	156	37 51.023	-122 32.469
	C	21	156	37 51.029	-122 32.448
	D	23	160	37 51.043	-122 32.462
	E	23	130	37 51.043	-122 32.430
	F	19	148	37 51.057	-122 32.447
4	A	25	214	37 50.660	-122 30.044
	B	26	198	37 50.647	-122 30.048
	C	24	174	37 50.646	-122 30.032
5	A	22	190	37 50.770	-122 31.306
	B	21	173	37 50.776	-122 31.283
	C	19	160	37 50.792	-122 31.254
	D	25	176	37 50.752	-122 31.284
	E	30	190	37 50.752	-122 31.311
	F	28	198	37 50.786	-122 31.323
6	A	23	220	37 50.441	-122 31.250
	B	20	265	37 50.415	-122 31.248
	C	20	230	37 50.399	-122 31.240
	D	17	238	37 50.391	-122 31.278
	E	30	206	37 50.379	-122 31.226
	F	22	178	37 50.378	-122 31.203
7	A	25	186	37 50.310	-122 30.604
	B	22	160	37 50.320	-122 30.580
	C	19	180	37 50.335	-122 30.552
	D	23	208	37 50.341	-122 30.521
	E	15	178	37 50.331	-122 30.493

Stand	Sample Unit	Slope (Degrees)	Aspect (Degrees)	Latitude	Longitude
8	A	14	196	37 49.917	-122 29.491
	B	22	162	37 49.889	-122 29.488
	C	24	156	37 49.856	-122 29.472
9	A	16	213	37 50.885	-122 31.925
	B	13	254	37 50.888	-122 31.894
	C	19	178	37 50.890	-122 31.837
	D	20	167	37 50.903	-122 31.786

Appendix B. Species frequency per sampling unit for each stand

Species	Stand								
	1	2	3	4	5	6	7	8	9
Agavaceae									
<i>Chlorogalum pomeridianum</i>	6 / 6	3 / 5	4 / 6	3 / 3	2 / 6	6 / 6	5 / 5	3 / 3	2 / 4
Anacardiaceae									
<i>Toxicodendron diversilobum</i>	--	2 / 5	1 / 6	--	--	--	--	--	--
Apiaceae									
<i>Daucus pusillus</i>	--	1 / 5	2 / 6	--	--	--	--	--	1 / 4
<i>Lomatium dasycarpum</i>	4 / 6	5 / 5	3 / 6	3 / 3	6 / 6	2 / 6	3 / 5	--	3 / 4
<i>Lomatium</i> sp.	1 / 6	--	--	--	--	--	--	--	--
<i>Lomatium utriculatum</i>	--	--	1 / 6	1 / 3	--	--	--	--	--
<i>Sanicula bipinnatifida</i>	--	3 / 5	1 / 6	--	1 / 6	--	1 / 5	--	3 / 4
Asteraceae									
<i>Achillea millefolium</i>	5 / 6	1 / 5	5 / 6	1 / 3	3 / 6	5 / 6	4 / 5	2 / 3	2 / 4
<i>Artemisia californica</i>	1 / 6	2 / 5	2 / 6	--	1 / 6	2 / 6	--	2 / 3	--
<i>Baccharis pilularis</i>	2 / 6	--	1 / 6	3 / 3	1 / 6	3 / 6	3 / 5	2 / 3	3 / 4
<i>Carduus pycnocephalus</i>	--	2 / 5	1 / 6	1 / 3	--	--	2 / 5	--	--
<i>Centaurea melitensis</i>	--	--	1 / 6	3 / 3	4 / 6	2 / 6	1 / 5	1 / 3	--
<i>Cirsium occidentale</i> var. <i>venustum</i>	--	--	--	1 / 3	--	--	--	3 / 3	--
<i>Cirsium quercetorum</i>	--	2 / 5	4 / 6	--	3 / 6	1 / 6	1 / 5	--	--
<i>Eriophyllum lanatum</i> var. <i>arachnoideum</i>	1 / 6	--	--	--	--	--	--	--	--
<i>Gamochaeta ustulata</i>	--	--	--	--	2 / 6	--	2 / 5	--	2 / 4
<i>Grindelia hirsutula</i>	--	1 / 5	4 / 6	--	5 / 6	--	--	--	1 / 4
<i>Gutierrezia californica</i>	--	--	--	--	--	--	--	3 / 3	--
<i>Heterotheca sessiliflora</i> ssp. <i>bolanderi</i>	6 / 6	3 / 5	6 / 6	3 / 3	4 / 6	6 / 6	5 / 5	1 / 3	4 / 4
<i>Hypochaeris glabra</i>	6 / 6	3 / 5	6 / 6	3 / 3	4 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Hypochaeris radicata</i>	6 / 6	5 / 5	6 / 6	2 / 3	2 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Lasthenia californica</i>	--	--	--	--	--	--	1 / 5	--	--
<i>Logfia gallica</i>	6 / 6	5 / 5	6 / 6	3 / 3	6 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Madia gracilis</i>	--	--	--	1 / 3	--	--	--	--	--
<i>Pseudognaphalium californicum</i>	--	2 / 5	--	--	--	1 / 6	--	1 / 3	1 / 4
<i>Pseudognaphalium</i> cf. <i>microcephalum</i>	--	--	--	--	--	3 / 6	--	--	--
<i>Sonchus asper</i>	--	1 / 5	--	--	--	--	1 / 5	1 / 3	--
<i>Sonchus oleraceus</i>	--	2 / 5	--	3 / 3	1 / 6	1 / 6	1 / 5	--	1 / 4
<i>Wyethia angustifolia</i>	--	2 / 5	--	--	6 / 6	--	--	--	--

