Brachypodium Control, Phase II

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Executive Summary

The *Brachypodium* Phase II project treated 19.5 acres of *Brachypodium*-infested habitat, and compared monitoring methods and treatment effectiveness on the Crestridge Ecological Reserve and South Crest Preserve in San Diego County, California. This project continued treatments initiated under the *Brachypodium* Phase I project. The San Diego Association of Government (SANDAG) Transnet Environmental Mitigation Program provided grant funding for both projects.

Phase II objectives included (1) monitoring treatment areas, (2) assessing monitoring methods, (3) reducing nonnative species cover through herbicide application, and (4) refining Best Management Practices (BMPs) for *Brachypodium* control. We monitored treatment areas (native species richness, cover) quantitatively in 2016 and semi-quantitatively in 2016 and 2017, and continued herbicide treatment of *Brachypodium* and nonnative grasses and forbs in all Phase I treatment areas.

The two monitoring methods were not interchangeable. We collected data faster in quadrats (quantitative) compared to circle plots (semi-quantitative). However, circle plots were less variable and better represented the range of conditions in treatment areas. In selecting a monitoring method, we recommend considering both cost and statistical precision needed for management decisions. While a large number of quadrats would provide the greatest precision, invasive species control generally focuses on large treatment effects. Semi-quantitative circle plot monitoring provided a cost-effective data collection method with adequate precision for adaptive management decisions.

Treatment effectiveness depended on vegetation community and location. We saw little increase in native species richness in coastal sage scrub with treatment. Coastal sage scrub had a high native species component before treatment and we did not dethatch coastal sage scrub treatment areas. *Brachypodium* removal enhanced growth of existing native species in scrub habitats, but the persistent thatch layer suppressed germination from the soil seedbank. In nonnative grasslands, dethatching and seeding both contributed to native species richness, while soil and seedbank composition drove site differences in native species richness after treatment.

Treatment maintained *Brachypodium* cover at ≤10% in both habitats on both sites in both years. In this study, treatment was more effective in grasslands than coastal sage scrub, which may be due to the difficulty of applying herbicide effectively under and around shrubs and through thatch. We did not eradicate *Brachypodium* from any treatment plots by 2017. Other nonnative grasses in the study responded similarly to *Brachypodium*. We controlled emergent nonnative forbs through herbicide application.

Brachypodium treatment type and duration will depend on site condition, habitat, and other factors. Treatment options include (1) herbicide only for sites that support an assemblage of native species and (2) dethatching, seeding, and herbicide or mowing for degraded sites with few or no native species. As nonnative grass cover decreases, nonnative forb cover often increases; therefore, we recommend treating nonnative forbs as part of a *Brachypodium* control effort.

We recommend treating *Brachypodium* intensively for a minimum of 5 years and as-needed thereafter to maintain the species at ≤10% cover. Our study showed that after 5 years, *Brachypodium* was still present at low levels in treatment areas. In addition, *Brachypodium* cover fluctuated depending on climatic conditions, with rainfall as the primary driver. These factors suggest that *Brachypodium*-infested sites will require some level of long-term management, particularly in high rainfall years. We do not believe *Brachypodium* eradication is possible at the restoration sites at this time based on its presence in surrounding untreated areas and its high reproductive output. Where *Brachypodium* cover is low, however, native shrubs, geophytes, and annual species can persist and thrive. We believe the most cost-effective long-term *Brachypodium* management strategy is to treat this species periodically and strategically to prevent its expansion in treatment areas.

Table of Contents

Figure		Page Number

1 Introduction

The Conservation Biology Institute (CBI), in coordination with the Endangered Habitats Conservancy (EHC) and Recon Environmental, Inc. (Recon), treated the nonnative grass, *Brachypodium distachyon* (*Brachypodium*), and other nonnative grasses and forbs in clay and gabbroic soils occupied by sensitive plant species over 19.5 acres on the Crestridge Ecological Reserve (Crestridge) and South Crest Preserve (South Crest) in southwestern San Diego County, California (Figure 1). Crestridge is owned by the California Department of Fish and Wildlife and managed EHC, while South Crest is owned and managed by EHC. Both preserves are in Management Unit (MU) 3 of the San Diego Management and Monitoring Program's (SDMMP) Management Strategic Plan Area (MSPA) for western San Diego County (SDMMP and TNC 2017). This work was conducted under a *Transnet* Environmental Mitigation Program (EMP) grant (5004735) from the San Diego Association of Governments (SANDAG), and was a continuation of an earlier SANDAG EMP grant (*Brachypodium* Control, Phase I, 5001965) that tested experimental control methods for *Brachypodium* on these preserves. The Phase I grant covered a 2-year period (2013-2014), EHC treated *Brachypodium* in select areas in 2015, and the current grant extended treatments for an additional 2 years (2016-2017).

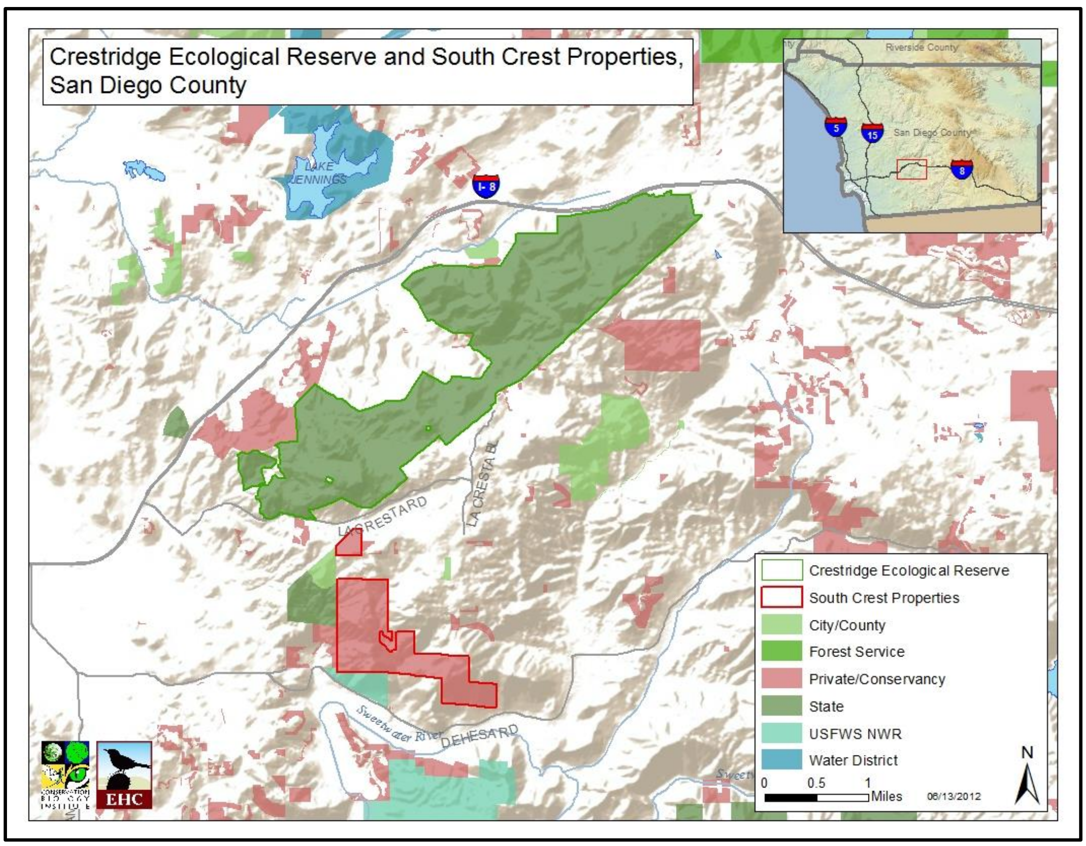

Figure 1. Project Location.

1.1 Project Background

Brachypodium is an annual, invasive grass with potentially widespread ecological implications for native species, habitats, and ecosystem processes. In southern California, *Brachypodium* has increased in extent and dominance in recent years, possibly in response to fires and changing climatic conditions. The species forms dense stands and produces a thick, persistent thatch layer that suppresses germination of annual species and may affect recruitment of perennials and geophytes. *Brachypodium* appears to out-compete native and other nonnative species for resources, potentially alters soil ecology, vegetation community structure, and vegetation composition, and may contribute to a grass/fire cycle and habitat-type conversions. The densest *Brachypodium* stands occur on clay and gabbro-derived soils where they threaten edaphic endemic plants such as *Acanthomintha ilicifolia*, *Bloomeria clevelandii*, *Brodiaea filifolia*, *Brodiaea orcuttii*, *Deinandra conjugens*, *Dudleya variegata*, *Nolina interrata*, and *Tetracoccus dioicus*. Management Strategic Plan (MSP) species and habitats addressed in this project include *Acanthomintha ilicifolia*, *Nolina interrata*, *Dudleya variegata*, native grassland, and coastal sage scrub.

The *Brachypodium* Phase I project demonstrated that both herbicide and mechanical (mowing) methods were effective in reducing *Brachypodium* cover (CBI 2014). In Phase I, we dethatched and seeded select areas to improve native species richness, and treated co-occurring invasive grasses and forbs. EHC treated *Brachypodium* in select areas in 2015, with a focus on maintaining dethatched and seeded areas. *Brachypodium* produces large quantities of highly viable seeds that persist in the soil seedbank; thus, we recommended additional management to prevent this species from rebounding quickly in treated areas.

In Phase II, we continued herbicide treatment of *Brachypodium* and nonnative grasses and forbs in all Phase I treatment areas. Phase II objectives included (1) reducing nonnative species cover, (2) monitoring treatment areas, (3) assessing monitoring methods, and (4) developing Best Management Practices (BMPs). We coordinated experimental design and monitoring methods with SDMMP and the City of San Diego; study results will contribute to a regional analysis of *Brachypodium* control across multiple sites, habitats, and microclimates with the objective of scaling up *Brachypodium* control and site restoration.

1.2 Relationship to MSP Goals

This project benefits the following MSP species and habitats by improving habitat quality and reducing fire risk:

- Dehesa nolina (MSP occurrence NOIN_3SOCR003)
- San Diego thornmint (MSP occurrence ACIL_3CRER004)

- Variegated dudleya (MSP occurrence DUVA_3SKFL009)
- Parry's tetracoccus (MSP occurrence TEDI_3SOCR001)
- Native grassland, coastal sage scrub, and chaparral habitats

This project contributes specifically to the following MSP objectives:

- Management Development: Refine Best Management Practices (BMPs) to control invasive species that threaten populations (San Diego thornmint [Objective MGT-DEV ACAILI-4], Dehesa nolina [Objective MGT-DEV NOLINT-3]).
- Management Implementation: Reduce the potential impact of fire by reducing fuel loads of invasive annual species (San Diego thornmint [Objective MGT-IMP ACAILI-1]).

1.3 Project Goals and Approach

The overarching project goal was to control *Brachypodium* where it threatens the persistence of MSP species and habitats and increases wildfire risk to these resources. To meet this goal, we focused on controlling *Brachypodium* and other nonnative species in 19.5 acres of grassland and coastal sage scrub habitat occupied (or previously occupied) by MSP species.[1]

Specific objectives of the Phase II project were to (1) maintain *Brachypodium* at <10% cover in treatment areas, (2) develop recommendations for treatment frequency and treatment methods in different habitat types, (3) assess quantitative versus semi-quantitative monitoring methods and (4) refine BMPs for *Brachypodium* control based on results.

The Phase II management approach included herbicide control of *Brachypodium* and other nonnative grasses and forbs, using methods demonstrated successfully during the Phase I study (http://sdmmp.com/Libraries/Management_Plans_and_Reports).

2 Methods

In the following sections, we detail methods, results, and recommendations for the Phase II *Brachypodium* control project. While this study continued Phase I efforts, it differed with respect to experimental design and some objectives, as discussed below.

2.1 Experimental Design

The Phase I experimental design used elements of both blocked and split-plot designs to test the effectiveness of management actions while minimizing the amount of untreated (control) habitat

[1] All MSP species within the project area are also covered species under the City of San Diego's Multiple Species Conservation Plan.

(CBI 2014). Phase I treatments included various combinations of dethatching, herbicide, mechanical treatment (mowing), seeding, and controls. Phase I demonstrated both site and treatment effects, and confirmed that herbicide was more effective than mowing in reducing *Brachypodium* cover.

For Phase II, we modified the experimental design to reflect Phase I results. We grouped Phase II treatments into seeded or unseeded areas by habitat (coastal sage scrub or nonnative grasslands). We added monitoring plots in treatment areas to balance the design and improve statistical power, and located control plots outside of treatment areas (Table 1). We treated all treatment plots with herbicide in 2016 and 2017.

Table 1. Phase II Experimental Design.[1]

Treatment	Crestridge		South Crest		Total
	CSS[2]	NNGL[2]	CSS[2]	NNGL[2]	
Herbicide Only	6		6		12
Dethatch/Seeding/Herbicide		6		6	12
Control	3	3	3	3	12
Total	9	9	9	9	36

[1] Numbers represent number of treatment or control plots.
[2] CSS = coastal sage scrub; NNGL = nonnative grassland.

2.2 Monitoring

We monitored all Phase II plots (treatments and controls) approximately three months after grass-specific herbicide application. In 2016, we monitored treatment and control plots on Crestridge and South Crest using both semi-quantitative and quantitative methods to estimate species richness and cover. We compared monitoring methods for accuracy and efficiency as part of the data analysis.

In 2017, we monitored these same areas using semi-quantitative methods only. We describe monitoring schedule and protocols below. See Appendix A for photodocumentation of treatment progress at all plots in 2016 and 2017.

2.2.1 Monitoring Schedule

CBI biologists Patricia Gordon-Reedy and Jessie Vinje monitored treatment and control plots in 2016 and 2017 according to the schedule in Table 2. Monitoring field visits generally consisted of 10-12 hour days. We were able to reduce field time in 2017 because we did not monitor quantitatively. In both years, additional field time included site visits to check phenology or site status, conduct photodocumentation, stake treatment areas, and coordinate with the Recon field crew.

Table 2. Monitoring Schedule.

Monitoring Date	Site	CBI Personnel[1]
4/18/2016	South Crest	PGR, JV
4/19/2016	Crestridge	PGR, JV
4/20/2016	South Crest	PGR, JV
4/21/2016	Crestridge	PGR, JV
5/8/2016	South Crest	PGR, JV
5/9/2016	Crestridge	PGR, JV

[1] PGR = Patricia Gordon-Reedy; JV = Jessie Vinje.

2.2.2 Semi-Quantitative (Circle Plot) Monitoring

We conducted semi-quantitative monitoring using circle plots, which are a time-efficient method to collect biotic and abiotic information. In 2016, we established a total of 36 circle plot sampling locations (18 at each site) using SDMMP's random sample grid (Figure 2). At each site, we located 12 circle plots within treatment polygons (CBI 2014) and 6 circle plots outside treatment polygons to function as controls (Table 1). Within each treatment polygon, we selected sampling locations sequentially starting with the highest numbered cells in the random sampling grid. Where a sampling location was not suitable (e.g., partially out of the polygon), we selected the next highest numbered cell. To speed the process in the field, we pre-selected sampling locations in the office and verified locations in the field. Controls were selected outside treatment polygons in the same manner.

For seeded plots, the sampling location had to include at least ½ of a seeded strip (see CBI 2014 for a discussion of seeding methodology and seeded species). If the pre-selected location did not include a seeded strip, we selected the next sampling location in the field using the random sample grid.

Once we selected a circle plot sampling location, we monitored as follows:

1. Recorded the start and stop time for each plot to estimate labor requirements for future efforts (2016 only).
2. Recorded random sample grid number and geographic positioning system (GPS) coordinates at the center point of the grid to facilitate relocation of the circle plot in subsequent sampling years (2016 only).

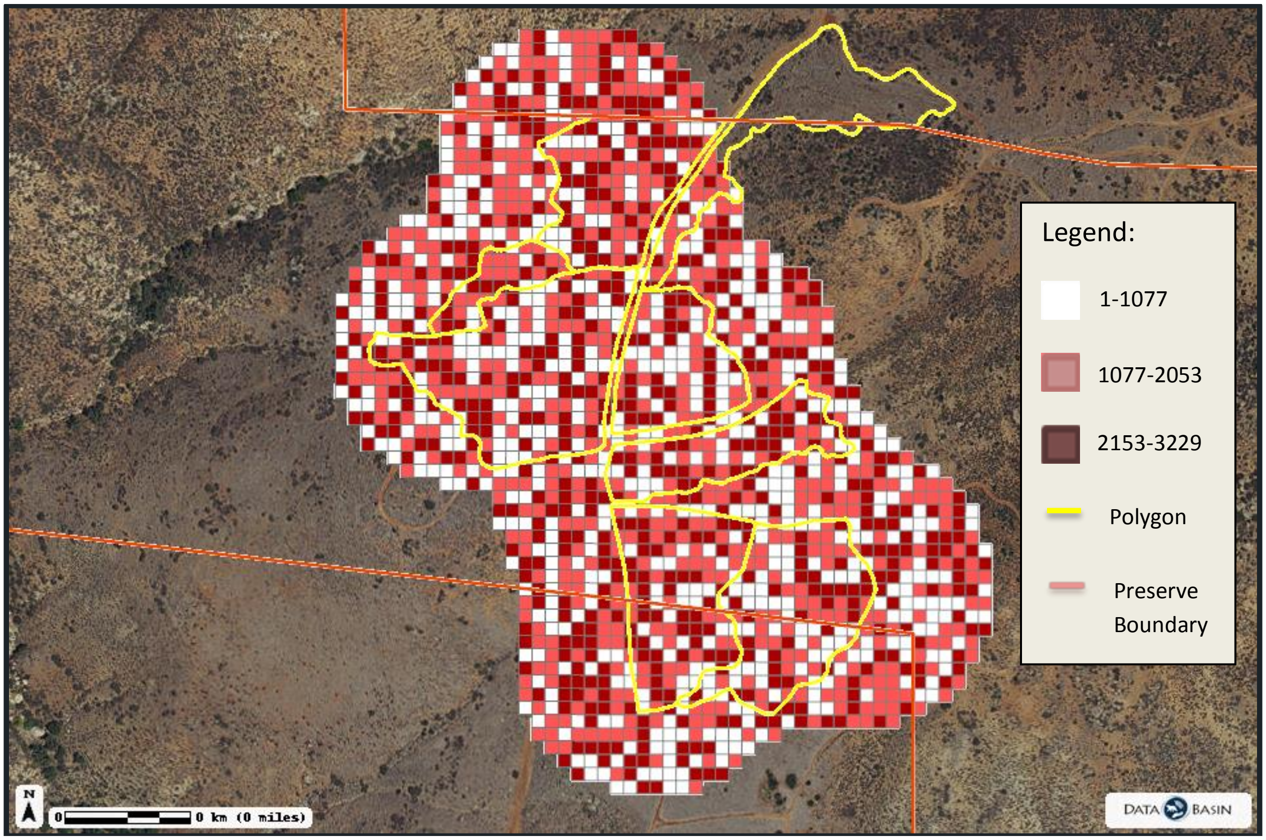

Figure 2. Random Sampling Grid, South Crest Preserve (note: sampling grid numbers are shown not on map, but range from 1-3,229).

3. Established a 6 meter $(m)^2$ circle plot using the center point of the 10 m grid as the center point of the plot, holding or securing a tape measure at the center point of the grid, and extending it 3 m in either direction. Using the same method, we laid out a second tape measure perpendicular to the first, secured tape ends to the ground (if necessary), and sampled within a visualized 6 m^2 circle bounded by the tape edges (Figure 3).

4. Photographed the circle plot in at least one of the cardinal directions from outside the plot looking towards the center of the plot.

5. Recorded each species within the circle plot to provide a measure of species richness, including only living plants (or those that completed their life cycle within the year) rooted within the plot.

6. Visually estimated cover (absolute cover) for each species within the circle plot, including only living plants rooted within the plot in cover estimates.

7. Visually estimated percent bare ground, rock, and thatch (nonnative, dead grass only) within the circle plot.

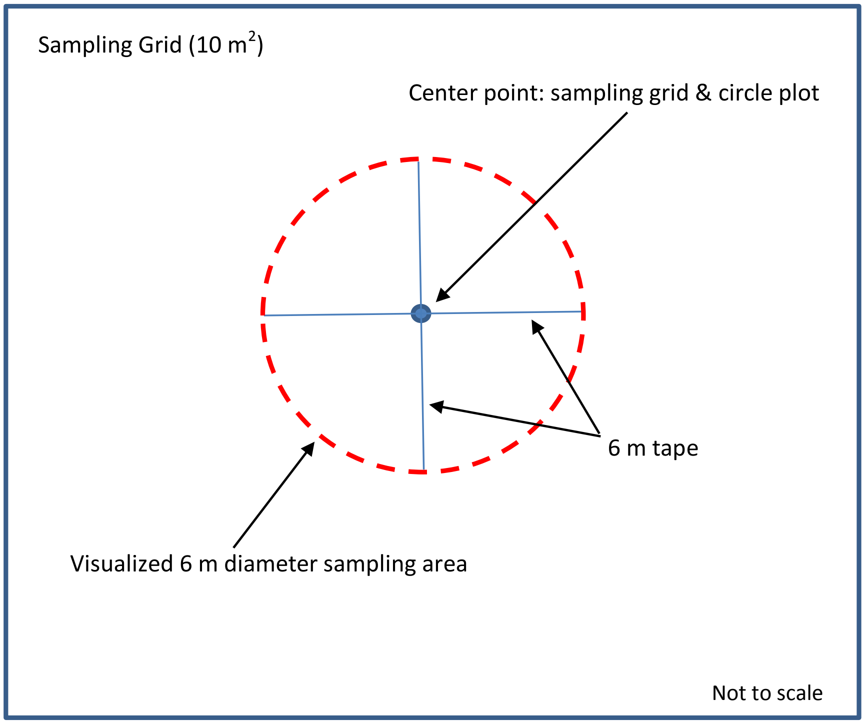

Figure 3. Circle Plot Set-up.