Species	Stand								
	1	2	3	4	5	6	7	8	9
Berberidaceae									
<i>Berberis pinnata</i> ssp. <i>pinnata</i>	1 / 6	--	--	--	--	--	--	--	--
Caryophyllaceae									
<i>Paronychia franciscana</i>	2 / 6	--	--	--	--	--	--	--	--
<i>Polycarpon tetraphyllum</i>	1 / 6	--	--	--	--	1 / 6	2 / 5	1 / 3	--
<i>Silene gallica</i>	6 / 6	4 / 5	6 / 6	3 / 3	5 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Spergula arvensis</i>	--	--	--	--	--	1 / 6	--	--	--
Convolvulaceae									
<i>Calystegia purpurata</i> ssp. <i>purpurata</i>	4 / 6	5 / 5	4 / 6	3 / 3	5 / 6	6 / 6	4 / 5	3 / 3	2 / 4
<i>Dichondra donelliana</i>	4 / 6	--	6 / 6	2 / 3	2 / 6	2 / 6	3 / 5	--	2 / 4
Crassulaceae									
<i>Dudleya farinosa</i>	1 / 6	1 / 5	--	--	1 / 6	2 / 6	1 / 5	--	1 / 4
Cyperaceae									
<i>Carex brevicaulis</i>	6 / 6	3 / 5	3 / 6	2 / 3	4 / 6	6 / 6	5 / 5	--	3 / 4
Dennstediaceae									
<i>Pteridium aquilinum</i>	3 / 6	1 / 5	--	--	1 / 6	5 / 6	1 / 5	1 / 3	3 / 4
Fabaceae									
<i>Acmispon glaber</i> var. <i>glaber</i>	4 / 6	--	--	1 / 3	1 / 6	6 / 6	2 / 5	2 / 3	--
<i>Acmispon parviflorus</i>	1 / 6	--	--	1 / 3	--	1 / 6	3 / 5	--	--
<i>Genista monspessulana</i>	--	--	--	--	--	--	--	1 / 3	--
<i>Lathyrus vestitus</i>	1 / 6	--	--	--	--	--	--	1 / 3	--
<i>Lupinus albifrons</i> var. <i>collinus</i>	--	--	--	--	--	--	--	2 / 3	--
<i>Lupinus arboreus</i>	2 / 6	--	--	--	--	6 / 6	1 / 5	1 / 3	--
<i>Lupinus nanus</i>	6 / 6	2 / 5	4 / 6	3 / 3	5 / 6	3 / 6	1 / 5	2 / 3	3 / 4
<i>Trifolium dubium</i>	--	--	--	--	2 / 6	--	--	--	1 / 4
Geraniaceae									
<i>Erodium botrys</i>	6 / 6	5 / 5	6 / 6	3 / 3	6 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Erodium brachycarpum</i>	1 / 6	--	--	--	--	--	--	--	--
<i>Erodium cicutarium</i>	--	--	--	--	1 / 6	--	--	--	--
<i>Geranium dissectum</i>	--	--	--	--	--	--	--	--	1 / 4
Iridaceae									
<i>Iris macrosiphon</i>	--	--	--	--	1 / 6	--	--	--	--
<i>Sisyrinchium bellum</i>	5 / 6	5 / 5	4 / 6	1 / 3	5 / 6	2 / 6	4 / 5	2 / 3	4 / 4
Juncaceae									
<i>Luzula comosa</i>	1 / 6	2 / 5	1 / 6	--	1 / 6	--	1 / 5	--	3 / 4