Refer to Appendix B for 2016 and 2017 data summaries.

2.2.3 Quantitative (Quadrat) Monitoring

We conducted quantitative monitoring using quadrats. In 2016, we monitored treatment and control areas quantitatively using a 0.5 x 1 m quadrat with a point intercept grid placed at the center point of each circle plot. In each grid, we collected species richness and cover data. We recorded time for each quantitative monitoring event to compare efficiency of this method with circle plots. Refer to Appendix B for 2016 data summaries.

2.3 Treatment

Recon conducted invasive plant treatments in 2016 and 2017 (Table 3). In both years, CBI biologists coordinated with Recon in the field to ensure treatment areas were covered adequately.

Herbicide treatments included Fusilade II® to control *Brachypodium* and other nonnative grasses and glyphosate to control nonnative annual forbs. Recon field crews applied herbicide using backpack and, truck-mounted sprayer with hose and reel taking care to avoid MSP plants and native plants, as feasible.

Table 3. Herbicide Application in Treatment Areas, 2016-2017.

Date	Site	Treatment[1]
2/8-2/10//2016	South Crest	Applied Fusilade II® to nonnative grasses via backpack sprayer and truck-mounted sprayer with hose and reel.
2/11/2016	South Crest	Applied Fusilade II® and glyphosate to nonnative grasses and annual forbs via backpack sprayer and truck-mounted sprayer with hose and reel.
2/22-2/24//2016	Crestridge	Applied Fusilade II® to nonnative grasses via backpack sprayer.
2/25/2016	Crestridge	Applied Fusilade II® and glyphosate to nonnative grasses and annual forbs via backpack sprayer.
3/21-3/22/2016 4/5-4/6/2016	South Crest	Applied glyphosate to nonnative annual forbs via backpack sprayer and truck-mounted sprayer with hose and reel.
4/4/2016 4/15/2016	Crestridge	Applied glyphosate to nonnative annual forbs via backpack sprayer and truck-mounted sprayer with hose and reel.
2/20-2/22//2017	Crestridge	Applied Fusilade II® to nonnative grasses and glyphosate to nonnative annual forbs via backpack sprayer.
2/23-2/24//2017	South Crest	Applied Fusilade II® to nonnative grasses via backpack sprayer and truck-mounted sprayer with hose and reel.
3/13/2017	South Crest	Applied Fusilade II® to nonnative grasses and glyphosate to nonnative annual forbs via backpack sprayer and truck-mounted sprayer with hose and reel.
3/14-3/15//2017	South Crest	Applied glyphosate to nonnative annual forbs via backpack sprayer and truck-mounted sprayer with hose and reel.
3/16-3/17/2017	Crestridge	Applied glyphosate to nonnative annual forbs via backpack sprayer and truck-mounted sprayer with hose and reel.

[1] Recon field crews conducted all herbicide applications listed in table.

2.4 Data Analysis

We conducted three sets of analyses to compare (1) monitoring methods (2016 data only), (2) herbicide treatments in coastal sage scrub at both sites (2016 and 2017), and (3) herbicide treatments in nonnative grasslands at both sites (2016 and 2017) (Table 4). The first analysis compared effort (time) and results of circle plots and quadrats using paired t-tests and linear regression. This analysis showed that circle plot data were more representative and less variable than quadrat data; therefore, the remaining analyses were conducted on circle plot data only. The second and third analyses used repeated measures ANOVA (RANOVA). They were analyzed separately because nonnative grasslands were dethatched and seeded previously (CBI 2014), thus confounding treatment with vegetation community.

Table 4. Statistical Testing Methodologies.

Comparison	Analysis Type	Independent Variables
Monitoring Methods (Quadrats vs. Circle Plots)	Paired t-test and Regression	Monitoring Method
Herbicide vs. Control (Coastal sage scrub)	RANOVA with Variance Partitioning	Treatment, Site, Year
Herbicide vs. Control (Nonnative Grassland)[1]	RANOVA with Variance Partitioning	Treatment, Site, Year

[1] Treatment plots were dethatched and seeded previously.

2.4.1 Paired t-test

Paired t-tests determine if there is a significant difference between two responses for the same experimental unit (e.g., plot). Paired t-tests are powerful statistically because the between-subject variation (plot) is eliminated by collecting data from the same subject. The output of interest is the P-value (designated P_t in this report), which is the probability that the variable of interest (i.e., treatment or monitoring method) had no effect. P-values of or below 0.05 are generally considered significant.

In this study, we collected data at the same plot using two different methods (circle plot and quadrat) which stand in as *treatments*. Paired t-testing allowed us to compare these two data collection methods and determine if they yielded numerically similar results.

Paired t-tests assume that the data distribution is normal. In 2016, data collection time, species richness, and bare ground variables were normally distributed. All other cover values (except bare ground) were log(x+1) transformed to address skew. This transformation resulted in acceptable distributions for total cover, *Brachypodium* cover, nonnative grass cover, and litter and rock cover. Native and nonnative forb cover data and native grass cover data had too many 0 values to be transformed successfully and their results should be interpreted with caution.

2.4.2 Simple Linear Regression

Simple linear regression assesses the strength and significance of the relationship between two scalar variables. In this study, we used linear regression to compare species richness and cover values returned by the two methods.

Our interpretation of linear regression results revolved around two outputs:

1. The significance of the relationship as described by the P-value (the probability that the two methods do not scale, designated P_r). In this case, a significant P-value ($\leq$0.005) indicated that the two methods produced results that scale with one another in a linear fashion, even if those values are significantly different. The numeric values of two methods can be significantly different (as indicated by P_t), while also being significantly related (as indicated by P_r).

2. The coefficient of determination (r^2) describes the strength of the relationship between the two techniques. We can also interpret this relationship as the proportion of the variance in the dependent variable explained by the independent variable. It should be noted that such a relationship can be significant yet weak (significant P_r-value with a low r^2), meaning that results of each method are poorly predictive of (i.e., related to) one another.

Linear regression assumes that there is a normal distribution of the predictor and response variables and that the relationship between the two is linear. In addition, the variance in both variables must be close to equivalent and independent of each other. In 2016, three variables (time, species richness, and bare ground) were normally distributed. All other cover values (except bare ground) were log(x+1) transformed to address skew. The transformation resulted in acceptable distributions for total cover, nonnative grass cover, *Brachypodium* cover, and litter and rock cover. Transformation was problematic for data with many 0 values (native forbs, nonnative forbs, native grasses); thus, we should interpret those results with caution.

2.4.3 Repeated Measures Analysis of Variance

Repeated measures ANOVA (RANOVA) tests detect differences between related means. In this study, plots were retreated and monitored in 2016 and 2017, so year is the relating variable. RANOVA presents an advantage over testing results from each year separately (e.g., performing multiple comparisons across tests) because the false positive (Type I error) rate is fixed at the significance level (α, usually set at 5%) instead of inflating with each additional test performed.

Another advantage of RANOVA is the ability to explore the interaction between different factors. This is especially important when working with annual plants where germination rate, phenology, and treatment response can vary with different annual weather conditions. In addition, plant distribution is often spatially patchy, so accounting for location (site) is desirable.

The primary drawback of RANOVA is the requirement for normally distributed data within each factor (in this case, year). Skewed data can affect test results, often inflating the false-positive rate. Many biological data sets are right-skewed (many zeros or small values and few large values). In this study, plant cover data were right-skewed, which we addressed by applying a log(X+1) transformation.

In RANOVA, test statistics (including P-values) are generated for each term in the model (e.g., the *main effect* of a variable) and for interactions of two or more terms (two and three-way interactions). As in linear regression, a significant P-value does not always indicate a strong influence on outcome. We used a technique known as variance partitioning to determine which model terms were both significant and strong drivers of outcome. Variance partitioning is a simple procedure whereby the variance explained by a single variable is divided by the total pool of variance in a model, yielding a percentage. Highly influential variables explain high percentages of the variance.

3 Results

3.1 Comparison of Monitoring Methods

We tested some basic assumptions about the circle plot and quadrat methods, while exploring their performance. Our first assumption involved species area relationships. We expected species richness values in circle plots to be higher than quadrats, because the two methods measure different areas. Circle plots should be more representative of on-the-ground conditions because they measure a larger proportion of the treatment plot.

Second, multiple authors have demonstrated that point-intercept techniques tend to yield higher cover values than visual estimates for a number of reasons (Kercher et al. 2003, Godinez-Alvarez et al. 2009), and there is no reason to expect point-intercept quadrats to perform differently.

Finally, if the distribution of plant cover is finely patchy (which is typical of these systems), an individual quadrat is likely to fall on a single patch, making it homogenous internally, but increasing the overall variability of the method collectively. In other words, due to their small size, the placement of quadrats has a major influence on results.

3.1.1 Time

Circle plots take twice as long to collect data than quadrats on average (P_t<0.001, Figure 4). Although this relationship is significant, the strength of that relationship is weak (P_r=0.016, r^2=0.13), meaning that the time the two methods take do not scale with one another reliably because the methods (as implemented here) measure different areas.

3.1.2 Species Richness

Total Species Richness. Circle plots returned much higher total species richness values than quadrats (P_t<0.001, Figure 5). The factor driving this mismatch was area. Larger areas typically contain more species, and circle plots are substantially larger than quadrats.

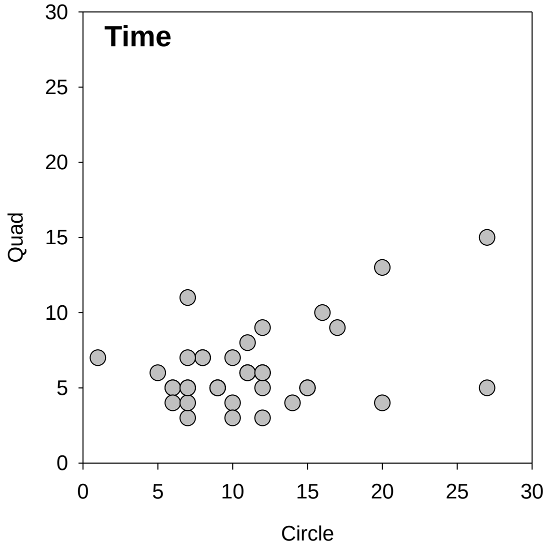

Figure 4. Comparison of Monitoring Methods (Time). This analysis compares monitoring effort (time) in quadrats and circle plots. The diagonal line represents the 1:1 line. Points landing on the 1:1 line are equivalent. Points landing below the 1:1 line indicate that the value (time) for a circle plot is greater than the corresponding quadrat value. Points above the 1:1 line indicate that the value for the quadrat is greater than the corresponding circle plot value.

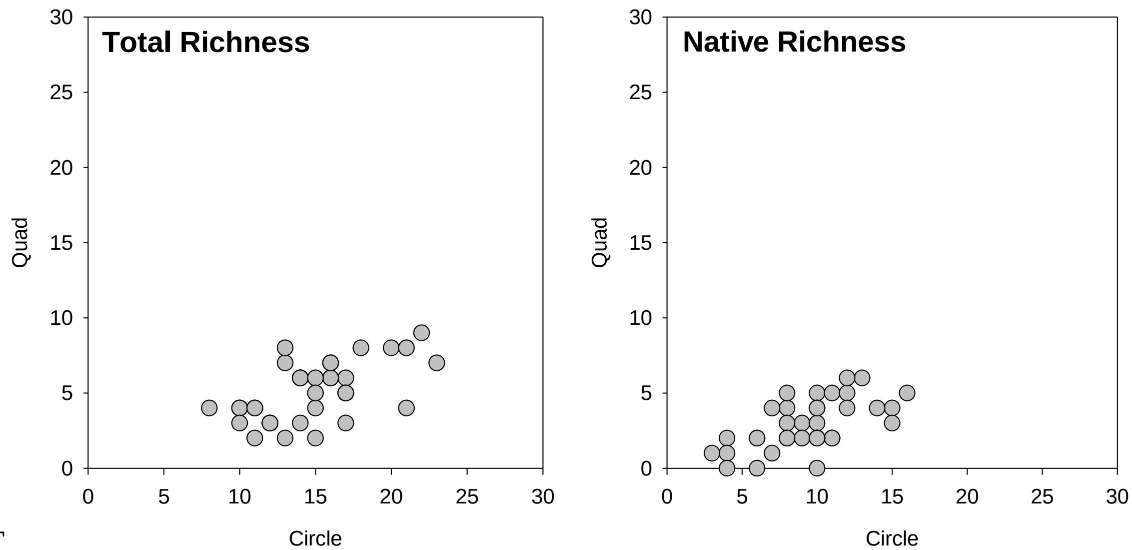

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Figure 5. Comparison of Monitoring Methods (Species Richness). This analysis compares species richness in quadrats and circle plots. The diagonal line represents the 1:1 line. Points landing on the 1:1 line are equivalent. Points landing below the 1:1 line indicate that the species richness value for a circle plot is greater than the value for the corresponding quadrat value. Points above the 1:1 line indicate that the species richness value for a quadrat is greater than the corresponding circle plot value.

The values returned by both methods are significantly related (i.e., when species richness is high, both methods return relatively high values), although this relationship is not especially strong

(P_r<0.001, r^2=0.32). The poor fit is likely a combination of the species-area relationship and random chance in quadrat placement.

Native Species Richness. Circle plots also return native species richness values that are much higher than quadrats (P_t<0.001, Figure 5). The values returned by both methods are significantly related although this relationship is not especially strong (P_r<0.001, r^2=0.34). The poor fit is likely a combination of the species-area relationship and random chance in quadrat placement.

3.1.3 Cover

Total Cover. Quadrats tended to return higher total cover values than circle plots (P_t = 0.003, Figure 6). The relationship between the methods is significant but relatively weak (P_r=0.001, r^2=0.263).

Brachypodium. Quadrats tended to return higher (often substantially so) *Brachypodium* cover values than circle plots (P_t=0.005, Figure 6). Although significant, the relationship between the methods is relatively poor (P_r=0.007, r^2=0.171). We attribute differences to patchiness in cover and random chance in quadrat placement. For example, a quadrat might land on a patch of grass in an otherwise barren circle plot or land on an empty spot inside a highly invaded plot; both scenarios yield unrepresentative data and drive down the coefficient of determination relative to the larger, more representative circle plot. Other studies have noted that ocular estimates of cover by humans tend to yield consistently lower values than non-subjective point-intercept techniques (Kercher et al. 2003, Godinez-Alvarez et al. 2009).

Nonnative Grasses. Quadrats tended to return higher nonnative grass cover values than circle plots, (P_t<0.001, Figure 6). Unlike the previous two variables, the relationship between the methods is fairly strong (P_r<0.001 r^2=0.705). The strength of this relationship may inflate with a large number of plots with little or no grass cover throughout (i.e., many zeros and small values in the data). Although this is problematic for statistical analysis, it is reflective of highly effective treatments. We attribute differences between the methods to random chance in quadrat placement and the subjectivity of ocular cover estimates.

Nonnative Forbs. Low nonnative forb cover in 2016 resulted in many zeros in the data, particularly in the smaller quadrats which often missed forbs captured in larger circle plots (Figure 6). Quadrats that landed on nonnative forbs returned higher cover values, consistent with other cover metric results. The two monitoring methods did not return significantly different results (P_t=0.279) and the relationship between them only approaches significance (P_r=0.062).

Native Grasses. Native grasses on both sites were primarily perennial bunch grasses (e.g., *Stipa* spp.). At a large scale (circle plots), these grasses are patchy and often occur at low cover. On a

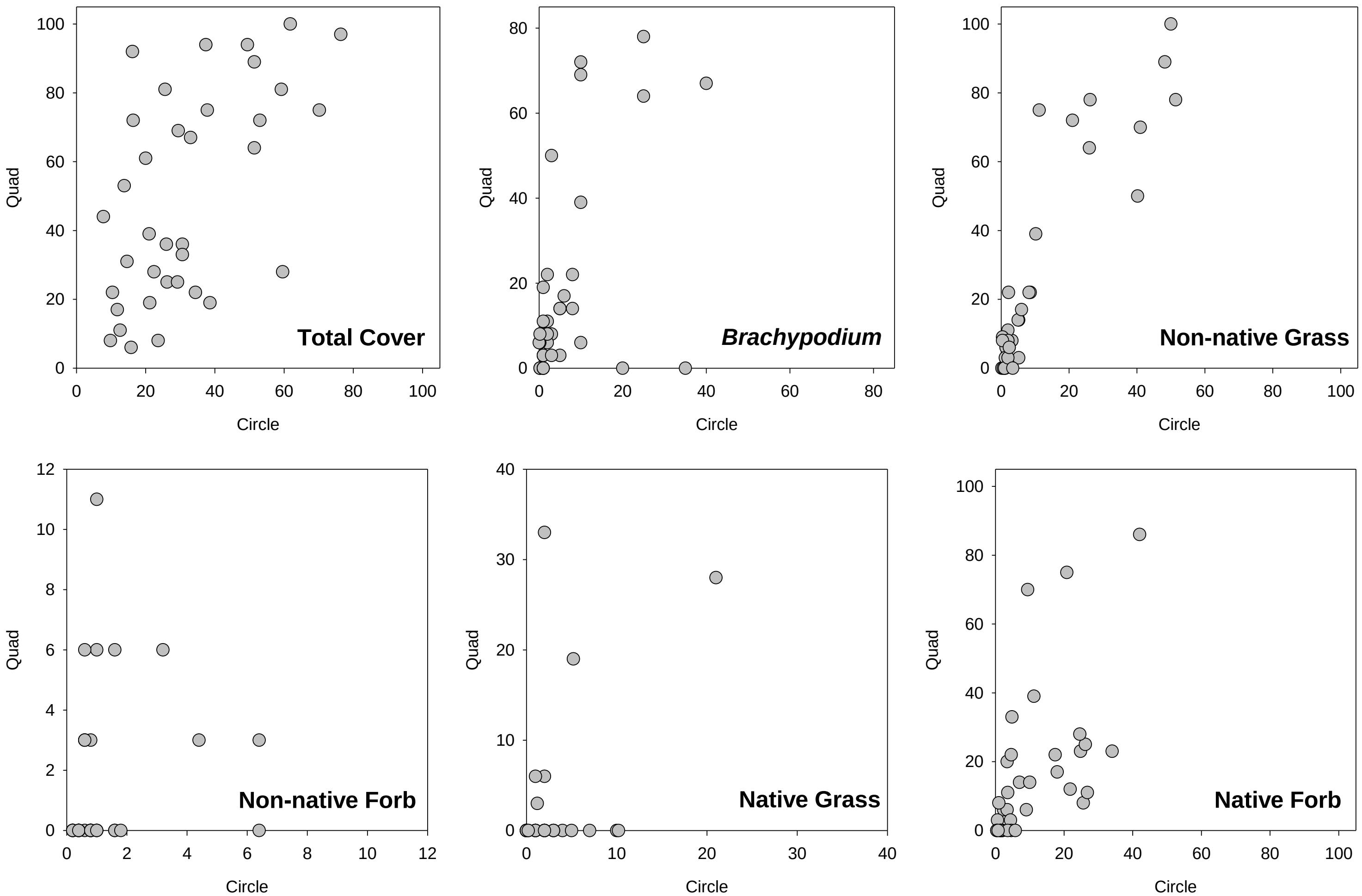

Figure 6. Comparison of Monitoring Methods (Cover). This analysis compares vegetation in quadrats and circle plots. The diagonal line represents the 1:1 line. Points landing on the 1:1 line are equivalent. Points landing below the 1:1 line indicate that the cover value for a circle plot is greater than the corresponding quadrat value. Points above the 1:1 line indicate that the cover value for a quadrat is greater than the corresponding circle plot value.

small scale (quadrats), their morphology makes them quite dense. This spatial distribution reduced the probability that a single quadrat would detect bunch grass, but ensures that cover will be high if encountered (P_t=0.006, Figure 6). As a result, the relationship between native grass cover in quadrats and circles is relatively weak (r^2=0.104), but significant (P_r=0.031).

Native Forbs. Circle plots and quadrats did not return significantly different values for native forb cover (P_t=0.918, Figure 6). The relationship between the two methods appears to be significant and moderately strong (P_r<0.001, r^2=0.521). The relative scarcity of native forbs drives these results, producing many matching zeros in the data. Low cover and a higher degree of spatial patchiness is the norm for native forb distribution, so the data conform to our expectations although they are statistically problematic.

Bare Ground. Circle plots and quadrats did not return significantly different values from one another (P_t=0.918), and the relationship between the two variables was strong and significant (P_r<0.001, r^2=0.751). This relationship is likely driven by homogenous plots on either end of the spectrum (with either lots of bare ground or lots of litter) anchoring the distribution at low and high values (Figure 6). The methods did not have as tight a match at intermediate values where spatial patchiness was a factor (Figure 7).

Litter. Quadrats tended to return significantly higher values for litter cover than circle plots (P_t=0.046, Figure 7). However, the relationship between the two methods was somewhat strong and significant (P_r<0.001, r^2=0.633).

Rock. Circle plots returned significantly more rock cover than quadrats (P_t=0.003; Figure 7). The relationship between the two methods was significant but not strong (P_r=0.018, r^2=0.129).

3.2 Treatment Effect in Coastal Sage Scrub

Coastal sage scrub plots had native shrubs, some native forbs, and nonnative grasses in the understory prior to treatment. Because of the relatively high native component, treatment in these plots consisted of herbicide only to target nonnative grasses and forbs in both phases of this study. The following section discusses only variables with a treatment effect; refer to Appendix C for all analyses and Appendix D for model results.

3.2.1 Species Richness

Total Species Richness. Treatment effect on total species richness was mediated by site ($P_{site*treatment}$=0.005, 26% variance). Treatment reduced total species richness slightly at Crestridge, while increasing it at South Crest (Figure 8). Year by site interaction was also influential (P=0.005, 14% variance). Species richness decreased at Crestridge from 2016 to 2017, but increased at South Crest during the same time period.

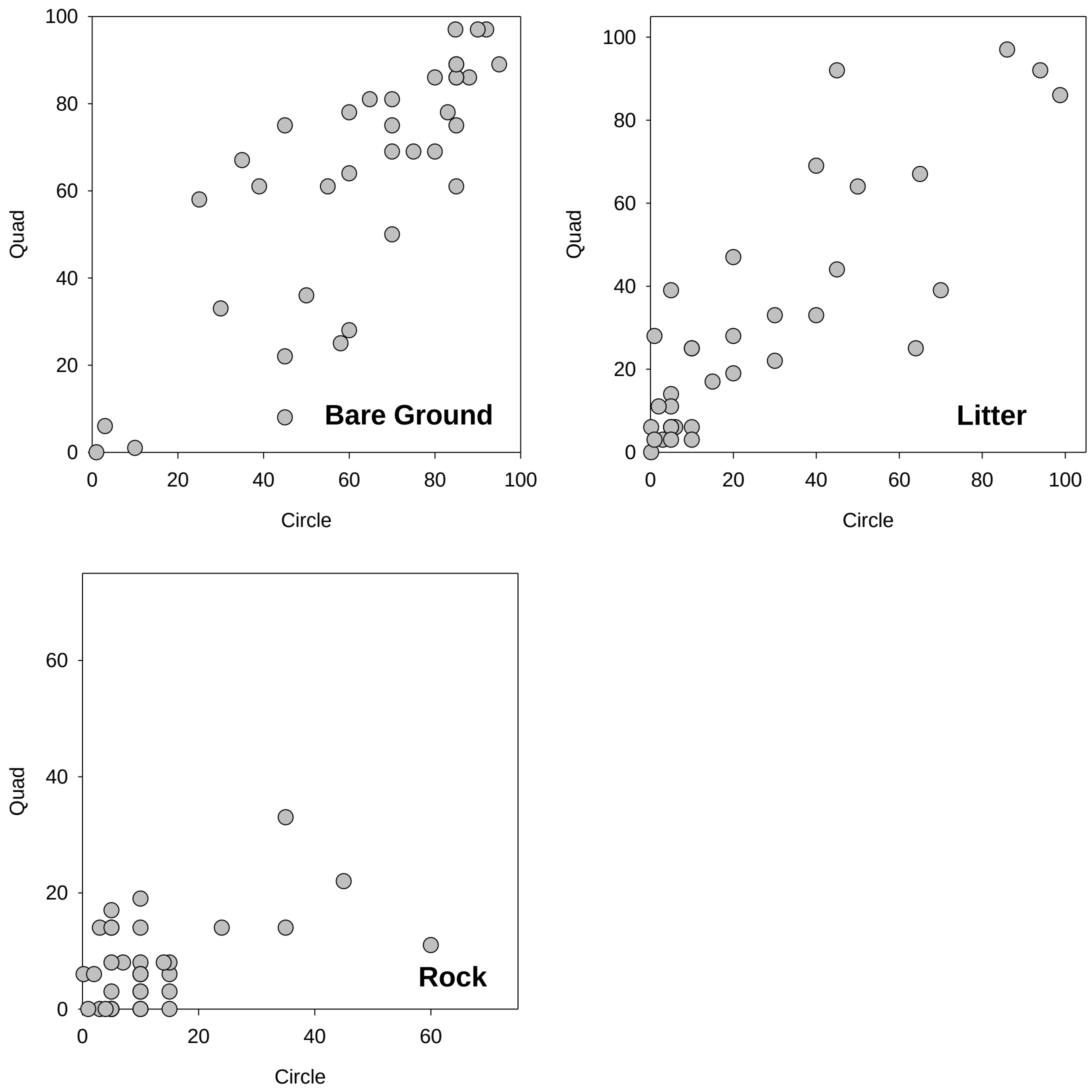

Figure 7. Comparison of Monitoring Methods (Cover). This analysis compares bare ground, litter, and rock cover in quadrats and circle plots. The diagonal line represents the 1:1 line. Points landing on the 1:1 line are equivalent. Points landing below the 1:1 line indicate that the cover value for a circle plot is greater than the corresponding quadrat value. Points above the 1:1 line indicate that the cover value for a quadrat is greater than for the corresponding circle plot value.

Native Species Richness. Native species richness in coastal sage scrub was idiosyncratic. Year and year by site interaction terms were both significant ($P<0.05$ for both), but explained very little variance in the data (5% and 7%, respectively). Native forbs are spatially and temporally variable, so this result is not unusual. While treatment effect was not significant statistically, it explained an additional 7% of the variance in the model. It appears that herbicide may have increased native species richness slightly, except at Crestridge in 2016 (Figure 9).

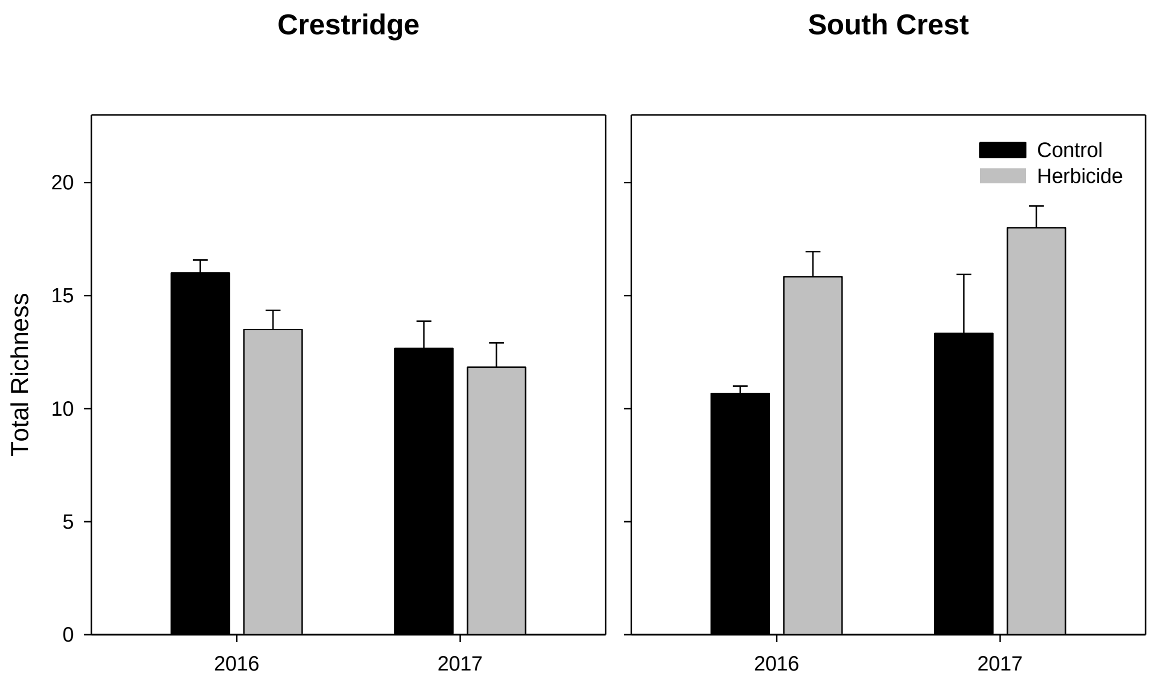

Figure 8. Coastal Sage Scrub Treatment: Total Species Richness.

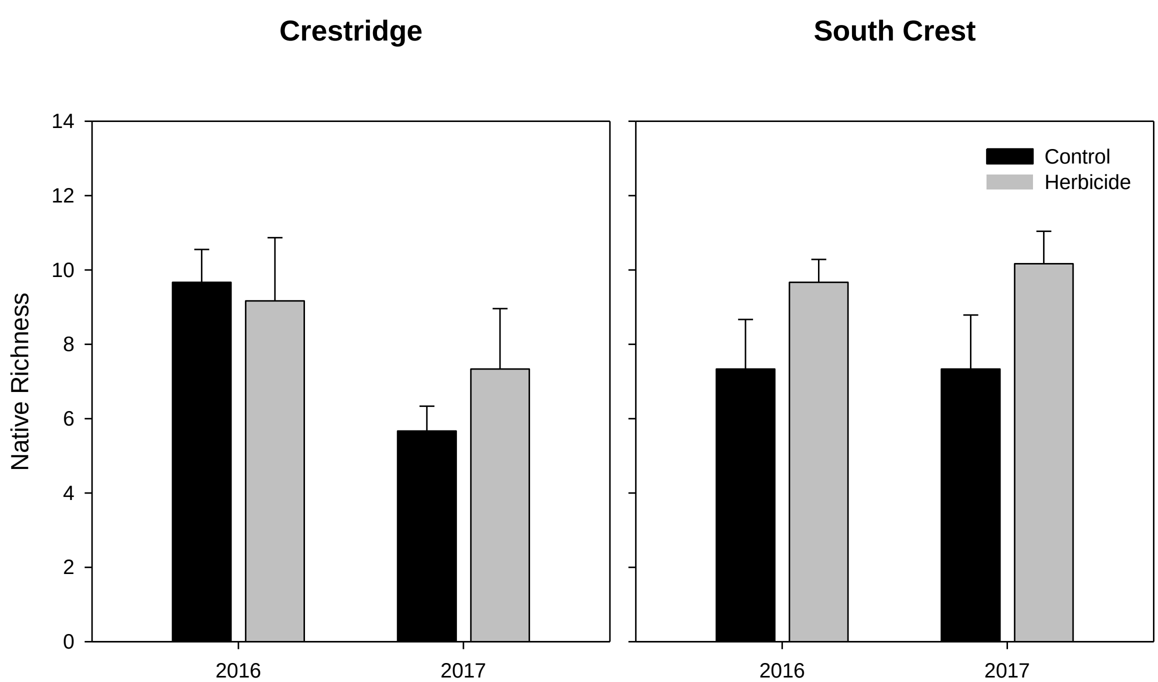

Figure 9. Coastal Sage Scrub Treatment: Native Species Richness.

3.2.2 Cover

Brachypodium. Treatment reduced *Brachypodium* cover significantly in coastal sage scrub (P<0.001, 65% variance, Figure 10). The increase of *Brachypodium* in control plots from 2016 to 2017 (P_{year}=0.005, 11% variance) was due to annual precipitation; 2016 was a below-average rainfall year while 2017 was an above-average rainfall year. *Brachypodium* dominated the nonnative grass functional group; thus, results for nonnative grasses as a whole are similar (but additive) to *Brachypodium* results (Figure 11).

Nonnative Forbs. Nonnative forb cover was highly idiosyncratic in coastal sage scrub. There were no significant explanatory variables. Treatment explained the most variability in the model (only 5%), but a pattern is hard to discern. Treatment may have increased nonnative forb cover at South Crest, but only by a small percentage which may not be biologically important (Figure 12). Potential reasons for this lack of explanatory power are extremely low cover and high variability of nonnative forbs in coastal sage scrub (note scale of Y-axis on Figure 12).

Native Forbs. Treatment increased native forb cover significantly in coastal sage scrub (P=0.05, Figure 13). However, native forbs were idiosyncratic, much like nonnative forbs, with treatment explaining 19% of the variance in a model that accounts only for 27% of the variance overall.

Potential reasons why treatment may have been a significant driver of native forb cover but not nonnative forb cover include (1) above-ground presence of native forbs (primarily, geophytes and other perennial species) prior to Phase I treatment and expansion of these species subsequent to treatment, and (2) a persistent thatch layer that suppressed germination of nonnative forbs (primarily annuals) from the soil seedbank.

Bare Ground. Bare ground is a function of site rather than treatment with Crestridge (the drier site) typically having more bare ground than South Crest (P_{site}=0.024, 19% variance, Figure 14).

Litter. Site was the primary driver of litter, with South Crest (the wetter site) having more litter than Crestridge (P=0.001, 35% variance, Figure 15). There is also a smaller, but significant year by site interaction which may be due to an increase in litter at Crestridge from 2016 to 2017, while litter decreased or stayed the same at South Crest (P=0.016, 11% variance).

3.3 Treatment Effect in Nonnative Grassland

Nonnative grassland supported dense, nearly monotypic stands of nonnative grasses with few or no native species prior to treatment. Because of this habitat degradation, Phase I treatments consisted of dethatching, seeding, and herbicide or mechanical control (D+S+H in Figures 16-23). In Phase II, we treated these areas with herbicide only. We discuss only variables with a treatment effect below; see Appendix C for all analyses and Appendix D for model results.

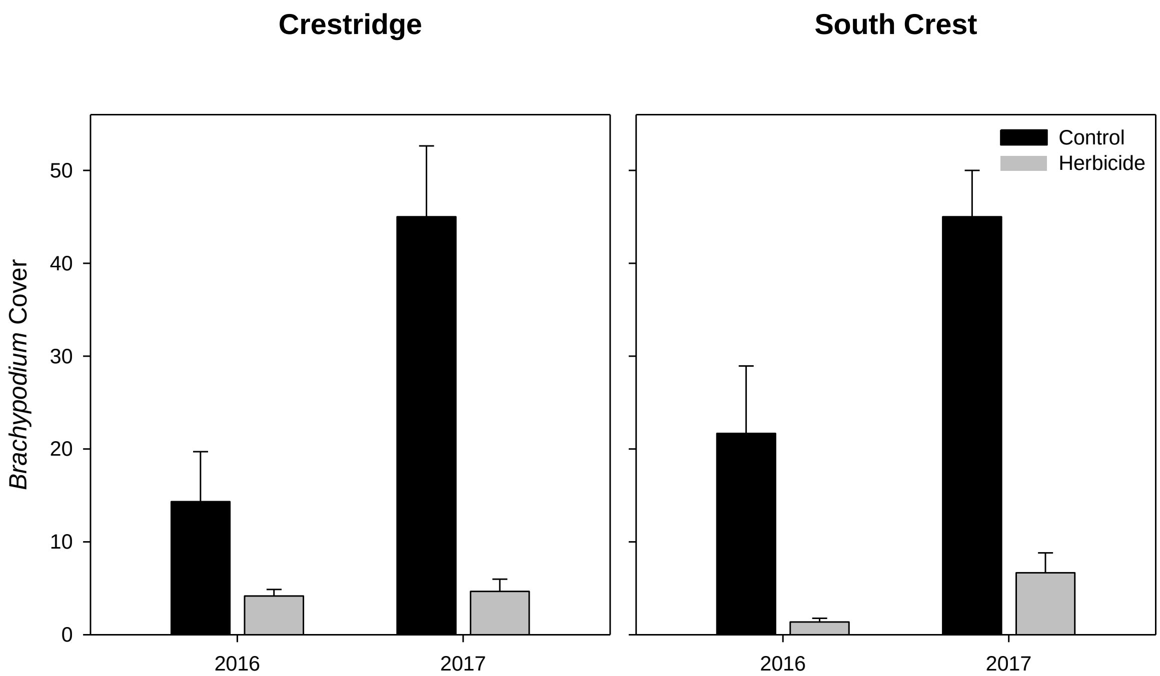

Figure 10. Coastal Sage Scrub Treatment: *Brachypodium* Cover.

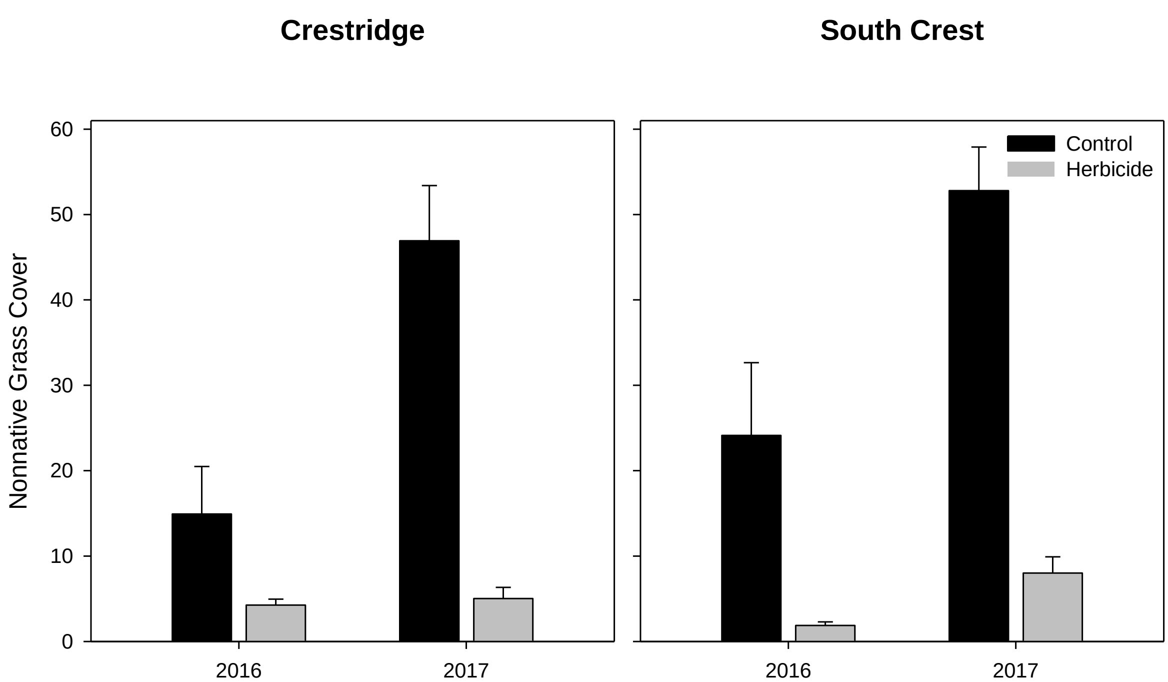

Figure 11. Coastal Sage Scrub Treatment: Nonnative Grass Cover.

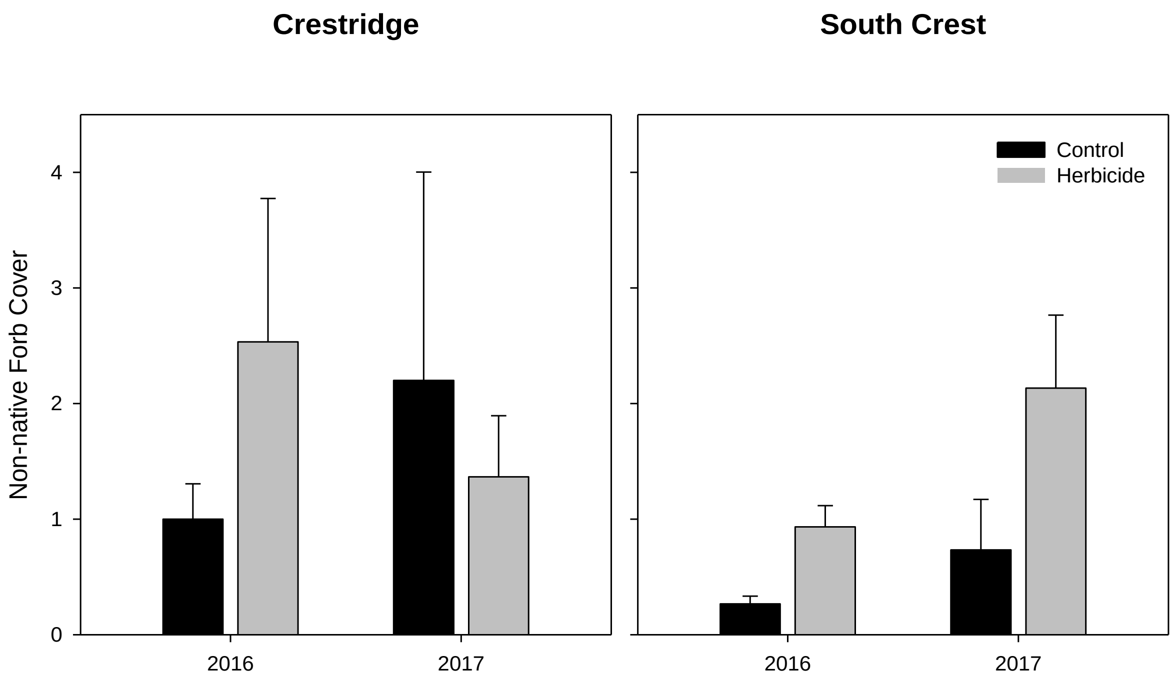

Figure 12. Coastal Sage Scrub Treatment: Nonnative Forb Cover.