Species	Stand								
	1	2	3	4	5	6	7	8	9
Lamiaceae									
<i>Monardella villosa</i> ssp. <i>franciscana</i>	--	--	--	--	--	--	--	--	1 / 4
<i>Monardella villosa</i> ssp. <i>villosa</i>	--	--	2 / 6	--	3 / 6	--	--	2 / 3	--
<i>Stachys rigida</i> var. <i>quercetorum</i>	1 / 6	--	--	1 / 3	--	--	--	2 / 3	--
Linaceae									
<i>Linum bienne</i>	--	--	1 / 6	--	2 / 6	--	--	--	4 / 4
Malvaceae									
<i>Sidalcea malviflora</i>	1 / 6	2 / 5	6 / 6	--	6 / 6	3 / 6	2 / 5	--	3 / 4
Melanthiaceae									
<i>Toxicoscordion fremontii</i>	--	2 / 5	5 / 6	--	4 / 6	--	--	--	3 / 4
Myrsinaceae									
<i>Anagallis arvensis</i>	4 / 6	5 / 5	6 / 6	3 / 3	6 / 6	4 / 6	4 / 5	3 / 3	4 / 4
Onagraceae									
<i>Clarkia purpurea</i> ssp. <i>quadrivulnera</i>	--	--	--	--	1 / 6	--	--	--	--
<i>Taraxia ovata</i>	--	--	--	--	--	--	--	--	3 / 4
Orobanchaceae									
<i>Castilleja densiflora</i> ssp. <i>densiflora</i>	--	1 / 5	4 / 6	--	1 / 6	--	--	--	3 / 4
<i>Castilleja subinclusa</i> ssp. <i>franciscana</i>	--	--	--	--	1 / 6	--	--	--	--
<i>Triphysaria pusilla</i>	--	--	--	--	--	--	--	--	1 / 4
Oxalidaceae									
<i>Oxalis pilosa</i>	--	--	--	--	2 / 6	--	--	--	--
Papaveraceae									
<i>Eschscholzia californica</i>	6 / 6	5 / 5	6 / 6	3 / 3	4 / 6	6 / 6	4 / 5	3 / 3	4 / 4
Phrymaceae									
<i>Mimulus aurantiacus</i>	--	--	--	1 / 3	--	1 / 6	3 / 5	--	--
Plantaginaceae									
<i>Plantago erecta</i>	6 / 6	3 / 5	6 / 6	2 / 3	1 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Plantago lanceolata</i>	6 / 6	3 / 5	6 / 6	3 / 3	5 / 6	4 / 6	5 / 5	2 / 3	3 / 4
Poaceae									
<i>Agrostis</i> cf. <i>hallii</i>	3 / 6	1 / 5	4 / 6	--	1 / 6	5 / 6	5 / 5	--	2 / 4
<i>Aira caryophyllea</i>	3 / 6	1 / 5	6 / 6	3 / 3	4 / 6	5 / 6	2 / 5	1 / 3	4 / 4
<i>Avena barbata</i>	6 / 6	5 / 5	6 / 6	3 / 3	5 / 6	6 / 6	5 / 5	3 / 3	4 / 4
<i>Avena fatua</i>	--	--	1 / 6	2 / 3	--	--	--	1 / 3	--
<i>Brachypodium distachyon</i>	--	5 / 5	3 / 6	3 / 3	6 / 6	--	1 / 5	2 / 3	2 / 4
<i>Briza maxima</i>	6 / 6	5 / 5	6 / 6	1 / 3	6 / 6	6 / 6	5 / 5	2 / 3	4 / 4
<i>Briza minor</i>	--	--	--	--	1 / 6	--	--	--	3 / 4

Species	Stand								
	1	2	3	4	5	6	7	8	9
Rubiaceae									
<i>Sherardia arvensis</i>	--	1 / 5	--	--	--	--	--	--	2 / 4
Themidaceae									
<i>Dichelostemma capitatum</i>	4 / 6	1 / 5	--	1 / 3	1 / 6	--	2 / 5	--	--
<i>Triteleia laxa</i>	1 / 6	--	6 / 6	--	1 / 6	--	--	2 / 3	4 / 4
Unknown									
Unknown forb seedling	1 / 6	--	--	--	--	--	--	--	--

Appendix C. Mean species cover and standard error per stand based on 1 x 1 m quadrats