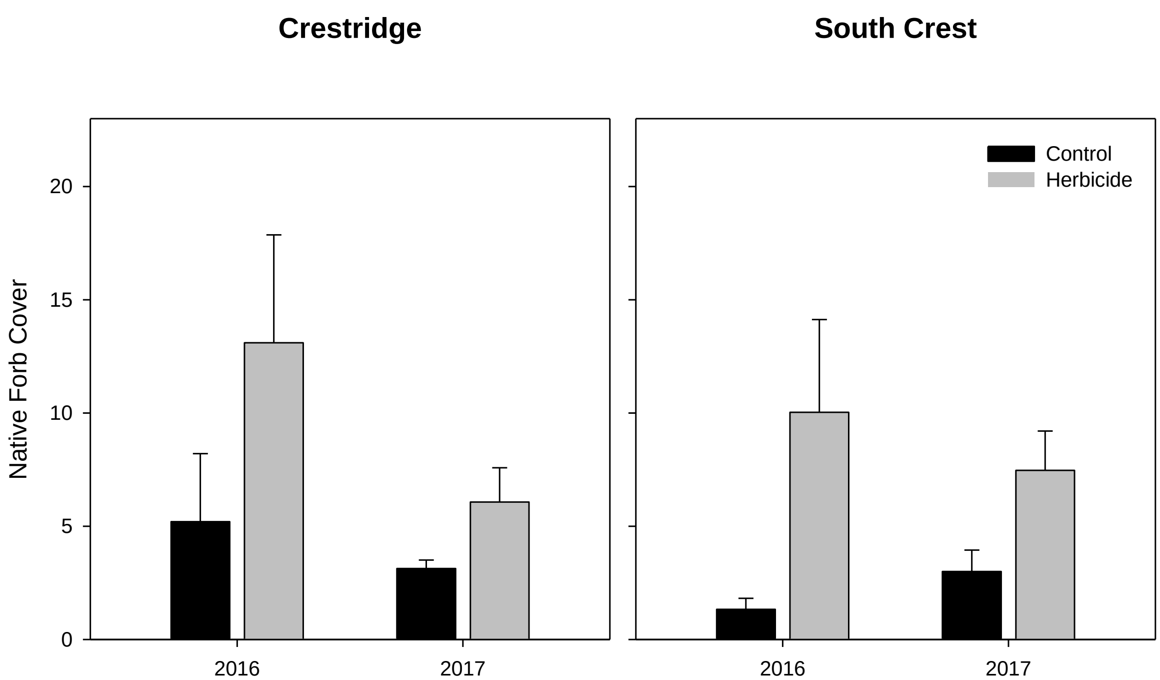

Figure 13. Coastal Sage Scrub Treatment: Native Forb Cover.

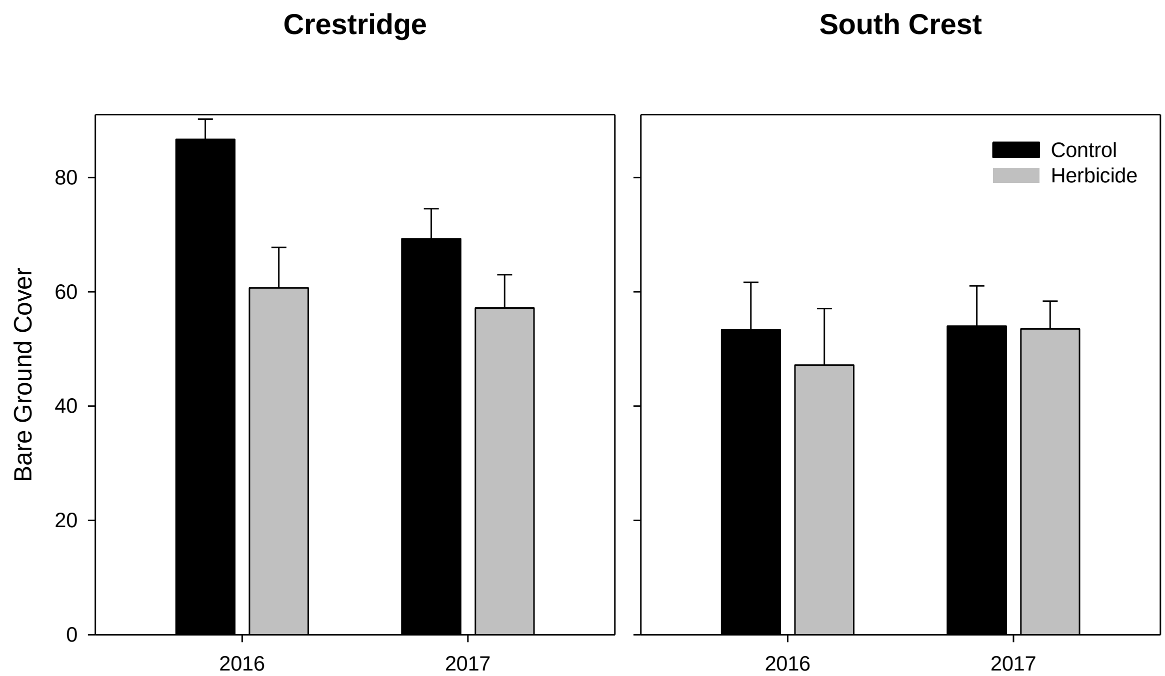

Figure 14. Coastal Sage Scrub Treatment: Bare Ground Cover.

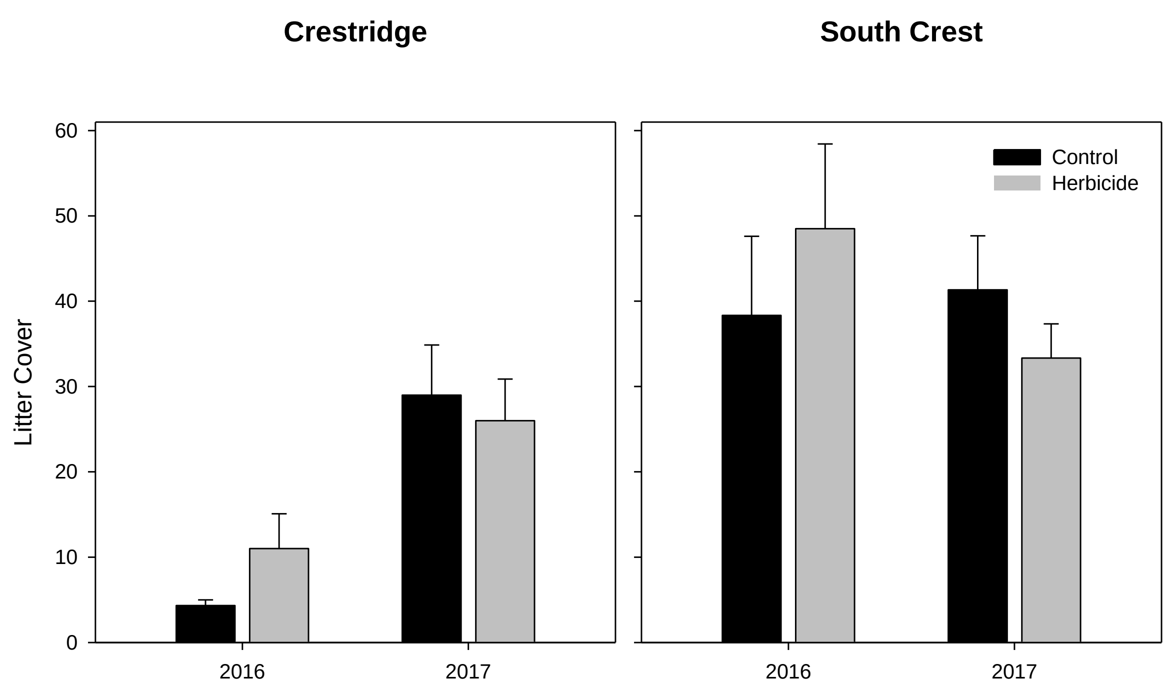

Figure 15. Coastal Sage Scrub Treatment: Litter Cover.

3.3.1 Species Richness

Total Species Richness. Treatment increased total species richness in South Crest grasslands, leading to a significant treatment and treatment by site interaction ($P_{treatment}<0.001$, $P_{treatment*site}=0.001$) that explained 66% of the model variance when combined (Figure 16). Although total species richness at Crestridge did not increase with treatment, native forb cover appears to have increased (see *Native Forb Cover*, below). This indicates seedbank composition differences between the sites. Site characteristics or history may drive seedbank differences (e.g., soils, time since invasion).

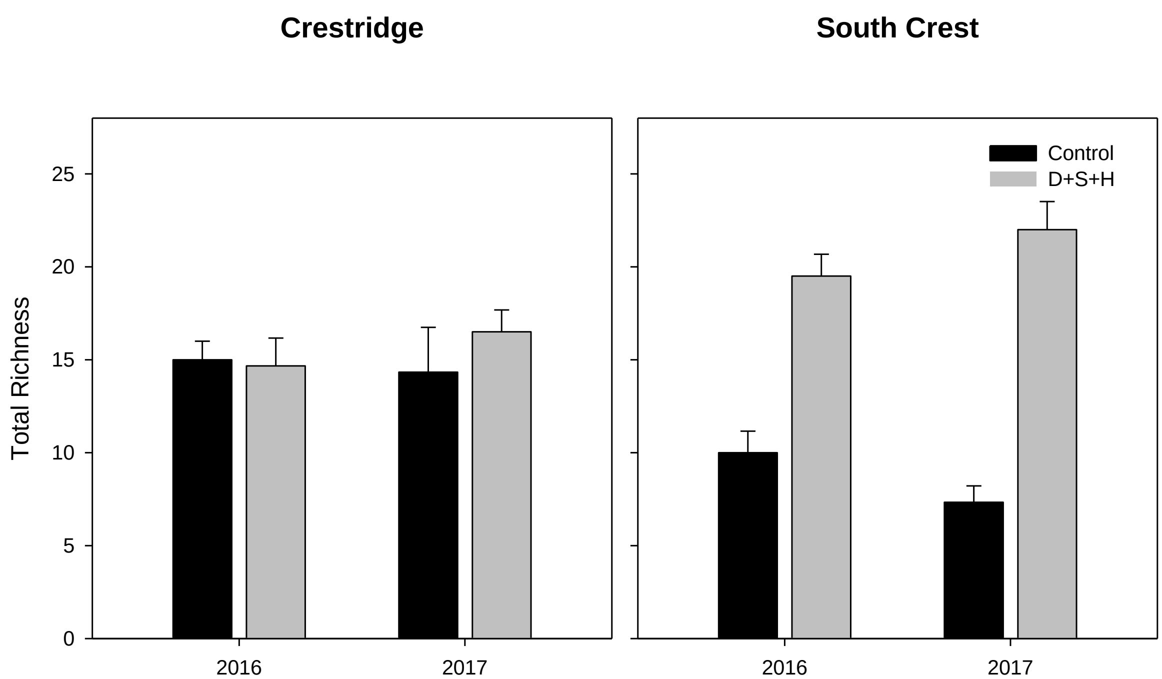

Figure 16. Grassland Treatment: Total Species.

Native Species Richness. We saw large increases in native species richness at South Crest only (Figure 17). Treatment and treatment by site interactions were both highly significant ($P<0.001$) and explained a combined 69% of the model variance. Site characteristics or history may drive native species richness.

3.3.2 Cover

Brachypodium. Treatment reduced *Brachypodium* cover significantly in nonnative grasslands ($P<0.001$, 67% variance, Figure 18). Site was a smaller but significant factor, and likely a result of higher nonnative grass cover on Crestridge at the beginning of Phase II treatments ($P<0.001$, 12% variance). *Brachypodium* dominated the nonnative grass functional group; thus, results for nonnative grasses as a whole are similar (but additive) to *Brachypodium* results (Figure 19).

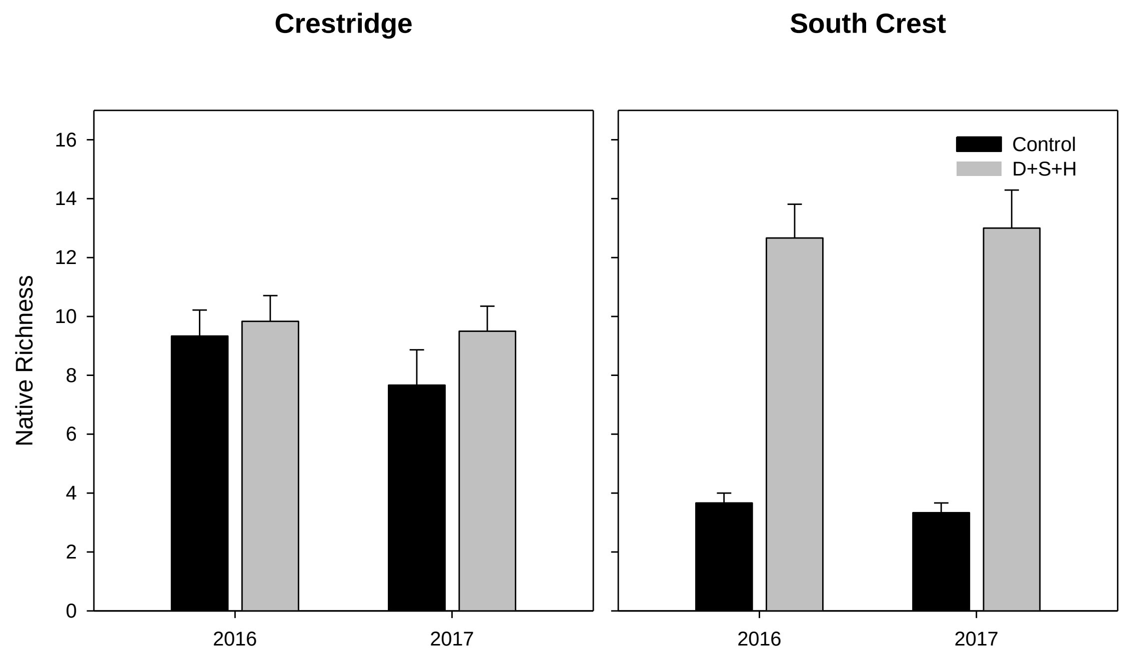

Figure 17. Grassland Treatment: Native Species Richness.

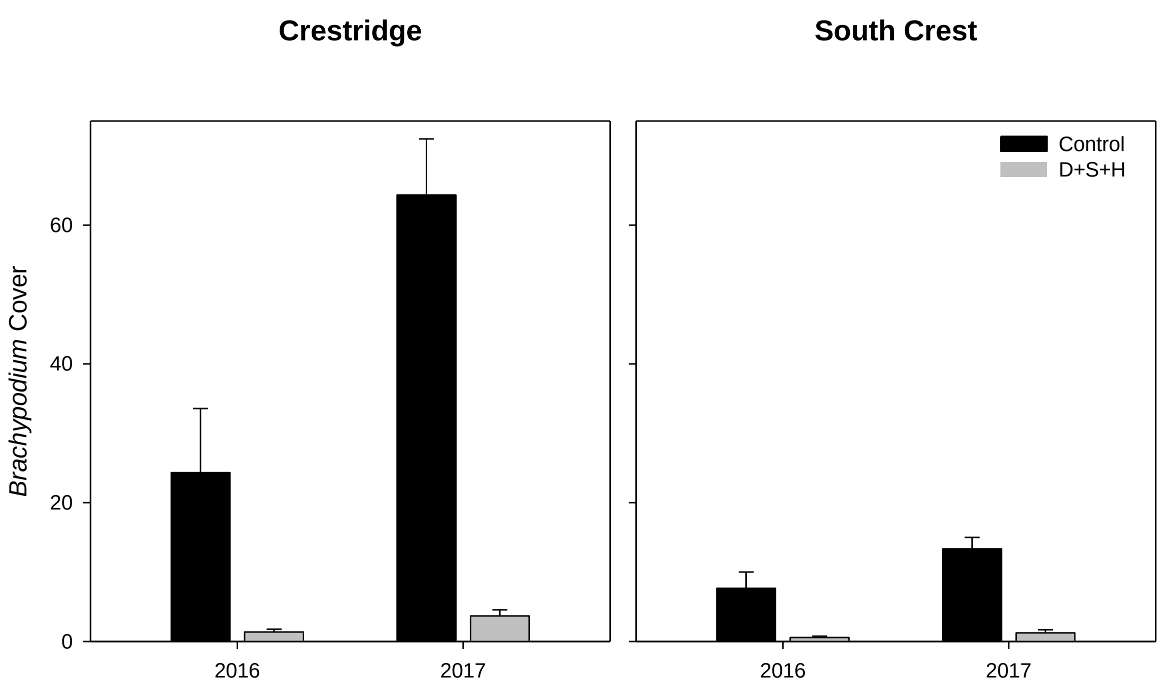

Figure 18. Grassland Treatment: *Brachypodium* Cover.

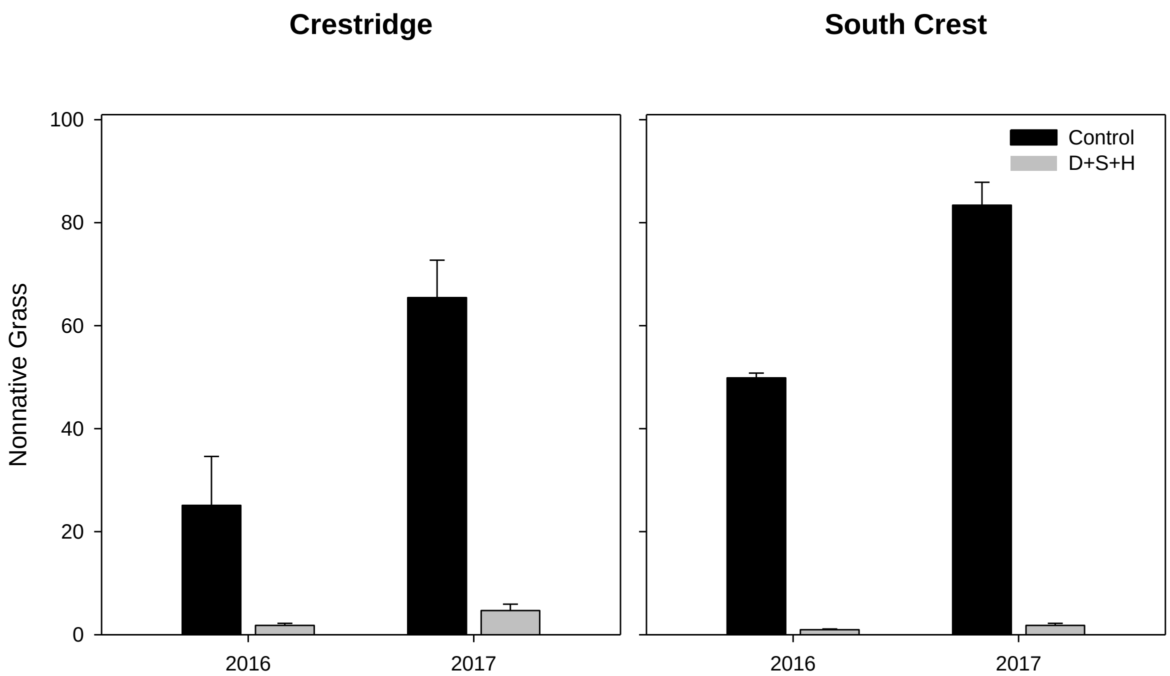

Figure 19. Grassland Treatment: Nonnative Grass Cover.

Nonnative Forbs. Nonnative forb cover was spatially patchy, temporally idiosyncratic, and relatively low across both sites. These features make drawing reliable conclusions based on statistics problematic. As a result, no factors emerged as influencing nonnative forb cover significantly in nonnative grasslands treated with herbicide.

Treatment decreased nonnative forb cover at Crestridge in both years and at South Crest in 2016. In 2017, nonnative forb cover increased significantly on South Crest, due largely to increases in *Erodium cicutarium* and *Hedypnois cretica* in polygon 2. The main effects of site and treatment are not significant, while their interaction is highly significant, explaining 31% of the model variance (P<0.001). For the same reason, the year and treatment interaction is also significant (P=0.017, 11% variance, Figure 20), as is the three-way interaction of year, site, and treatment (P=0.007, 15% variance, Figure 20).

Native Forbs. Treatment increased native forb cover significantly in nonnative grasslands ($P_{treatment}$<0.001, 35% variance, Figure 21). Crestridge had higher native forb cover than South Crest (P_{site}=0.001, 27% variance, Figure 21), due largely to the abundance of fascicled tarplant (*Deinandra fasciculata*), a native forb with generalist requirements.