Species	Stand								
	1	2	3	4	5	6	7	8	9
Ground Parameters									
Bare ground	10 ± 3.19	6.67 ± 3.72	9.67 ± 2.74	10.67 ± 1.39	8 ± 2.56	20.89 ± 5.93	24 ± 2.02	17.33 ± 2.52	12.67 ± 4.45
Burrow	--	--	0.11 ± 0.11	--	--	0.11 ± 0.11	--	--	--
Lichen	1.78 ± 1.01	0.53 ± 0.53	0.44 ± 0.33	1.33 ± 0.67	0.11 ± 0.11	0.33 ± 0.33	3.33 ± 2.51	1.33 ± 1.02	0.67 ± 0.47
Litter	12.78 ± 0.96	12.4 ± 1.82	7.67 ± 1.01	10.67 ± 2.04	9.67 ± 1.63	6.11 ± 1.45	7.07 ± 1.78	12.89 ± 3.93	8 ± 2.68
Moss	--	0.13 ± 0.13	--	--	--	--	--	--	--
Rock	3.22 ± 1	0.67 ± 0.3	0.33 ± 0.15	6.22 ± 3.47	0.33 ± 0.15	0.22 ± 0.14	0.67 ± 0.21	4.44 ± 1.9	0.5 ± 0.5
Root/bole	--	--	--	--	--	0.67 ± 0.46	--	--	--
Wood	--	--	--	0.22 ± 0.22	--	0.11 ± 0.11	0.13 ± 0.13	--	--
Agavaceae									
<i>Chlorogalum pomeridianum</i>	12.81 ± 3.97	0.27 ± 0.27	1.02 ± 0.58	2.29 ± 2.24	0.03 ± 0.02	0.88 ± 0.4	0.75 ± 0.5	0.77 ± 0.67	--
Anacardiaceae									
<i>Toxicodendron diversilobum</i>	--	0.13 ± 0.13	--	--	--	--	--	--	--
Apiaceae									
<i>Daucus pusillus</i>	--	--	0.03 ± 0.02	--	--	--	--	--	0.03 ± 0.03
<i>Lomatium dasycarpum</i>	0.19 ± 0.12	1.2 ± 0.88	0.03 ± 0.02	2.48 ± 2.43	0.35 ± 0.23	0.03 ± 0.03	0.02 ± 0.02	--	0.08 ± 0.03
<i>Lomatium utriculatum</i>	--	--	--	0.26 ± 0.26	--	--	--	--	--
<i>Sanicula bipinnatifida</i>	--	--	0.02 ± 0.02	--	0.13 ± 0.13	--	0.02 ± 0.02	--	0.69 ± 0.4
Asteraceae									
<i>Achillea millefolium</i>	0.33 ± 0.33	0.02 ± 0.02	1 ± 0.64	0.89 ± 0.89	0.02 ± 0.02	0.16 ± 0.11	0.42 ± 0.26	--	--
<i>Carduus pycnocephalus</i>	--	0.55 ± 0.55	--	--	--	--	--	--	--
<i>Centaurea melitensis</i>	--	--	--	0.42 ± 0.17	0.16 ± 0.11	0.02 ± 0.02	0.02 ± 0.02	--	--
<i>Cirsium quercetorum</i>	--	--	0.26 ± 0.22	--	--	--	--	--	--
<i>Gamochaeta ustulata</i>	--	--	--	--	0.02 ± 0.02	--	--	--	--
<i>Grindelia hirsutula</i>	--	0.13 ± 0.13	0.22 ± 0.14	--	0.13 ± 0.11	--	--	--	0.03 ± 0.03
<i>Heterotheca sessiliflora</i> ssp.									
<i>bolanderi</i>	6.78 ± 1.61	1.24 ± 0.75	1.7 ± 0.78	1.69 ± 0.41	1.78 ± 0.97	2.42 ± 0.71	6.73 ± 0.9	0.89 ± 0.89	0.83 ± 0.5
<i>Hypochaeris glabra</i>	6.91 ± 0.85	2.44 ± 1.43	6.18 ± 1.76	3.66 ± 1.33	2.64 ± 2.54	6.53 ± 2.14	6.97 ± 1.91	0.27 ± 0.03	1.82 ± 0.73
<i>Hypochaeris radicata</i>	1.46 ± 0.87	2.02 ± 1.1	8.22 ± 1.94	0.07 ± 0.07	0.57 ± 0.55	1.19 ± 0.57	3.41 ± 0.96	1.06 ± 0.38	12.38 ± 1.83
<i>Logfia gallica</i>	0.91 ± 0.3	0.61 ± 0.29	0.37 ± 0.13	0.49 ± 0.19	0.26 ± 0.11	0.23 ± 0.11	0.77 ± 0.35	0.36 ± 0.16	0.37 ± 0.17
<i>Madia gracilis</i>	--	--	--	0.03 ± 0.03	--	--	--	--	--
<i>Sonchus oleraceus</i>	--	0.4 ± 0.4	--	0.13 ± 0.07	0.02 ± 0.02	--	--	--	0.03 ± 0.03
<i>Wyethia angustifolia</i>	--	--	--	--	22 ± 6.01	--	--	--	--
Caryophyllaceae									
<i>Paronychia franciscana</i>	0.22 ± 0.22	--	--	--	--	--	--	--	--
<i>Polycarpon tetraphyllum</i>	0.14 ± 0.14	--	--	--	--	0.02 ± 0.02	0.19 ± 0.15	--	--

Species	Stand								
	1	2	3	4	5	6	7	8	9
<i>Silene gallica</i>	0.53 ± 0.14	0.08 ± 0.04	0.13 ± 0.04	1.24 ± 1.04	0.27 ± 0.13	0.22 ± 0.03	0.77 ± 0.38	0.61 ± 0.42	0.13 ± 0.08
<i>Spergula arvensis</i>	--	--	--	--	--	0.26 ± 0.26	--	--	--
Convolvulaceae									
<i>Calystegia purpurata</i> ssp. <i>purpurata</i>	0.11 ± 0.11	2.55 ± 1.41	0.37 ± 0.35	0.03 ± 0.03	0.05 ± 0.02	--	0.15 ± 0.13	1.18 ± 0.46	0.17 ± 0.17
<i>Dichondra donelliana</i>	0.59 ± 0.55	--	0.97 ± 0.41	0.26 ± 0.21	0.02 ± 0.02	0.35 ± 0.23	0.46 ± 0.3	--	0.05 ± 0.03
Cyperaceae									
<i>Carex brevicaulis</i>	1.4 ± 0.54	1.33 ± 0.92	0.78 ± 0.4	--	1.84 ± 1.53	2.81 ± 1.31	1.3 ± 0.61	--	0.38 ± 0.22
Dennstaedtiaceae									
<i>Pteridium aquilinum</i>	0.68 ± 0.68	--	--	--	0.11 ± 0.11	0.24 ± 0.15	0.02 ± 0.02	--	0.19 ± 0.16
Fabaceae									
<i>Acemispom glaber</i> var. <i>glaber</i>	2.13 ± 1.72	--	--	--	--	2.33 ± 1.54	0.42 ± 0.4	--	--
<i>A. glaber</i> var. <i>glaber</i> (D)	--	--	--	--	--	--	0.4 ± 0.4	--	--
<i>Acemispom parviflorus</i>	0.02 ± 0.02	--	--	0.03 ± 0.03	--	0.05 ± 0.05	0.06 ± 0.02	--	--
<i>Lathyrus vestitus</i>	0.02 ± 0.02	--	--	--	--	--	--	0.48 ± 0.48	--
<i>Lupinus albifrons</i> var. <i>collinus</i>	--	--	--	--	--	--	--	2.92 ± 1.97	--
<i>Lupinus arboreus</i>	--	--	--	--	--	0.22 ± 0.14	--	--	--
<i>Lupinus nanus</i>	0.05 ± 0.03	--	0.11 ± 0.11	0.36 ± 0.21	0.02 ± 0.02	0.02 ± 0.02	--	0.03 ± 0.03	--
Geraniaceae									
<i>Erodium botrys</i>	0.64 ± 0.27	8.46 ± 2.41	1.55 ± 0.41	11.56 ± 5.67	3.84 ± 2.09	4.07 ± 0.92	3.79 ± 1.2	3.66 ± 1.72	2.19 ± 1.12
<i>Erodium cicutarium</i>	--	--	--	--	0.02 ± 0.02	--	--	--	--
Iridaceae									
<i>Iris macrosiphon</i>	--	--	--	--	0.02 ± 0.02	--	--	--	--
<i>Sisyrinchium bellum</i>	0.13 ± 0.11	0.99 ± 0.38	0.33 ± 0.23	0.22 ± 0.22	1.27 ± 0.79	--	--	0.03 ± 0.03	1.19 ± 1.19
Juncaceae									
<i>Luzula comosa</i>	--	0.04 ± 0.04	0.02 ± 0.02	--	0.02 ± 0.02	--	--	--	0.08 ± 0.05
Lamiaceae									
<i>Monardella villosa</i> ssp. <i>villosa</i>	--	--	--	--	0.14 ± 0.11	--	--	--	--
<i>Stachys rigida</i> var. <i>quercetorum</i>	0.13 ± 0.13	--	--	--	--	--	--	--	--
Linaceae									
<i>Linum bienne</i>	--	--	--	--	0.89 ± 0.89	--	--	--	2.1 ± 0.44
Malvaceae									
<i>Sidalcea malviflora</i>	0.03 ± 0.03	0.02 ± 0.02	1.08 ± 0.75	--	0.4 ± 0.17	0.13 ± 0.11	0.04 ± 0.02	--	0.22 ± 0.15
Melanthiaceae									
<i>Toxicoscordion fremontii</i>	--	0.27 ± 0.27	0.81 ± 0.4	--	0.19 ± 0.14	--	--	--	0.33 ± 0.33
Myrsinaceae									
<i>Anagallis arvensis</i>	0.05 ± 0.03	0.24 ± 0.02	0.29 ± 0.12	1.76 ± 0.89	0.8 ± 0.24	0.02 ± 0.02	0.41 ± 0.24	0.83 ± 0.3	1.51 ± 0.56