Bare Ground. Treatment increased bare ground at South Crest, but had little impact at Crestridge (Figure 22). This led to significant treatment, site, and site by treatment effects

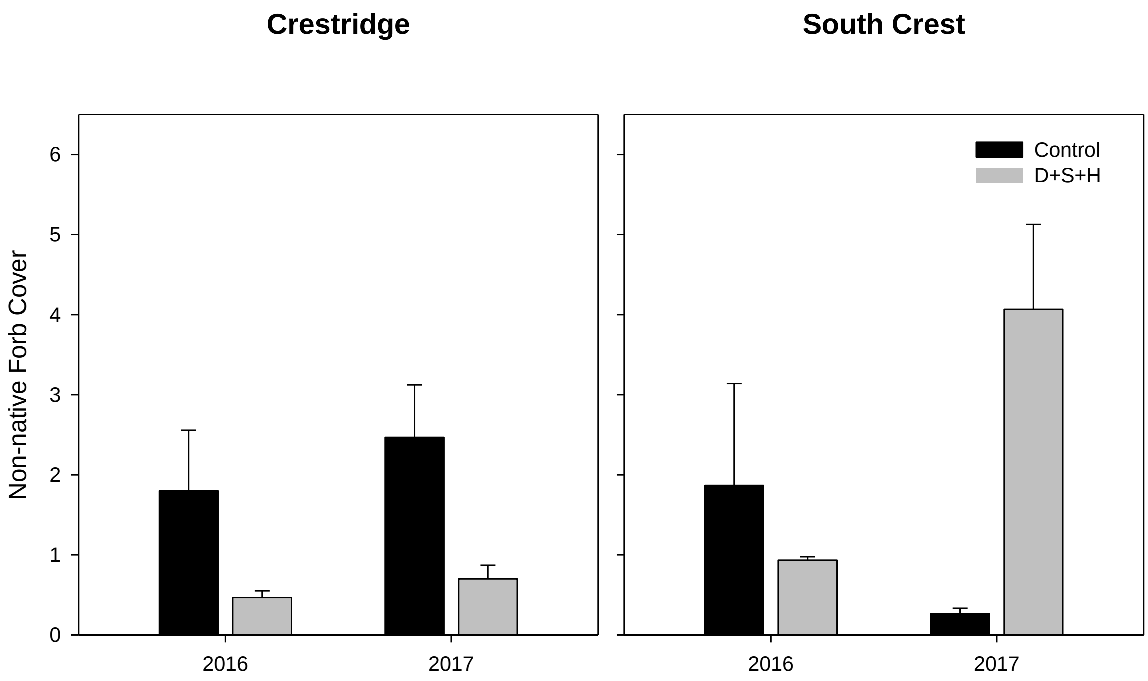

Figure 20. Grassland Treatment: Nonnative Forb Cover.

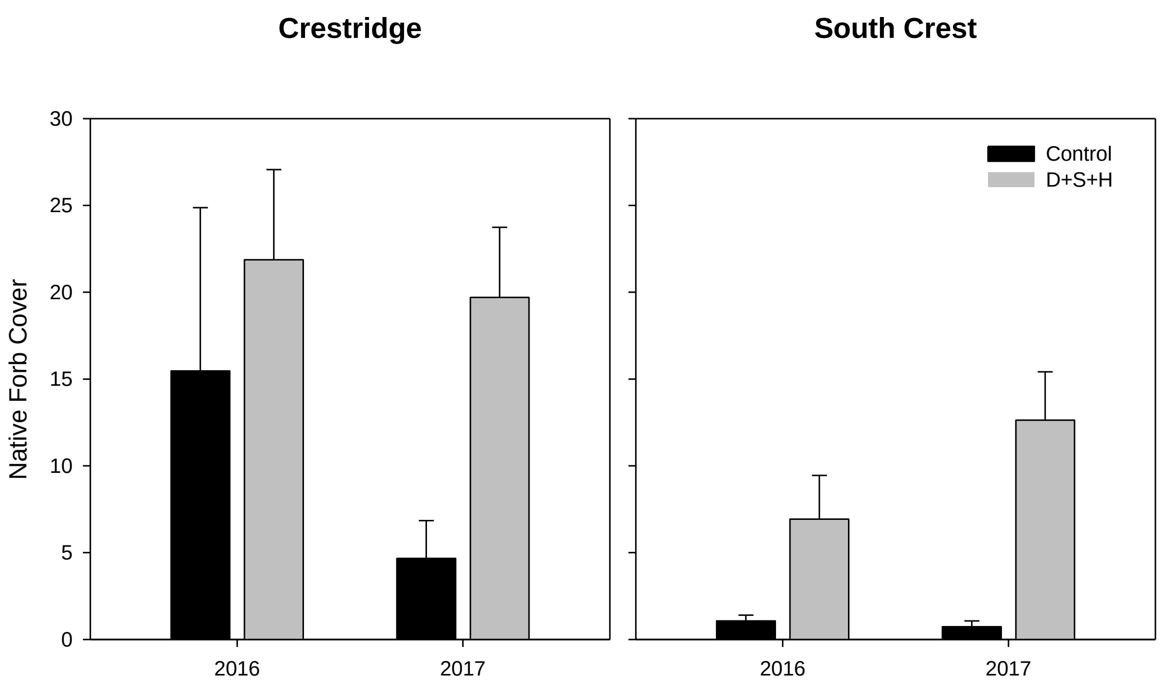

Figure 21. Grassland Treatment: Native Forb Cover.

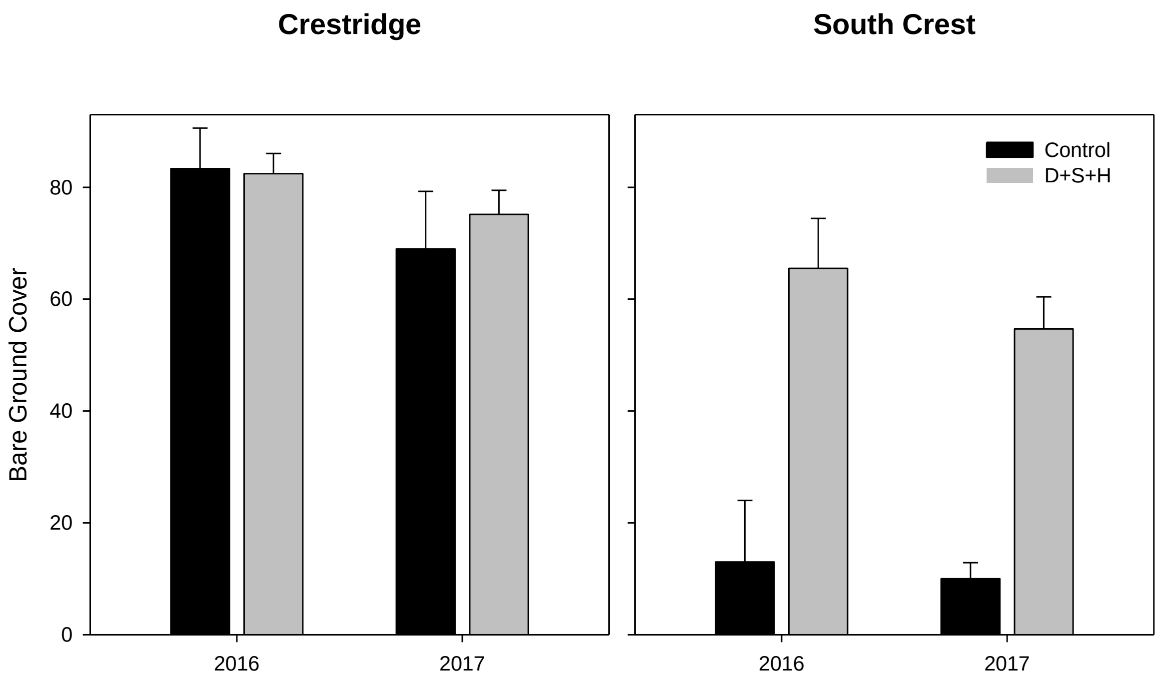

Figure 22. Grassland Treatment: Bare Ground Cover.

(P<0.001 for all, 17%, 46%, and 14% variance, respectively). The amount of bare ground in Crestridge control plots may be a function of relatively dry site conditions.

Litter. Treatment decreased the amount of litter at South Crest, but had little impact at Crestridge (Figure 23). This led to significant treatment, site, and site by treatment effects (P<0.001 for all, 17%, 46%, and 14% variance respectively). As with bare ground, lower levels of litter on Crestridge may be a function of drier site conditions. In general, there is an inverse relationship between litter and bare ground.

4 Discussion and Recommendations

Herbicide is highly effective at reducing nonnative grass cover (including *Brachypodium*), regardless of site and vegetation community. The effect of treatment on other response variables varies by site. South Crest experienced larger treatment effects than Crestridge, possibly due to soil conditions or the presence of a diverse seedbank. Coastal sage scrub often benefitted less from treatment than nonnative grasslands. However, we cannot tell if this difference is due to treatment prescriptions (Phase I and Phase II), or because coastal sage scrub was generally less invaded by *Brachypodium*, resulting in a smaller change due to treatment.

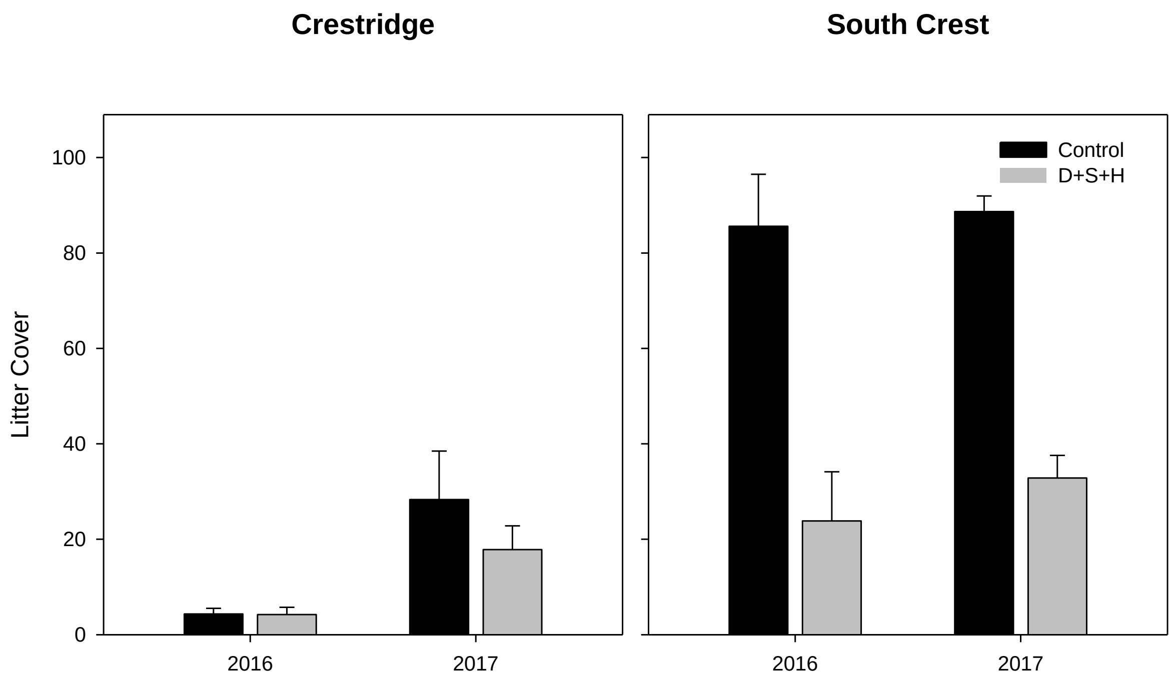

Figure 23. Grassland Treatment: Litter Cover.

4.1 Monitoring Methods

In most cases, circle plots returned statistically higher species richness values and quadrats returned significantly higher cover values. However, the two methods often correlated weakly (e.g., scaled together). Strong relationships between methods were driven by many zeros (strongly right-skewed data) that inflated the r^2 value in a misleading way.

These results indicate that the two methods are not interchangeable. Although we collected data faster in single quadrats, we used circle plot monitoring exclusively in the second year of the study to better-represent the range of conditions in plots. In our study, quadrat data were more variable than circle plot data making statistical inferences about experimental results more challenging. Including multiple quadrats within a single plot and averaging their results would lead to more representative information with lower variance; however, adding more than two additional quadrats would make the quadrat method slower than circle plots.

In selecting a monitoring method, consider both implementation cost and statistical precision necessary for management decisions. While a large number of quadrats would provide the greatest precision, invasive species management generally assesses large treatment effects (e.g., reduction in cover from 50% to 10% rather than from 5% to 4%). Therefore, we recommend circle plots as a cost-effective method for collecting data with an adequate level of precision to guide adaptive management decisions. We recommend visual cover estimate training and calibration for practitioners before using the circle plot method.

4.2 Treatments

4.2.1 Species Richness

Treatment effectiveness varied depending on vegetation community and location. In this study, species richness responded differently in coastal sage scrub and grassland on Crestridge and South Crest (Figure 24). Overall, we saw the greatest increases in species richness in South Crest treatment areas, possibly due to edaphic conditions, a diverse soil seedbank, or a combination of both.

Figure 24. Species Response to Treatment. Left: Geophytes on South Crest. Right: Fascicled tarplant (*Deinandra fasciculata*) on Crestridge.

Treatment accounted for small increases in native species richness in coastal sage scrub plots (an average of 1 and 3 species at Crestridge and South Crest, respectively). Coastal sage scrub had a relatively high native species component prior to treatment and treated areas were not dethatched. Removing nonnative grasses enhanced growth of existing species, while retention of thatch likely suppressed germination of additional species from the soil seedbank.

We observed relatively large increases in native species richness in South Crest grasslands (average of 9 species) compared to Crestridge grasslands (average of 1 species). The only treatment difference between these two areas was mowing to control *Brachypodium* on Crestridge in Phase I, which may have impacted early-germinating native forbs. We cannot formally test the contribution of seeding to species richness due to the experimental design; however, seeding appears to have contributed more to native species richness at South Crest (at least initially) than at Crestridge. That said, a number of native forbs in South Crest grasslands were not part of the seed mix, so presumably emerged from the seedbank after treatment. This further confounds the assessment of seeding treatment effectiveness. Nonetheless, seeding plays a role in restoration by filling gaps (even temporarily) after removal of nonnative species and before native species present onsite have an opportunity to re-establish.

We recommend seeding degraded sites with low native species cover, as determined during pre-treatment habitat assessments. Where the above-ground native component is absent or sparse, consider delaying seeding until after 1-2 years of treatment to determine native species response (if any) from the soil seedbank.

4.2.2 Cover

This study validated Phase I results demonstrating effective *Brachypodium* control with herbicide regardless of vegetation community or location. Site was important statistically, but likely due to lower nonnative grass cover on South Crest at the beginning of Phase II. We maintained *Brachypodium* cover at our target threshold of ≤10% in treatment plots in both habitats on both sites in 2016 and 2017. *Brachypodium* treatment appears to be more effective in grasslands than coastal sage scrub, which may be due to the difficulty of applying herbicide under and around shrubs and through thatch.

While we were not able to eradicate *Brachypodium* from treatment plots in 2017, all South Crest treatment plots had ≤3% *Brachypodium* cover (92% of plots had ≤2% cover and 83% had ≤1% cover). On Crestridge, all treatment plots had ≤6% *Brachypodium* cover (67% of plots had ≤3% cover). *Brachypodium* has the ability to rebound quickly in a high rainfall year, and maintaining this species at low cover will require long-term management. Other nonnative grasses in the study responded similarly to *Brachypodium*.

Removal of nonnative grasses created gaps for colonization. In coastal sage scrub, nonnative grass removal allowed native species present onsite to thrive, while the persistent thatch suppressed native and nonnative forb germination from the soil seedbank. In South Crest grasslands, seeded species and species germinating or emerging from the seedbank filled these gaps. We controlled emergent nonnative forbs through herbicide application. In Crestridge grasslands, native species richness was relatively low, but native species cover was high and driven by a few key species, including fascicled tarplant. Fascicled tarplant formed dense stands that out-competed native and nonnative forbs and grasses (Figure 25). This demonstrates that with respect to native forbs, we can evaluate success differently depending on location.

Refer to Section 4 for specific recommendations for *Brachypodium* and other nonnative species control.

Figure 25. Dense Stand of Fascicled Tarplant in Crestridge Treatment Area.

5 Best Management Practices

In Phase II, we refined BMPs to treat *Brachypodium* in coastal sage scrub and grassland communities. Treatment options include (1) herbicide only, which is appropriate for sites that support an assemblage of native species and (2) dethatching, seeding, and herbicide or mowing, which are appropriate for degraded sites with few native species or where the extant seedbank is depauperate or absent. While herbicide is more effective than mowing in controlling *Brachypodium*, mowing decreases *Brachypodium* cover significantly and is an option where land managers choose not to use herbicide.

Removal of *Brachypodium*, other nonnative grasses, and thatch provide gaps for colonization by native or nonnative species. As nonnative grass cover decreases, nonnative forb cover often increases as these species invade from surrounding (untreated) habitat or are released from the soil seedbank. For this reason, we recommend treating nonnative forbs along with nonnative grasses as part of the restoration effort.

Dethatching is beneficial in (1) enhancing germination from the soil seedbank and (2) improving contact between herbicide and target invasive species. Despite higher initial costs, dethatching results in increased native species richness (where there is an extant seedbank) and nonnative grass control.

The benefit of seeding is unclear and likely depends on site conditions (soil, topography, invasion history). In sites with a native component, seeding of early successional species may be useful in filling gaps while existing native species reestablish as competition from nonnative grasses is relieved. In sites lacking a native component, seeding increases native species richness. In all cases, seeding success may not be apparent immediately, depending on climatic conditions. To enhance seeding success, we recommend (1) developing seed mixes that include species known or expected to occur onsite (as determined through onsite or sentinel site habitat assessments), (2) using seed from genetically appropriate sources, and (3) using purchased seed (if appropriate based on 1 and 2) with high viability/germination rates.

We recommend treating *Brachypodium* for a minimum of 5 years. Our study showed that after 5 years, *Brachypodium* was still present at low levels in treatment areas. In addition, *Brachypodium* cover fluctuated in control areas depending on climatic conditions, with rainfall as the primary driver. These factors suggest that *Brachypodium*-infested sites will require some level of long-term management, particularly in high rainfall years.

5.1 Herbicide Only Treatment

5.1.1 Fusilade II® Application

Treat *Brachypodium* and other nonnative grasses with the herbicide, Fusilade II® for at least 5 years. Fusilade II® is a grass-specific herbicide that will kill most nonnative annual grasses, with the exception of rat-tail fescue (*Festuca myuros*). Fusilade II® will also kill native, annual grasses and native, perennial grass seedlings, but will not affect mature bunchgrasses. Where there is a high native grass component, use care in application, to the degree feasible.

Spray Fusilade II® in late winter (January–early March) when most nonnative, annual grasses are between 4-6 inches tall. Some grasses (*Avena* spp.) may be taller than 4-6 inches at this time. Regardless, ensure that spraying occurs prior to species bolting and flowering. Several site visits will be necessary to ensure correct application timing. Fusilade II® application is highly effective when contact is made with the target species, so application consistency is important.

Apply Fusilade II® at least once during the growing season. *Brachypodium* germinates continuously with sufficient rainfall, so budget for a second application in case rain occurs after the first Fusilade II® application. *Brachypodium* produces copious amounts of highly viable seed, so failure to treat late-season cohorts could increase the number of years of intensive treatment required.

Spraying can be accomplished using a backpack sprayer, truck-mounted sprayer with hose and reel, or all-terrain vehicle mounted skid sprayer. The selected method will be based on terrain, site access, existing vegetation community, and budget. In coastal sage scrub or other habitats with a shrub component, it will be important to treat *Brachypodium* underneath shrubs and adjacent to the shrub dripline to reduce the seed source. Spray applicators often miss these areas or under-spray *Brachypodium* seedlings, allowing for germination, flowering, and seed set.

5.1.2 Glyphosate Application

Treat nonnative forbs in late winter and early spring (March−April) with a glyphosate-based herbicide for at least 5 years. Spot-treat basal rosettes and bolting and flowering target species. In our experience, there is an inverse relationship between nonnative forb and nonnative grass cover, so the treatment effort for nonnative forbs may increase over time.

Apply glyphosate-based herbicide at least twice during the growing season. In addition, budget for a third application to accommodate above average rainfall years.

Spot-treat nonnative forbs using a backpack sprayer. Expect limited levels of native species collateral damage where native and nonnative species co-occur densely.

5.2 Dethatch–Seed–Herbicide Treatment

Year 1

Remove (dethatch) dead, dry grass thatch in late summer/early fall (August−October), prior to onset of the rainy season and after native forbs have completed their life cycle.

Dethatch using one of several methods: (1) dethatch rakes (small areas) (2) line (string) trimmers or (3) tractor-mounted mower (large areas devoid of native shrubs). Remove all cut biomass prior to seed application.

Apply native seed using the modified DeSimone Strip Method (see Seeding Treatment, below) in November−December, during the beginning to middle of the rainy season to take advantage of natural precipitation.

Years 2 -5

Apply Fusilade II® and a glyphosate-based herbicide based on the Herbicide Only guidelines (Section 4.1).

5.3 Mow–Seed–Herbicide Treatment

Year 1

Mow nonnative, annual grasses with a line (string) trimmer in February–March, prior to fruit formation (when species is flowering or just as fruit is forming). If fruit has matured and seed is setting, then it is too late to mow. Remove all cut biomass prior to seed application.

Apply native seed using the modified DeSimone Strip Method (see below) during the beginning to middle of the rainy season (November-December) to take advantage of natural precipitation.

Year 2

Mow nonnative, annual grasses with a line (string) trimmer in February–March, prior to fruit formation (when species is flowering or just as fruit is forming). If fruit has matured and seed is setting, then it is too late to mow. Leave biomass in place.

Years 3-5

Apply Fusilade II® and a glyphosate-based herbicide based on the Herbicide Only guidelines (Section 4.1).

5.4 Seeding Treatment (Modified DeSimone Strip Method)

In Phase I, we seeded restoration areas using a modified version of the DeSimone strip seeding method, which consists of seeding in long rows or strips that extended along slope contours. Native species in these strips serve as a seed source for unplanted, intervening habitat; thus, combining active and passive restoration. Advantages of this method include cost efficiencies by (1) concentrating seed in a smaller area to maximize germination success and bolster the seed bank and (2) focusing nonnative species control in intervening areas where native species are not as dense initially. We modified the DeSimone strip method by varying width and distance between strips, and using herbicide for nonnative plant control. Refer to CBI (2014) for additional details on this seeding method.

To implement the modified DeSimone strip method, stratify the restoration area into alternating 1 m and 5 m wide strips. Strips should be parallel to the slope and run the entire length of the restoration area.

Demarcate 1 m wide strips with flagging and use rakes, pick axes, or other suitable soil-scarifying equipment to break or loosen soil significantly within the 1 m wide strips. Hand scatter native seed into the 1 m wide strips and then tamp soil using a tamper.

5.5 Conclusion

On Crestridge and South Crest, we treated a portion of invaded habitat to test control methods. On both sites, additional invaded habitat surrounds treatment areas, including an estimated 28 acres of habitat at Crestridge and 30-32 acres at South Crest. We recommend maintaining existing treatment areas through routine preserve management and securing funding to expand treatment into adjacent areas. Prioritize additional treatment according to *Brachypodium* density, slope (treat upslope areas before downslope areas), proximity to treated areas, and presence of MSP priority species. Benefits to treating adjacent habitat include restoring native habitat and decreasing the potential for *Brachypodium* to reinvade treated areas by decreasing the *Brachypodium* seed source.

We recommend that land managers assess treatment need yearly after the initial five-year intensive restoration effort. Factors guiding treatment need include site, habitat, and climatic conditions. Below-average rainfall years may require minimal treatment to maintain *Brachypodium* at low levels, while above-average rainfall years may require intensive treatment to prevent large-scale reinvasion. *Brachypodium* produces a large quantity of highly viable seeds, and can expand exponentially in a short period of time if left unchecked. We believe the most cost-effective management strategy will be to maintain *Brachypodium* at ≤10% cover in treated areas.

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Appendix A

Appendix A-1:

Crestridge Photodocumentation

Appendix A-2:

South Crest Photodocumentation

Appendix A-1 Crestridge Photodocumentation

Treatment Plot Photos

2016-2017

Crestridge Treatment Plots

CER-1-1_2016

CER_1-1_2017

Crestridge Treatment Plots

CER_1-2_2016

CER_1-2_2017

Crestridge Treatment Plots

CER_1-3_2016

CER_1-3_2017

Crestridge Treatment Plots

CER_1-4_2016

CER_1-4_2017

Crestridge Treatment Plots

CER_1-5_2016

CER_1-5_2017

Crestridge Treatment Plots

CER_1-6_2016

CER_1-6_2017

Crestridge Treatment Plots

CER_3-1_2016

CER_3-1_2017

Crestridge Treatment Plots

CER_3-2_2016

CER_3-2_2017

Crestridge Treatment Plots

CER_3-3_2016

CER_3-3_2017

Crestridge Treatment Plots

CER_5-1_2016

CER_5-1_2017

Crestridge Treatment Plots

CER_5-2_2016

CER_5-2_2017

Crestridge Treatment Plots

CER_5-3_2016

CER_5-3_2017

Crestridge Treatment Plots

CER_Control_CSS-1_2016

CER_Control_CSS-1_2017

Crestridge Treatment Plots

CER_Control_CSS-2_2016

CER_Control_CSS-2_2017

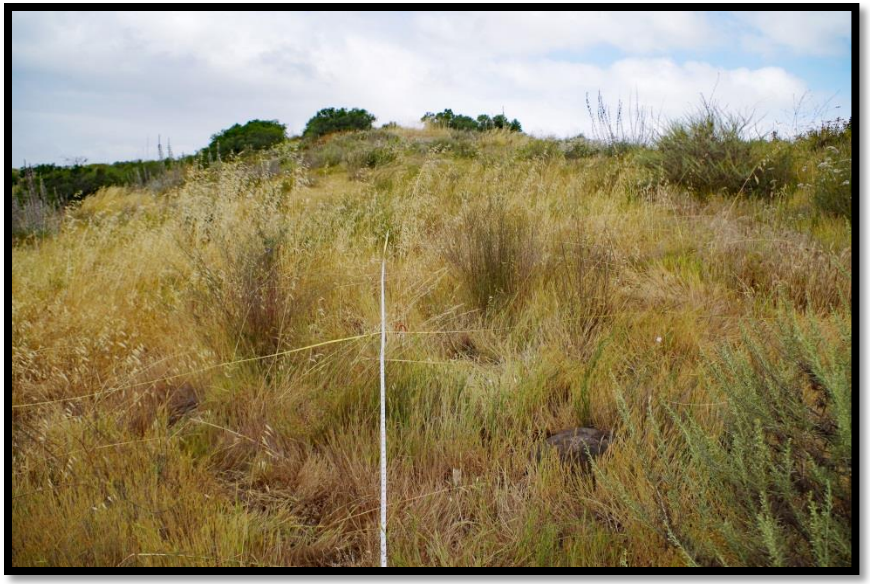
Crestridge Treatment Plots

CER_Control_CSS-3_2016

CER_Control_CSS-3_2017

Crestridge Treatment Plots

CER_Control_GL-1_2016



CER_Control_GL-1_2017

Crestridge Treatment Plots

CER_Control_GL-2_2016

CER_Control_GL-2_2017

Crestridge Treatment Plots

CER_Control_GL-3_2016

CER_Control_GL-3_2017

Appendix A-2 South Crest Photodocumentation

Treatment Plot Photos

2016-2017

South Crest Treatment Plots

SC_2-1_2016

SC_2-1_2017

South Crest Treatment Plots

SC_2-2_2016

SC_2-2_2017

South Crest Treatment Plots

SC_2-3_2016

SC_2-3_2017

South Crest Treatment Plots

SC_3-1_2016

SC_3-1_2017

South Crest Treatment Plots

SC_3-2_2016

SC_3-2_2017

South Crest Treatment Plots

SC_3-3_2016

SC_3-3_2017

South Crest Treatment Plots

SC_4_5-1_2016

SC_4_5-1_2017

South Crest Treatment Plots

SC_4_5-2_2016

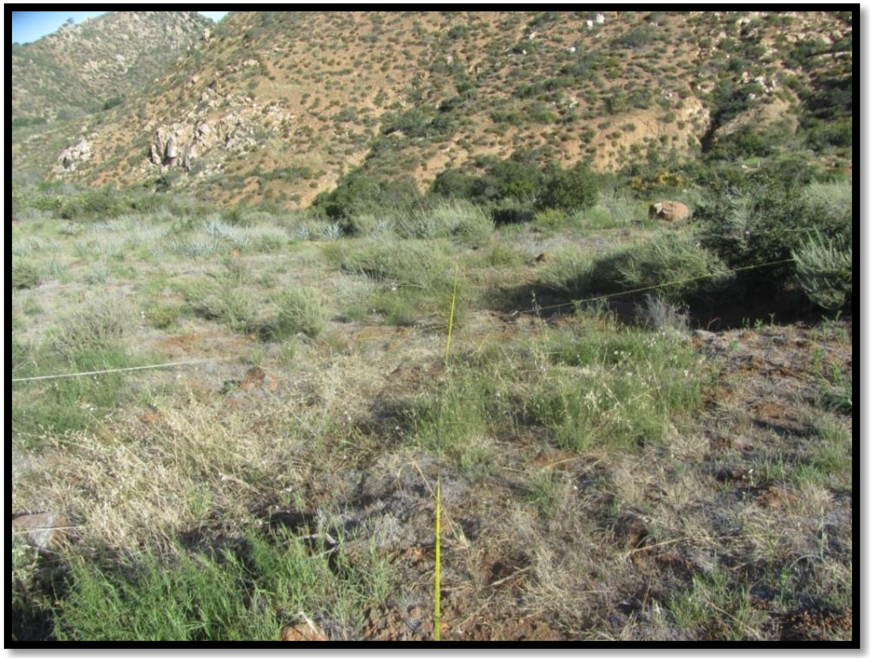
SC_4_5-2_2017

South Crest Treatment Plots

SC_4_5-3_2016

SC_4_5-3_2017

South Crest Treatment Plots



SC_8-1_2016

SC_8-1_2017

South Crest Treatment Plots

SC_8-2_2016

SC_8-2_2017

South Crest Treatment Plots

SC_8-3_2016

SC_8-3_2017

South Crest Treatment Plots

SC_Control_CSS-1_2016

SC_Control_CSS-1_2017

South Crest Treatment Plots

SC_Control_CSS-2_2016

SC_Control_CSS-2_2017

South Crest Treatment Plots

SC_Control_CSS-3_2016

SC_Control_CSS-3_2017

South Crest Treatment Plots

SC_Control_GL-1_2016

SC_Control_GL-1_2017

South Crest Treatment Plots

SC_Control_GL-2_2016

SC_Control_GL-2_2017

South Crest Treatment Plots

SC_Control_GL-3_2016

SC_Control_GL-3_2017

Appendix B
Data Summary
Crestridge and South Crest, 2016-2017

Appendix B

Data Summary: Crestridge and South Crest, 2016-2017

Year	Plot[1]	Vegetation[2]	Treatment[3]	Species Richness				Cover[4]									
				Total Richness	Nonnative Species	Native Species	Native Forbs	Total	BRDIS	NNG	NNF	NG	NF	NS	BG	Rock	Litter
2016	CER_1_1	NNGL	D-S-H	10	3	7	6	26.2	3	3.2	0.2	0	21.8	1	85	10	5
2016	CER_1_2	NNGL	D-S-H	13	3	10	7	49.4	0.2	0.2	0.4	0	42	7	84.8	15	0.2
2016	CER_1_3	NNGL	D-S-H	17	7	10	7	29.2	1	1.4	0.8	2	24.8	2	64.8	35	0.2
2016	CER_1_4	NNGL	D-S-H	20	7	13	6	16.4	1	1.6	0.6	0.2	9.4	7	90	5	5
2016	CER_1_5	NNGL	D-S-H	12	4	8	7	10.4	1	2	0.4	0	7	1	85	5	10
2016	CER_1_6	NNGL	D-S-H	16	5	11	7	30.6	2	2.4	0.4	1.2	26.2	3	85	10	5
2017	CER_1_1	NNGL	D-S-H	14	4	9	6	44.8	5	5.4	0.2	0	37.6	1.4	93	2	5
2017	CER_1_2	NNGL	D-S-H	16	5	10	6	38.6	4	4.2	0.6	0.2	16.4	16.2	73	7	20
2017	CER_1_3	NNGL	D-S-H	15	6	8	4	27.8	1	1.4	1.4	1	20.4	0.6	75	20	5
2017	CER_1_4	NNGL	D-S-H	19	8	10	5	29.8	5	6.4	0.8	0	13.4	8.2	60	2	38
2017	CER_1_5	NNGL	D-S-H	14	6	7	4	29.6	1	1.6	0.4	0	21.4	5.2	75	5	20
2017	CER_1_6	NNGL	D-S-H	21	7	13	7	26.8	6	9.2	0.8	0.2	9	7.4	75	6	19
2016	CER_3_1	CSS	H	13	6	7	4	34.4	5	5.2	6.4	1	25.6	1.2	60	10	30
2016	CER_3_2	CSS	H	12	6	6	6	30.6	2	2.2	1.6	0	26.8	0	75	15	10
2016	CER_3_3	CSS	H	11	7	4	4	59.6	5	5.2	6.4	0	17.4	0	85	5	10
2017	CER_3_1	CSS	H	10	4	6	4	11.2	1	1	2.4	0.2	5.6	2	67	3	30
2017	CER_3_2	CSS	H	13	7	6	5	20.6	4	6	2.8	0	10.8	1	70	5	25
2017	CER_3_3	CSS	H	9	6	2	2	15.8	2	2.2	2.4	0	10.2	0	70	7	23
2016	CER_5_1	CSS	H	14	3	11	7	37.8	5	5	0.4	21	4.8	7	39	60	1
2016	CER_5_2	CSS	H	14	2	12	2	21	6	6	0.2	5.2	0.6	15.2	60	35	5
2016	CER_5_3	CSS	H	17	2	15	9	38.6	2	2	0.2	7	3.4	30.4	45	45	10

Appendix B

Data Summary: Crestridge and South Crest, 2016-2017

Year	Plot[1]	Vegetation[2]	Treatment[3]	Species Richness				Cover[4]									
				Total Richness	Nonnative Species	Native Species	Native Forbs	Total	BRDIS	NNG	NNF	NG	NF	NS	BG	Rock	Litter
2017	CER_5_1	CSS	H	10	3	6	4	25.6	6	6	0.4	12	5.2	1	40	35	25
2017	CER_5_2	CSS	H	13	1	11	4	38.8	5	5	0	8.2	2.4	23	40	15	45
2017	CER_5_3	CSS	H	16	2	13	7	26	10	10	0.2	4.4	2.2	9	56	36	8
2016	CER_C-CSS_1	CSS	None	16	8	8	7	20	8	8.6	0.8	0	11.2	0.2	92	5	3
2016	CER_C-CSS_2	CSS	None	15	5	10	6	33	25	26	0.6	2	2	5	88	7	5
2016	CER_C-CSS_3	CSS	None	17	6	11	10	7.8	10	10.2	1.6	0	2.4	1	80	15	5
2017	CER_C-CSS_1	CSS	None	15	9	5	4	62	50	51.4	5.8	0	3.6	1	59.8	0.2	40
2017	CER_C-CSS_2	CSS	None	12	4	7	4	44.2	30	34.2	0.2	0.2	3.4	6	70	3	27
2017	CER_C-CSS_3	CSS	None	11	5	5	4	60.4	55	55.2	0.6	0	2.4	2	78	2	20
2016	CER_C-GL_1	NNGL	None	17	6	11	8	16.2	25	26.2	0.6	1	9	6	70	24	6
2016	CER_C-GL_2	NNGL	None	14	5	9	8	13.8	8	8.2	3.2	2	3.4	0	85	10	5
2016	CER_C-GL_3	NNGL	None	14	6	8	7	76.4	40	41	1.6	0	34	1	95	3	2
2017	CER_C-GL_1	NNGL	None	19	8	10	7	69	50	53	2.8	0.2	8.8	3.2	63	7	30
2017	CER_C-GL_2	NNGL	None	11	4	6	3	70.2	65	65.2	1.2	1.4	1.4	0	89	1	10
2017	CER_C-GL_3	NNGL	None	13	5	7	6	86.6	78	78.2	3.4	1	3.8	0	55	0	45
2016	SC_2_1	NNGL	D-S-H	22	8	14	9	26	0.2	0.6	1	3	10	11.4	83	15	2
2016	SC_2_2	NNGL	D-S-H	16	7	9	4	11.8	0.2	0.4	1	1	4.4	5	70	10	20
2016	SC_2_3	NNGL	D-S-H	23	7	16	10	21.2	0	1.4	0.8	2	3.6	13.4	85	14	1
2017	SC_2_1	NNGL	D-S-H	23	10	12	6	61.8	0.2	1.6	8.4	3.2	23.6	22	45	15	40
2017	SC_2_2	NNGL	D-S-H	20	8	11	6	46.6	1	2.4	4.4	2.2	17.6	15	45	20	35
2017	SC_2_3	NNGL	D-S-H	23	9	13	7	39	3	3.2	4.8	14	10.8	5.2	55	15	30
2016	SC_3_1	NNGL	D-S-H	18	6	12	8	22.4	1	1.2	0.8	1	18	1.4	25	5	70
2016	SC_3_2	NNGL	D-S-H	17	7	10	5	12.6	1	1.2	1	0	1	9.4	70	10	20

Appendix B

Data Summary: Crestridge and South Crest, 2016-2017

Year	Plot[1]	Vegetation[2]	Treatment[3]	Species Richness				Cover[4]									
				Total Richness	Nonnative Species	Native Species	Native Forbs	Total	BRDIS	NNG	NNF	NG	NF	NS	BG	Rock	Litter
2016	SC_3_3	NNGL	D-S-H	21	6	15	11	14.6	1	1	1	1	4.6	7	60	10	30
2017	SC_3_1	NNGL	D-S-H	16	6	9	6	20.4	1	1.2	1.6	0	11.4	6	68	7	25
2017	SC_3_2	NNGL	D-S-H	27	8	18	13	24.8	0.2	0.4	4	0.4	6	13	75	8	17
2017	SC_3_3	NNGL	D-S-H	23	7	15	10	22.8	2	2	1.2	4.2	6.4	8	40	10	50
2016	SC_8_1	CSS	Herbicide	15	5	10	6	15.8	1	2	0.6	2	5.8	6	58	2	40
2016	SC_8_2	CSS	Herbicide	21	9	12	5	37.4	1	2.4	1	10.2	4.6	22.6	10	4	86
2016	SC_8_3	CSS	Herbicide	16	6	10	4	23.6	3	3.4	0.6	0.2	0.8	22.2	80	5	15
2017	SC_8_1	CSS	Herbicide	19	8	11	8	16.6	2	3.4	0.8	0.2	6	6.2	56	14	30
2017	SC_8_2	CSS	Herbicide	17	7	10	6	43	5	6.2	0.8	7	4.8	24.2	62	3	35
2017	SC_8_3	CSS	Herbicide	22	8	14	8	34	1	4	2.6	1	2.4	24	68	2	30
2016	SC_4&5_1	CSS	Herbicide	13	5	8	7	29.4	2	2	0.8	2	24.6	0	55	5	40
2016	SC_4&5_2	CSS	Herbicide	15	5	10	8	25.6	1	1	0.8	1	20.8	2	30	5	65
2016	SC_4&5_3	CSS	Herbicide	15	7	8	6	9.8	0.2	0.4	1.8	3	3.6	1	50	10	45
2017	SC_4&5_1	CSS	Herbicide	17	8	9	7	42.2	15	15.2	1.2	14.2	11.6	0	35	15	50
2017	SC_4&5_2	CSS	Herbicide	18	9	9	6	29.6	7	7.2	4.8	3	13.6	1	45	20	35
2017	SC_4&5_3	CSS	Herbicide	15	6	8	5	32.4	10	12	2.6	5.2	6.4	6	55	25	20
2016	SC_C-CSS_1	CSS	None	11	5	6	2	53	20	21	0.4	4	0.4	3.4	70	10	20
2016	SC_C-CSS_2	CSS	None	10	4	6	4	70.2	10	11.2	0.2	3	1.6	1	45	5	50
2016	SC_C-CSS_3	CSS	None	11	1	10	6	51.4	35	40.2	0.2	5	2	4	45	10	45
2017	SC_C-CSS_1	CSS	None	13	5	7	4	73.2	55	60.2	0.4	5	3.4	4	60	5	35
2017	SC_C-CSS_2	CSS	None	9	4	5	3	54.6	40	43	0.2	3	4.4	4	40	6	54
2017	SC_C-CSS_3	CSS	None	18	7	10	6	73.2	40	55.2	1.6	6	1.2	9	62	3	35
2016	SC_C-GL_1	NNGL	None	8	4	4	3	61.8	10	50	0.4	10	1.4	0	1	0.2	98.8

Appendix B

Data Summary: Crestridge and South Crest, 2016-2017

Year	Plot[1]	Vegetation[2]	Treatment[3]	Species Richness				Cover[4]									
				Total Richness	Nonnative Species	Native Species	Native Forbs	Total	BRDIS	NNG	NNF	NG	NF	NS	BG	Rock	Litter
2016	SC_C-GL_2	NNGL	None	12	8	4	3	59.2	10	51.4	4.4	2	1.4	0	35	1	64
2016	SC_C-GL_3	NNGL	None	10	7	3	2	51.4	3	48.2	0.8	2	0.4	0	3	3	94
2017	SC_C-GL_1	NNGL	None	7	4	3	2	92.8	10	90.2	0.2	2	0.4	0	5	0	95
2017	SC_C-GL_2	NNGL	None	9	4	4	3	82	15	75	0.4	5	1.4	0	15	1	84
2017	SC_C-GL_3	NNGL	None	6	3	3	2	87.6	15	85	0.2	2	0.4	0	10	3	87

[1] Plot: CER = Crestridge, SC = South Crest; first number = treatment polygon number, second number = treatment plot number.