Species	Stand								
	1	2	3	4	5	6	7	8	9
Onagraceae									
<i>Taraxia ovata</i>	--	--	--	--	--	--	--	--	0.38 ± 0.32
Orobanchaceae									
<i>Castilleja densiflora</i> ssp. <i>densiflora</i>	--	--	0.16 ± 0.11	--	--	--	--	--	0.08 ± 0.05
<i>Triphysaria pusilla</i>	--	--	--	--	--	--	--	--	0.19 ± 0.19
Oxalidaceae									
<i>Oxalis pilosa</i>	--	--	--	--	0.07 ± 0.04	--	--	--	--
Papaveraceae									
<i>Eschscholzia californica</i>	0.26 ± 0.15	1.97 ± 1.05	0.05 ± 0.02	3.18 ± 2.75	0.27 ± 0.14	1.73 ± 1.09	0.02 ± 0.02	2.26 ± 1.32	0.63 ± 0.34
Plantaginaceae									
<i>Plantago erecta</i>	0.58 ± 0.21	0.55 ± 0.27	1.54 ± 0.35	2.96 ± 2.53	0.24 ± 0.24	0.59 ± 0.32	3.68 ± 2.02	0.36 ± 0.26	0.63 ± 0.29
<i>Plantago lanceolata</i>	3.57 ± 1.01	2.02 ± 1.54	12.91 ± 1.57	8.29 ± 1.93	9.61 ± 4.28	0.78 ± 0.53	6.4 ± 3.61	14.67 ± 7.42	0.13 ± 0.05
Poaceae									
<i>Agrostis</i> cf <i>hallii</i>	1.68 ± 1.41	--	4.91 ± 3.2	--	0.02 ± 0.02	1.19 ± 0.51	2.97 ± 1.41	--	7.17 ± 4.14
<i>Aira caryophyllea</i>	0.72 ± 0.46	0.8 ± 0.8	1.07 ± 0.51	1.81 ± 1.76	0.14 ± 0.11	0.49 ± 0.32	1.77 ± 1.75	--	1.65 ± 1.23
<i>Avena barbata</i>	0.48 ± 0.22	6.06 ± 1.69	3.18 ± 1.95	2.32 ± 0.27	0.58 ± 0.33	1.5 ± 0.44	4.27 ± 2.65	5.59 ± 1.71	1.6 ± 1.09
<i>Avena fatua</i>	--	--	--	0.22 ± 0.22	--	--	--	0.48 ± 0.48	--
<i>Brachypodium distachyon</i>	--	26.99 ± 12.98	0.44 ± 0.44	21.56 ± 3.87	36.22 ± 6.95	--	0.4 ± 0.4	13.14 ± 13.09	4.69 ± 4.66
<i>Briza maxima</i>	26.46 ± 6.1	25.87 ± 8.09	13.02 ± 5.78	0.03 ± 0.03	12.59 ± 2.43	35.81 ± 12.3	6.17 ± 1.64	0.03 ± 0.03	21.5 ± 2.87
<i>Briza minor</i>	--	--	--	--	0.02 ± 0.02	--	--	--	0.13 ± 0.08
<i>Bromus diandrus</i>	0.22 ± 0.14	0.97 ± 0.45	5.03 ± 2.02	0.67 ± 0.67	0.13 ± 0.11	1.26 ± 1.13	0.71 ± 0.3	0.7 ± 0.7	1.19 ± 0.81
<i>Bromus hordeaceus</i>	--	0.17 ± 0.17	0.61 ± 0.55	0.7 ± 0.7	--	--	0.33 ± 0.16	--	1.46 ± 0.73
<i>Cynosurus echinatus</i>	--	0.35 ± 0.3	--	1.76 ± 1.51	0.21 ± 0.12	0.51 ± 0.45	0.42 ± 0.42	--	0.98 ± 0.65
<i>Danthonia californica</i>	4.03 ± 1.41	2.13 ± 1.18	2.24 ± 0.76	--	0.53 ± 0.45	1.61 ± 0.51	2.31 ± 1.06	--	5.86 ± 1.64
<i>Elymus glaucus</i>	1.11 ± 1.11	--	--	0.03 ± 0.03	0.11 ± 0.11	--	--	0.51 ± 0.51	--
<i>Festuca bromoides</i>	7.38 ± 2.42	1.49 ± 0.54	8.38 ± 1.79	5.88 ± 2.21	2.72 ± 2.26	7.38 ± 2.77	8.97 ± 3.31	0.54 ± 0.45	10.83 ± 2.46
<i>Festuca idahoensis/rubra</i>	3.89 ± 1.84	0.13 ± 0.13	2 ± 1.24	2.22 ± 2.22	0.22 ± 0.22	1.11 ± 0.98	4.67 ± 2.27	6 ± 4.44	11.5 ± 10.21
<i>Festuca myuros</i>	1.02 ± 0.58	3.89 ± 1.86	0.62 ± 0.3	3.56 ± 1.35	0.62 ± 0.54	1.21 ± 0.85	3.13 ± 1.8	0.17 ± 0.09	1.55 ± 0.98
<i>Festuca perennis</i>	--	0.15 ± 0.15	10.7 ± 4.59	--	--	--	--	12.48 ± 6.2	0.24 ± 0.18
<i>Gastridium phleoides</i>	--	--	--	0.03 ± 0.03	--	--	--	--	--
<i>Koeleria macrantha</i>	--	0.02 ± 0.02	2.07 ± 1.86	--	--	0.03 ± 0.03	0.21 ± 0.12	0.7 ± 0.41	0.03 ± 0.03
<i>Melica californica</i>	0.22 ± 0.22	0.04 ± 0.04	0.03 ± 0.02	--	0.02 ± 0.02	0.03 ± 0.02	--	0.29 ± 0.24	0.03 ± 0.03
<i>Melica torreyana</i>	--	--	--	--	--	--	--	0.03 ± 0.03	--
<i>Poa secunda</i>	--	--	0.22 ± 0.22	--	--	--	--	--	--
<i>Stipa pulchra</i>	7.79 ± 3.27	2.44 ± 1.23	4.64 ± 2.46	3.4 ± 3.35	2.08 ± 0.93	2.49 ± 0.86	5.28 ± 1.89	1.12 ± 0.82	1.65 ± 0.52
<i>Stipa purpurata</i>	--	--	6.89 ± 6.89	--	--	4.22 ± 4.22	--	--	--

Species	Stand								
	1	2	3	4	5	6	7	8	9
Polygonaceae									
<i>Eriogonum latifolium</i>	0.92 ± 0.34	--	0.78 ± 0.78	0.26 ± 0.21	0.02 ± 0.02	0.03 ± 0.02	0.46 ± 0.26	0.67 ± 0.67	0.17 ± 0.17
<i>Rumex acetosella</i>	1.83 ± 1.19	--	0.37 ± 0.22	0.03 ± 0.03	0.13 ± 0.13	2.88 ± 1.09	1.15 ± 0.5	--	--
Ranunculaceae									
<i>Ranunculus californicus</i>	0.13 ± 0.11	0.02 ± 0.02	0.05 ± 0.03	--	0.13 ± 0.11	0.02 ± 0.02	--	--	0.08 ± 0.05
Rosaceae									
<i>Acaena pinnatifida</i> var. <i>californica</i>	--	--	0.11 ± 0.11	--	0.38 ± 0.34	--	0.15 ± 0.13	--	2.19 ± 1.27
Rubiaceae									
<i>Sherardia arvensis</i>	--	0.27 ± 0.27	--	--	--	--	--	--	0.05 ± 0.05
Unknown									
Forb seedling	0.02 ± 0.02	--	--	--	--	--	--	--	--

Appendix D. Mean species cover and standard error per stand for woody plants and vines measured along 10 m line intercept transects

Species	Stand								
	1	2	3	4	5	6	7	8	9
Anacardiaceae									
<i>Toxicodendron diversilobum</i>	0.02 ± 0.02	0.63 ± 0.63	--	--	--	--	--	--	--
Asteraceae									
<i>Artemisia californica</i>	0.41 ± 0.41	--	0.08 ± 0.08	1.74 ± 1.74	--	0.27 ± 0.27	--	2.29 ± 1.81	--
<i>Baccharis pilularis</i>	0.76 ± 0.72	--	--	4.19 ± 2.1	0.81 ± 0.81	0.18 ± 0.18	0.69 ± 0.62	3 ± 3	0.05 ± 0.05
<i>Baccharis pilularis</i> (D)	--	--	0.59 ± 0.59	0.03 ± 0.03	--	--	0.35 ± 0.35	--	--
<i>Eriogonum latifolium</i>	0.17 ± 0.1	--	0.14 ± 0.1	--	--	0.03 ± 0.03	0.05 ± 0.05	0.02 ± 0.02	--
<i>Gutierrezia californica</i>	--	--	--	--	--	--	--	0.6 ± 0.37	--
Berberidaceae									
<i>Berberis pinnata</i> ssp. <i>pinnata</i>	0.04 ± 0.04	--	--	--	--	--	--	--	--
Convolvulaceae									
<i>Calystegia purpurata</i> ssp. <i>purpurata</i>	--	0.16 ± 0.08	0.78 ± 0.48	0.01 ± 0.01	0.1 ± 0.08	0.24 ± 0.18	0.12 ± 0.1	0.63 ± 0.1	0.14 ± 0.14
Fabaceae									
<i>Genista monspessulana</i>	--	--	--	--	--	--	--	1.44 ± 1.44	--
<i>Lotus scoparius</i>	0.42 ± 0.23	--	--	--	--	2.37 ± 1.18	0.16 ± 0.16	0.53 ± 0.53	--
<i>Lupinus albifrons</i> var. <i>collinus</i>	--	--	--	--	--	--	--	3.96 ± 3.6	--
<i>Lupinus arboreus</i>	--	--	--	--	0.01 ± 0.01	1.12 ± 0.5	--	0.17 ± 0.17	--
<i>Lupinus arboreus</i> (D)	--	--	--	--	0.07 ± 0.05	--	--	--	--
Rosaceae									
<i>Cotoneaster pannosus</i>	--	--	--	0.5 ± 0.5	--	--	--	--	--
<i>Prunus emarginata</i>	0.24 ± 0.24	--	--	--	--	--	--	--	--
<i>Rubus ursinus</i>	--	--	--	--	--	--	--	0.21 ± 0.15	--