[2] Vegetation: CSS = coastal sage scrub, NNGL = nonnative grassland.

[3] Treatment: H = Herbicide only in Phase I and II; D-S-H = Dethatched and seeded in Phase I and treated with herbicide only in Phase II; * = plots mowed in Phase I, treated with herbicide in Phase II; None = no treatment (control).

[4] Cover: BRDIS = Brachypodium, NNG = nonnative grass, NNF = nonnative forb, NG = native grass, NF = native forb, NS = native shrub, BG = Bare Ground.

Appendix C
Data Analyses

Tables for Appendix C:

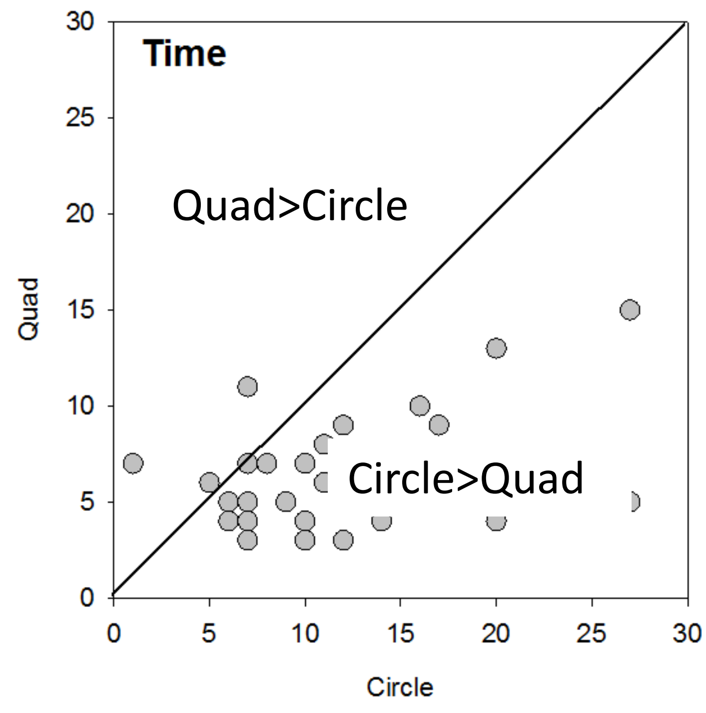
Herbicide in CSS

	Response Variables											
Model Terms:	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	6%	0%	7%	**17%**	**65%**	**66%**	5%	3%	19%	9%	13%	0%
SITE	2%	1%	1%	**7%**	0%	0%	3%	15%	2%	**19%**	5%	**35%**
SITE*FULL_TREATMENT	**26%**	**27%**	3%	**9%**	1%	1%	3%	11%	2%	4%	7%	0%
YEAR	0%	2%	**5%**	6%	**11%**	**13%**	2%	0%	0%	1%	2%	3%
YEAR*FULL_TREATMENT	0%	0%	1%	**9%**	1%	1%	0%	0%	1%	2%	0%	3%
YEAR*SITE	**14%**	6%	**7%**	0%	0%	1%	2%	1%	3%	3%	**4%**	**11%**
YEAR*SITE*FULL_TREATMENT	1%	0%	0%	**15%**	2%	2%	1%	0%	0%	0%	2%	0%
Total Variation Explained:	49%	37%	23%	63%	81%	84%	17%	30%	27%	38%	34%	53%

Dethatch, Herbicide & Seed in Grasslands

	Response Variables											
Model Terms:	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	**38%**	9%	**43%**	**33%**	**67%**	**86%**	0%	7%	**35%**	**17%**	16%	**22%**
SITE	0%	3%	1%	1%	**12%**	0%	0%	**30%**	**27%**	**46%**	2%	**42%**
SITE*FULL_TREATMENT	**28%**	14%	**26%**	5%	2%	**3%**	**31%**	0%	2%	**14%**	5%	**15%**
YEAR	0%	0%	0%	**20%**	**6%**	**4%**	2%	0%	0%	2%	**5%**	**3%**
YEAR*FULL_TREATMENT	**3%**	12%	0%	1%	1%	0%	**11%**	1%	**4%**	0%	1%	0%
YEAR*SITE	0%	3%	0%	0%	1%	1%	0%	1%	3%	0%	**8%**	1%
YEAR*SITE*FULL_TREATMENT	0%	3%	0%	3%	0%	0%	**15%**	2%	0%	0%	0%	0%
Total Variation Explained:	70%	45%	71%	65%	89%	94%	59%	41%	70%	80%	37%	84%

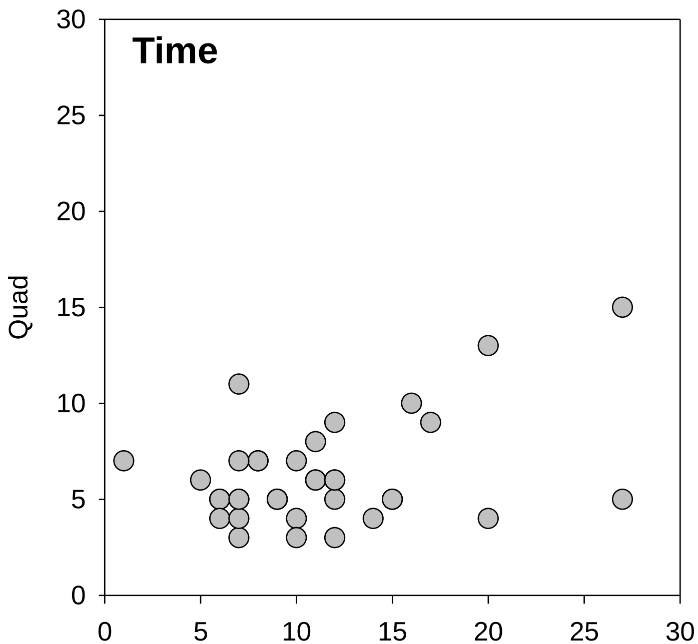
The values in each cell represent the percent of the variance explained by each model term (named in the left most column) for each response variable (named in the second row). The data bars through out the table visualize those values. Bold values indicate significant terms, black (but not bold) values indicate terms which approached significance, value in grey were not significant.



Least squares regression + paired t-tests

QUADRATS V CIRCLE PLOTS

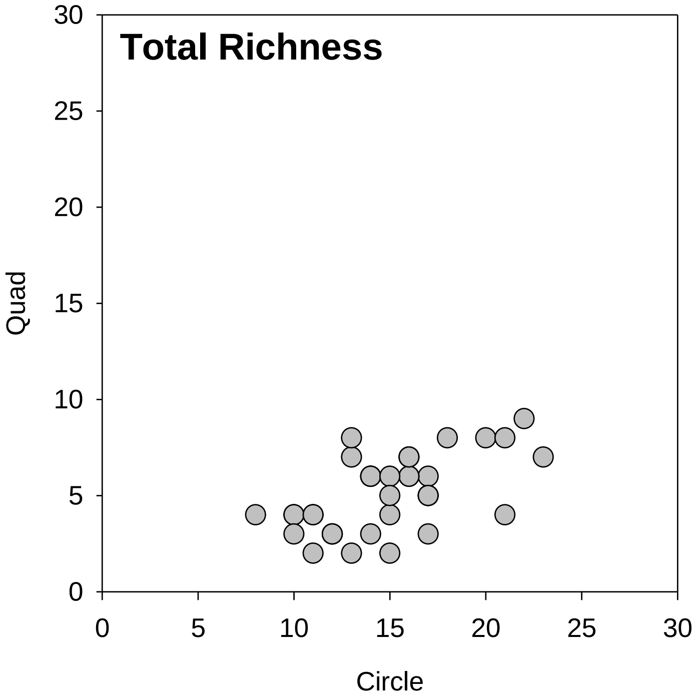
Time



- Circle>Quad
- Relationship between measures is significant, but poor (r2=0.13)

N	36					
Multiple R	0.398					
Squared Multiple R	0.159					
Adjusted Squared Multiple R	0.134					
Standard Error of Estimate	2.508					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	4.098	0.938	0	.	4.371	0
TIME_CIRCLE	0.19	0.075	0.398	1	2.531	0.016

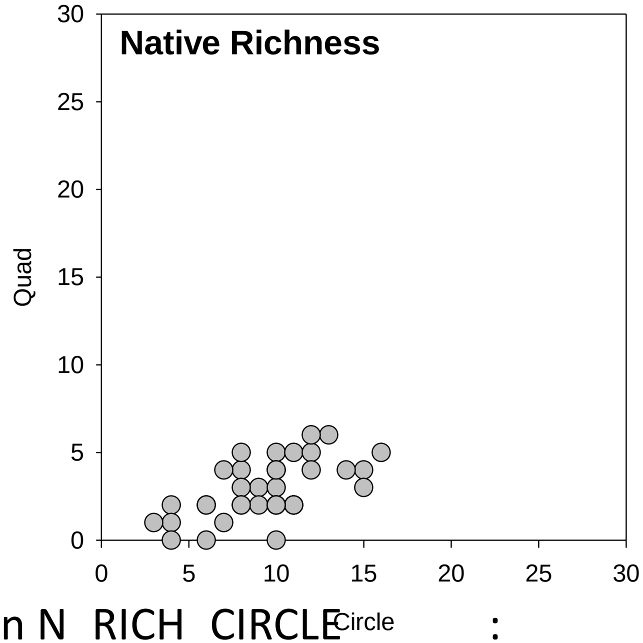
Total Species Richness



- Circle>Quad
- Relationship between measures is significant, but not great
  - (P<0.001) r2=0.32)

N	36					
Multiple R	0.586					
Squared Multiple R	0.343					
Adjusted Squared Multiple R	0.324					
Standard Error of Estimate	1.602					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std.	Tolerance	t	p-value
			Coefficient			
CONSTANT	0.387	1.146	0	.	0.337	0.738
TOT_RICH_CIRCLE	0.315	0.075	0.586	1	4.213	0

Native Species Richness

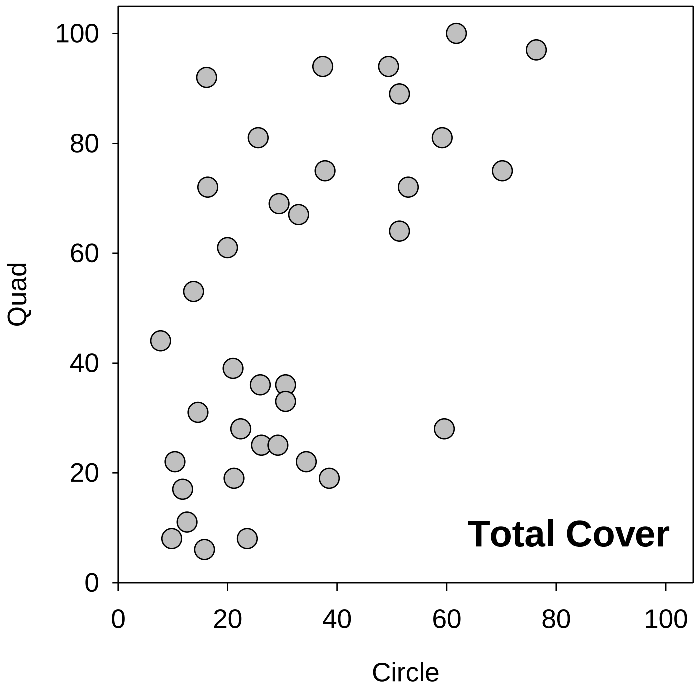


- Circle>Quad
- Relationship between measures is significant, but not great

Mean N_RICH_CIRCLE : 9.389
Mean N_RICH_QUAD : 2.889

N	36					
Multiple R	0.597					
Squared Multiple R	0.357					
Adjusted Squared Multiple R	0.338					
Standard Error of Estimate	1.345					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-0.006	0.703	0	.	-0.009	0.993
N_RICH_CIRCLE	0.308	0.071	0.597	1	4.342	0

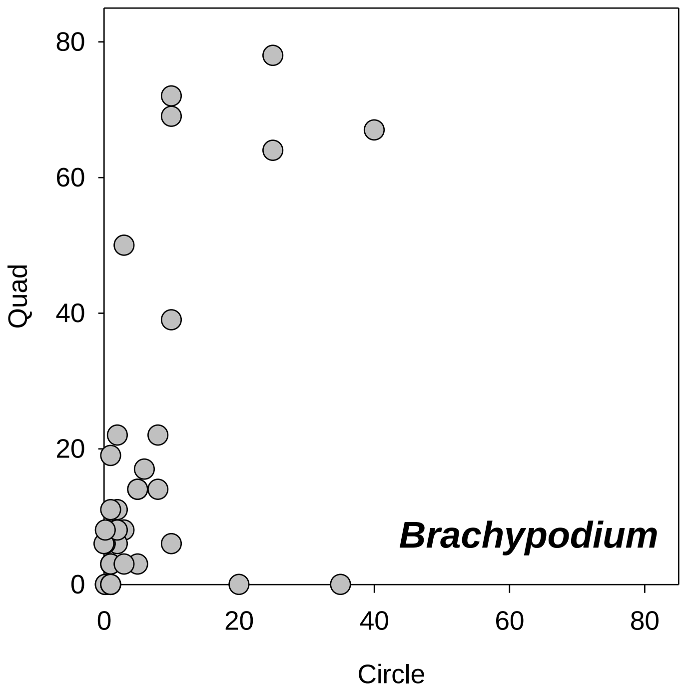
Total Cover



- Data log transformed
- Significantly different results
- Relationship between measures is significant, but poor

N	36					
Multiple R	0.533					
Squared Multiple R	0.284					
Adjusted Squared Multiple R	0.263					
Standard Error of Estimate	0.282					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	0.594	0.28	0	.	2.123	0.041
TOT_COVER_CIRCLE	0.698	0.19	0.533	1	3.669	0.001

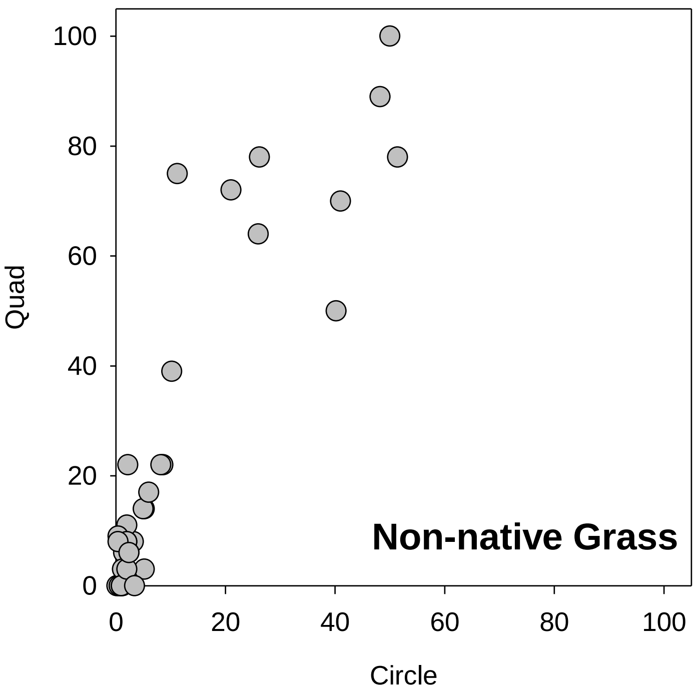
Brachypodium Cover



- Data log transformed
- Significantly different results
- Relationship between measures is significant, but poor

N	36					
Multiple R	0.441					
Squared Multiple R	0.194					
Adjusted Squared Multiple R	0.171					
Standard Error of Estimate	0.55					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std.	Tolerance	t	p-value
			Coefficient			
CONSTANT	0.557	0.161	0	.	3.455	0.001
BRADIS_CIRCLE	0.587	0.205	0.441	1	2.864	0.007

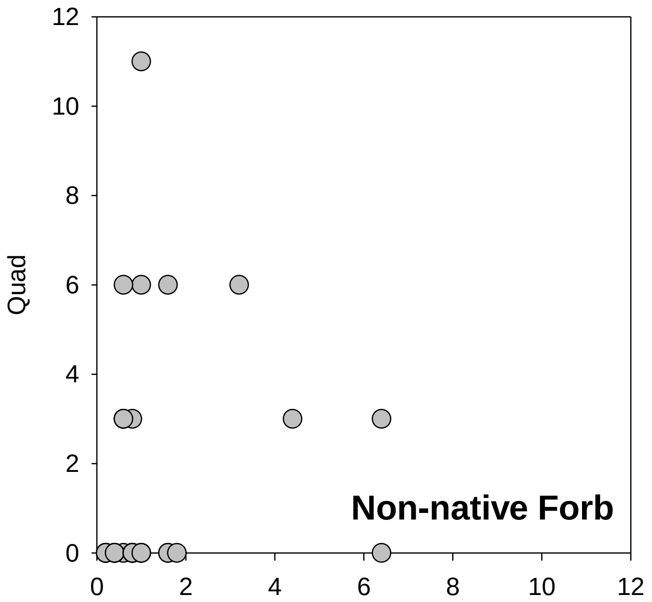
Nonnative Grass Cover



- Data log transformed
- Significantly different results
- Relationship between measures is significant and fairly strong

N	36					
Multiple R	0.845					
Squared Multiple R	0.713					
Adjusted Squared Multiple R	0.705					
Standard Error of Estimate	0.351					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std.	Tolerance	t	p-value
			Coefficient			
CONSTANT	0.214	0.108	0	.	1.994	0.054
NNG_CIRCLE	1.081	0.118	0.845	1	9.198	0

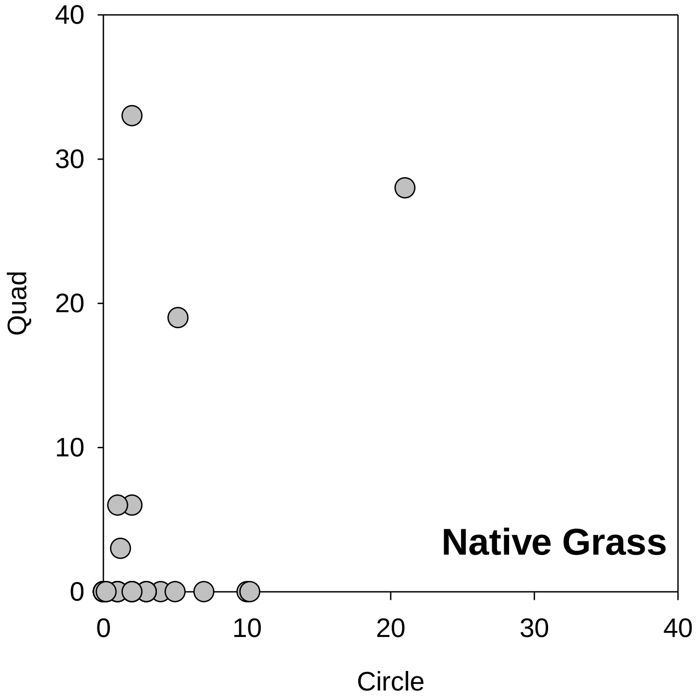
Nonnative Forb Cover



- Data log transformed
- Not significantly different
- Relationship approaching significance, but poor

N	36					
Multiple R	0.314					
Squared Multiple R	0.099					
Adjusted Squared Multiple R	0.072					
Standard Error of Estimate	0.341					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std.	Tolerance	t	p-value
			Coefficient			
CONSTANT	0.066	0.1	0	.	0.665	0.51
NNF_CIRCLE	0.548	0.284	0.314	1	1.93	0.062

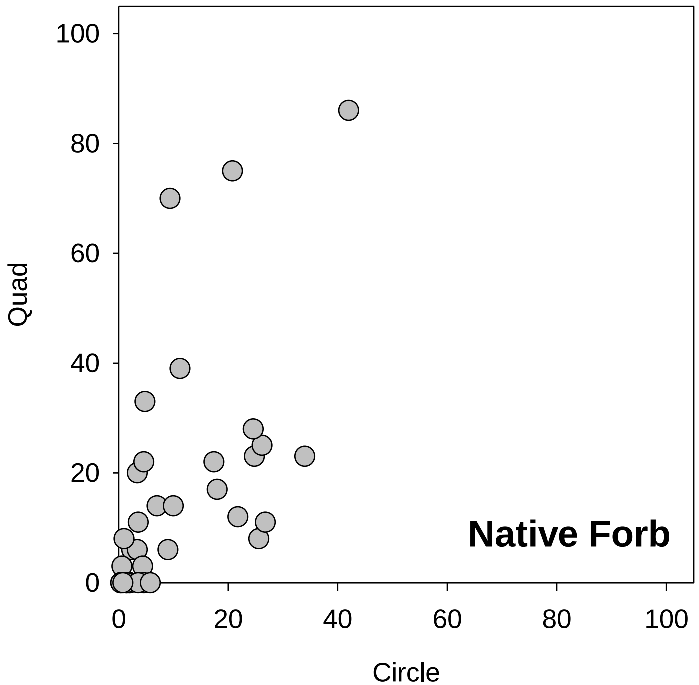
Native Grass Cover



- Data log transformed
- Significantly different results
- Relationship between measures is significant, but poor