Appendix E. Mean species density and standard error per stand for woody plant and vines measured in 3 x 3 m quadrats

Species	Stand								
	1	2	3	4	5	6	7	8	9
Anacardiaceae									
<i>Toxicodendron diversilobum</i>	--	0.3 ± 0.2	--	--	--	--	--	--	--
<i>T. diversilobum</i> (S)	--	0.1 ± 0.1	--	--	--	--	--	--	--
<i>T. diversilobum</i> (D)	--	--	--	--	--	--	--	--	--
Asteraceae									
<i>Artemisia californica</i>	0.1 ± 0.1	0.1 ± 0.1	--	--	--	--	--	0.4 ± 0.4	--
<i>Baccharis pilularis</i>	--	--	--	0.3 ± 0.3	--	0.1 ± 0.1	0.5 ± 0.3	--	0.3 ± 0.1
<i>B. pilularis</i> (S)	0.1 ± 0.1	--	--	--	--	--	--	--	--
<i>B. pilularis</i> (D)	--	--	--	--	--	--	0.1 ± 0.1	--	--
<i>Gutierrezia californica</i>	--	--	--	--	--	--	--	0.3 ± 0.3	--
Convolvulaceae									
<i>Calystegia purpurata</i> ssp. <i>purpurata</i>	--	1.4 ± 0.8	0.8 ± 0.5	0.9 ± 0.7	0.8 ± 0.4	0.1 ± 0.1	0.7 ± 0.3	2 ± 0.4	0.4 ± 0.4
<i>C. purpurata</i> ssp. <i>purpurata</i> (S)	--	--	--	--	0.1 ± 0.1	--	--	0.6 ± 0.4	--
Fabaceae									
<i>Genista monspessulana</i>	--	--	--	--	--	--	--	0.4 ± 0.4	--
<i>Lathyrus vestitus</i>	--	--	--	--	--	--	--	0.7 ± 0.7	--
<i>Acemispia glaber</i> var. <i>glaber</i>	2.3 ± 1.1	--	--	--	--	3.1 ± 1.2	0.1 ± 0.1	0.4 ± 0.4	--
<i>A. glaber</i> var. <i>glaber</i> (S)	0.1 ± 0.1	--	--	--	--	--	--	--	--
<i>Lupinus albifrons</i> var. <i>collinus</i>	--	--	--	--	--	--	--	5.6 ± 3	--
<i>L. albifrons</i> var. <i>collinus</i> (S)	--	--	--	--	--	--	--	1.7 ± 0.9	--
<i>L. arboreus</i>	--	--	--	--	--	0.6 ± 0.2	0.1 ± 0.1	--	--
<i>L. arboreus</i> (D)	--	--	--	--	--	0.1 ± 0.1	--	--	--
Polygonaceae									
<i>Eriogonum latifolium</i>	4.2 ± 1.3	--	0.6 ± 0.4	0.2 ± 0.1	0.1 ± 0.1	0.8 ± 0.3	2.3 ± 0.5	1.4 ± 1	0.1 ± 0.1
<i>E. latifolium</i> (S)	0.4 ± 0.2	--	--	0.1 ± 0.1	--	0.1 ± 0.1	0.9 ± 0.5	1.8 ± 1.5	--
<i>E. latifolium</i> (D)	0.1 ± 0.1	--	--	--	--	--	0.1 ± 0.1	--	--
Rosaceae									
<i>Cotoneaster pannosus</i>	--	--	--	0.1 ± 0.1	--	--	--	--	--
<i>Rubus ursinus</i>	--	--	--	--	--	--	--	0.2 ± 0.1	--

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