N	36					
Multiple R	0.36					
Squared Multiple R	0.13					
Adjusted Squared Multiple R	0.104					
Standard Error of Estimate	0.416					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-0.001	0.107	0	.	-0.007	0.994
NG_CIRCLE	0.455	0.202	0.36	1	2.252	0.031

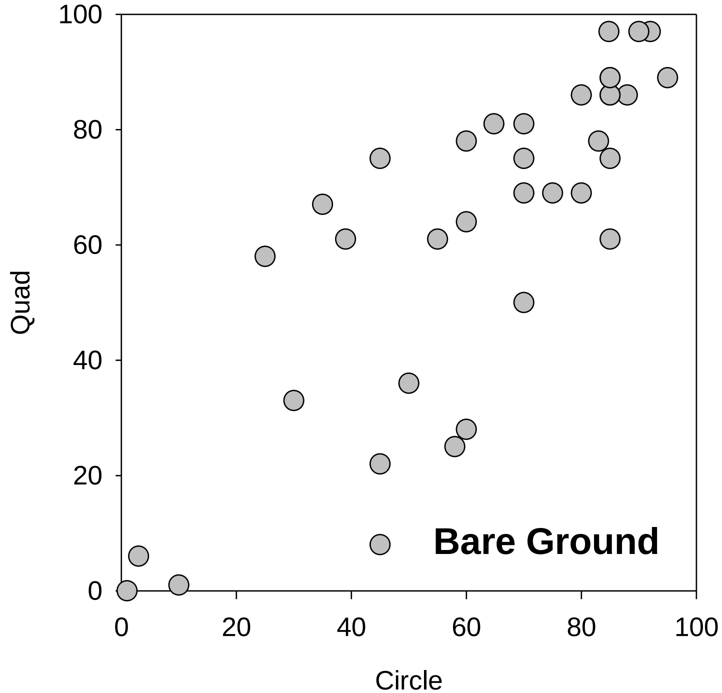
Native Forb Cover



- Data log transformed
- Results are not significantly different
- Relationship between measures is significant, and okay

N	36					
Multiple R	0.731					
Squared Multiple R	0.535					
Adjusted Squared Multiple R	0.521					
Standard Error of Estimate	0.452					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-0.049	0.164	0	.	-0.298	0.767
NF_CIRCLE	1.066	0.171	0.731	1	6.249	0

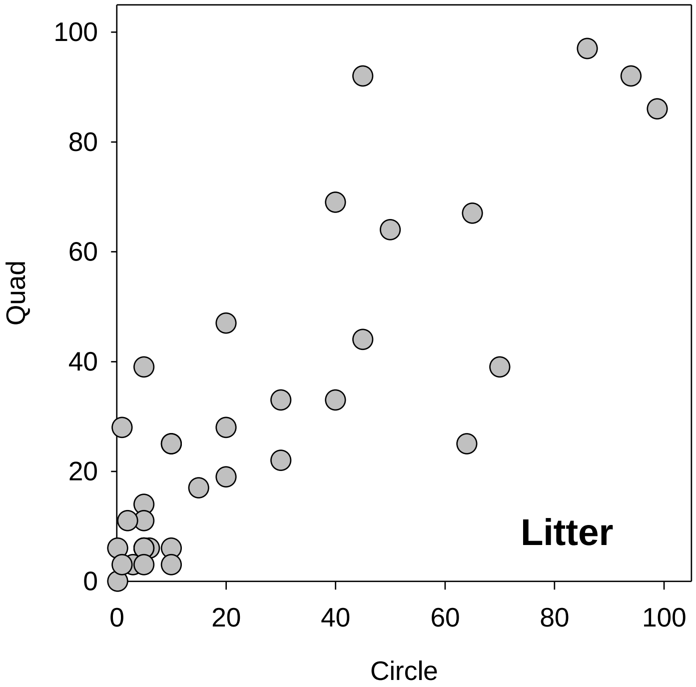
Bare Ground Cover



- Data log transformed
- Results are not significantly different
- Relationship between measures is significant, and strong

N	36					
Multiple R	0.871					
Squared Multiple R	0.758					
Adjusted Squared Multiple R	0.751					
Standard Error of Estimate	0.231					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std.	Tolerance	t	p-value
			Coefficient			
CONSTANT	-0.207	0.186	0	.	-1.113	0.274
BG_CIRCLE	1.097	0.106	0.871	1	10.321	0

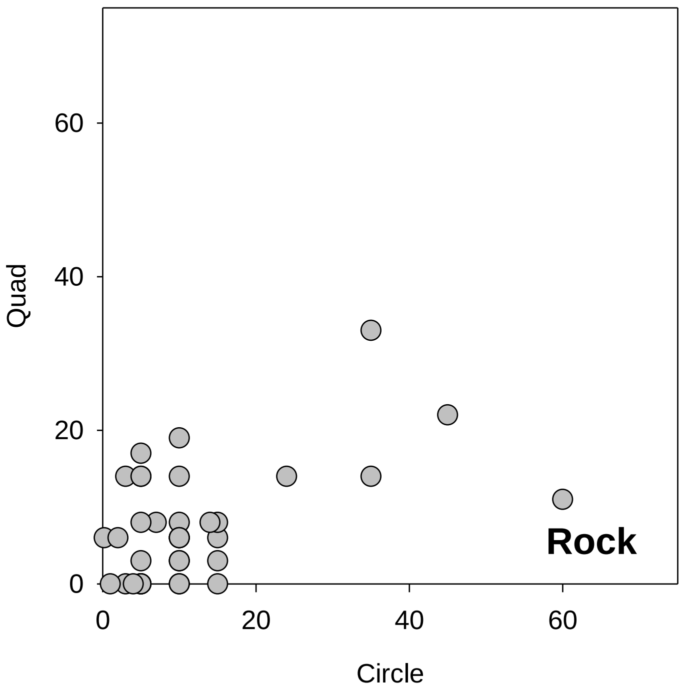
Litter Cover



- Data log transformed
- Results are significantly different
- Relationship between measures is significant, but poor

N	36					
Multiple R	0.802					
Squared Multiple R	0.643					
Adjusted Squared Multiple R	0.633					
Standard Error of Estimate	0.322					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	0.391	0.122	0	.	3.215	0.003
LITTER_CIRCLE	0.758	0.097	0.802	1	7.832	0

Rock Cover



- Data log transformed
- Results are significantly different
- Relationship between measures is significant but weak

N	36					
Multiple R	0.392					
Squared Multiple R	0.154					
Adjusted Squared Multiple R	0.129					
Standard Error of Estimate	0.465					
Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std.	Tolerance	t	p-value
			Coefficient			
CONSTANT	0.187	0.227	0	.	0.825	0.415
ROCK_CIRCLE	0.545	0.219	0.392	1	2.485	0.018

RANOVA

COASTAL SAGE SCRUB TREATMENT: CONTROL V. HERBICIDE

- 1st table: Warm colors indicate variables/interactions which explained a large amount of variance.
  2nd table: Yellow = a significant result. Green yellow = the variable was approaching significance. Blue = not significant
  Last table: % variance explained as a bar, significance indicated by bold

Herbicide in CSS

Variance components

	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	6%	0%	7%	17%	65%	66%	5%	3%	19%	9%	13%	0%
SITE	2%	1%	1%	7%	0%	0%	3%	15%	2%	19%	5%	35%
SITE*FULL_TREATMENT	26%	27%	3%	9%	1%	1%	3%	11%	2%	4%	7%	0%
YEAR	0%	2%	5%	6%	11%	13%	2%	0%	0%	1%	2%	3%
YEAR*FULL_TREATMENT	0%	0%	1%	9%	1%	1%	0%	0%	1%	2%	0%	3%
YEAR*SITE	14%	6%	7%	0%	0%	1%	2%	1%	3%	3%	4%	11%
YEAR*SITE*FULL_TREATMENT	1%	0%	0%	15%	2%	2%	1%	0%	0%	0%	2%	0%
Tot. Var. Exp.	49%	37%	23%	63%	81%	84%	17%	30%	27%	38%	34%	53%

P-values

	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	0.124	0.759	0.266	0.002	0	0	0.286	0.465	0.053	0.106	0.102	0.787
SITE	0.351	0.542	0.633	0.028	0.784	0.455	0.445	0.09	0.528	0.024	0.298	0.001
SITE*FULL_TREATMENT	0.005	0.011	0.476	0.014	0.121	0.149	0.415	0.145	0.527	0.245	0.221	0.945
YEAR	0.956	0.225	0.01	0.069	0.005	0.001	0.295	0.96	0.954	0.469	0.088	0.166
YEAR*FULL_TREATMENT	0.703	0.755	0.156	0.031	0.297	0.275	0.655	0.564	0.317	0.312	0.362	0.161
YEAR*SITE	0.005	0.058	0.003	0.827	0.486	0.382	0.239	0.147	0.118	0.157	0.011	0.016
YEAR*SITE*FULL_TREATMENT	0.481	0.876	0.365	0.007	0.146	0.112	0.345	0.883	0.622	0.666	0.063	0.659

Variance decomp + P-values

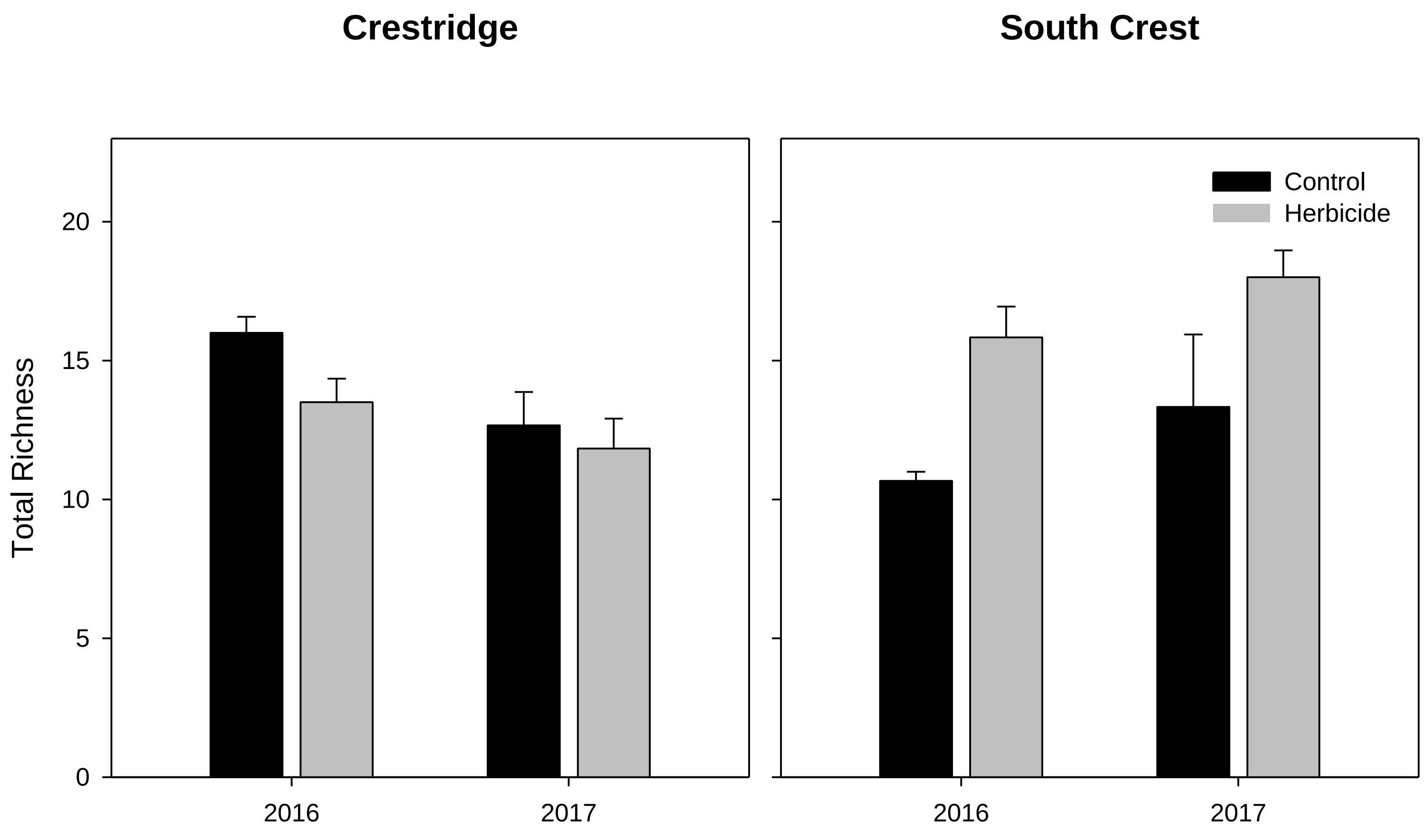
	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	6%	0%	7%	**17%**	**65%**	**66%**	5%	3%	19%	9%	13%	0%
SITE	2%	1%	1%	**7%**	0%	0%	3%	**15%**	2%	**19%**	5%	**35%**
SITE*FULL_TREATMENT	**26%**	**27%**	3%	**9%**	1%	1%	3%	11%	2%	4%	7%	0%
YEAR	0%	2%	**5%**	6%	**11%**	**13%**	2%	0%	0%	1%	**2%**	3%
YEAR*FULL_TREATMENT	0%	0%	1%	**9%**	1%	1%	0%	0%	1%	2%	0%	3%
YEAR*SITE	**14%**	6%	**7%**	0%	0%	1%	2%	1%	3%	3%	**4%**	**11%**
YEAR*SITE*FULL_TREATMENT	1%	0%	0%	**15%**	2%	2%	1%	0%	0%	0%	**2%**	0%
Tot. Var. Exp.	49%	37%	23%	63%	81%	84%	17%	30%	27%	38%	34%	53%

Signficant

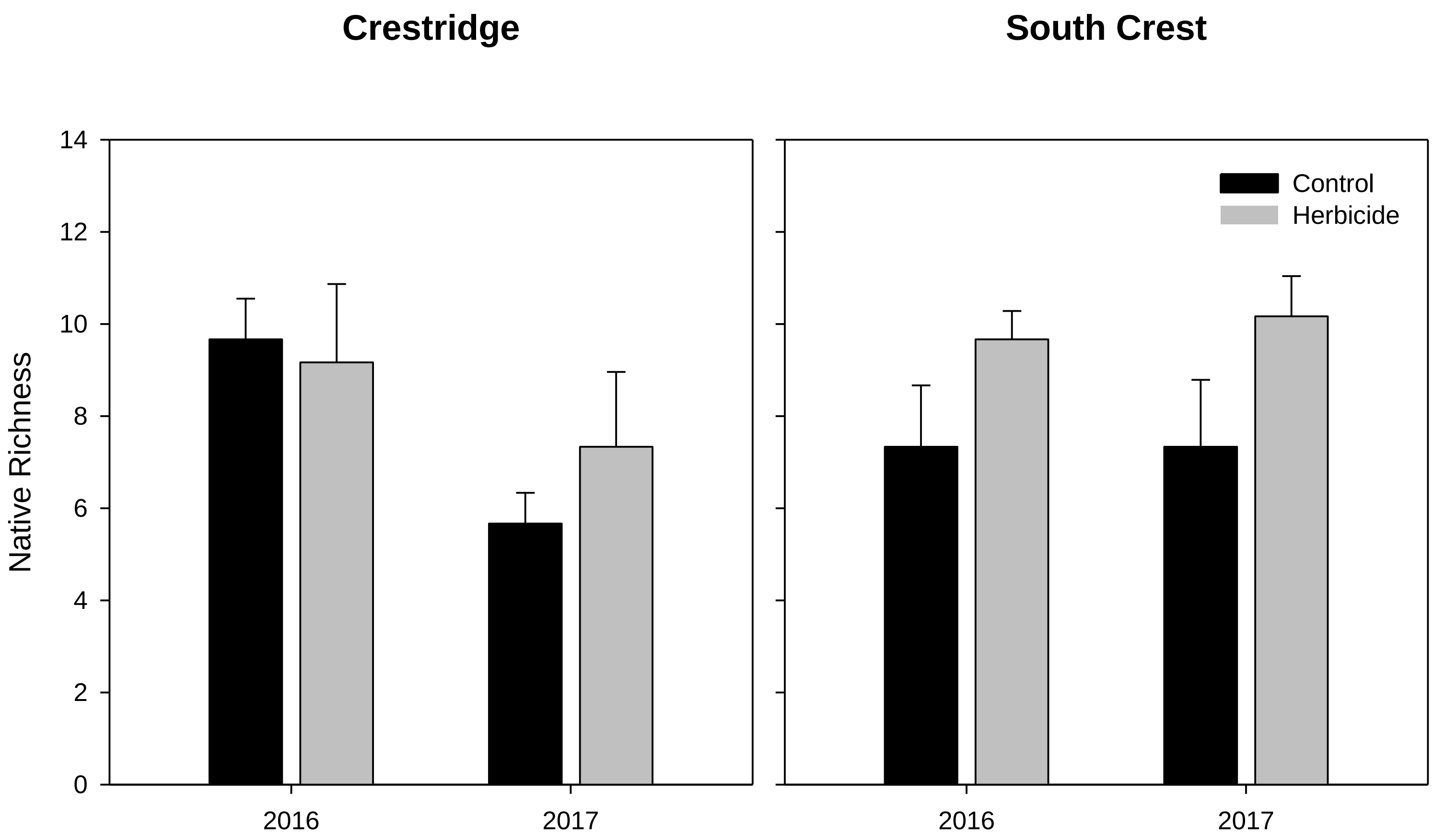
Approacing signficance

Not signficant

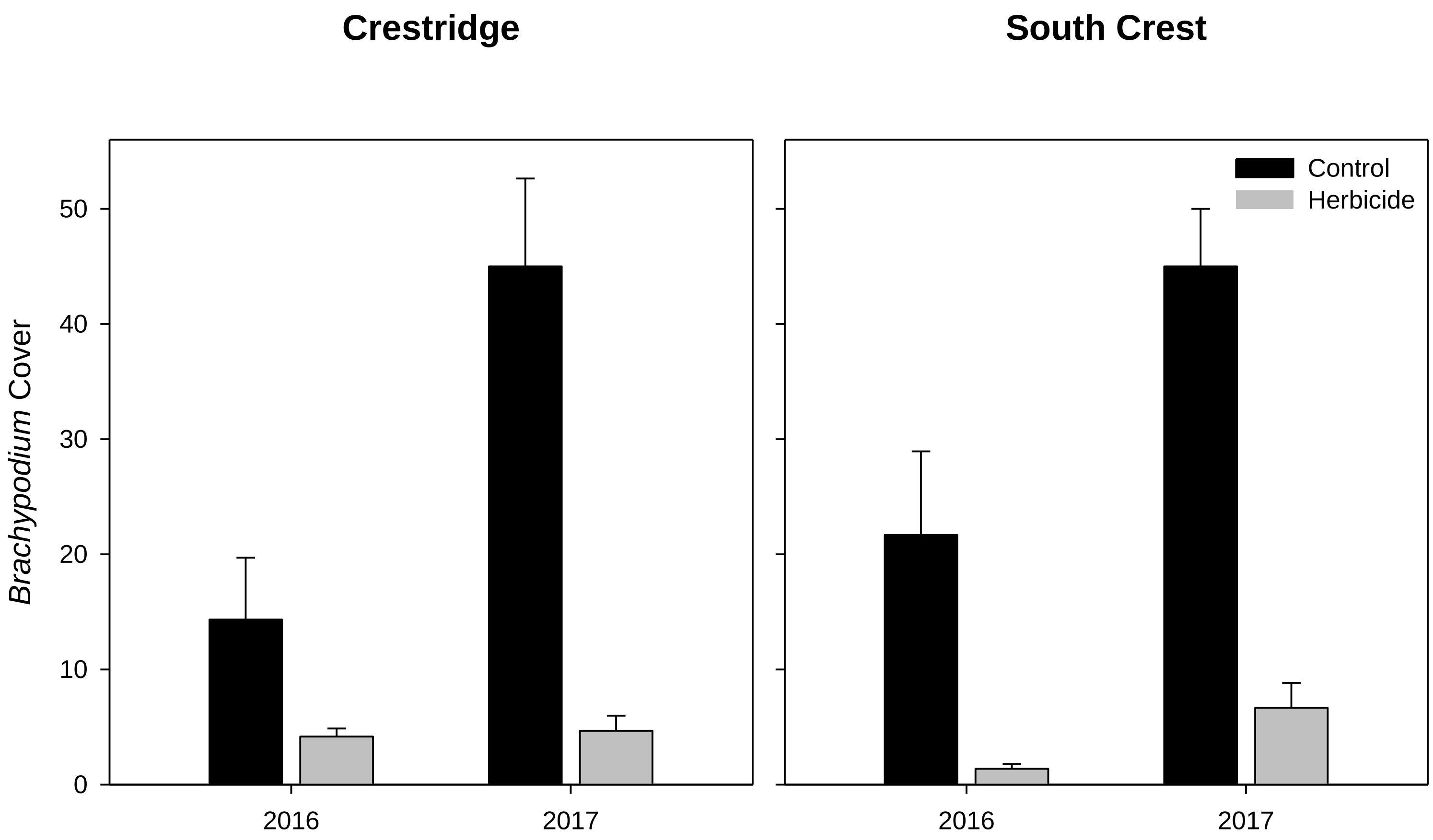
Total Species Richness



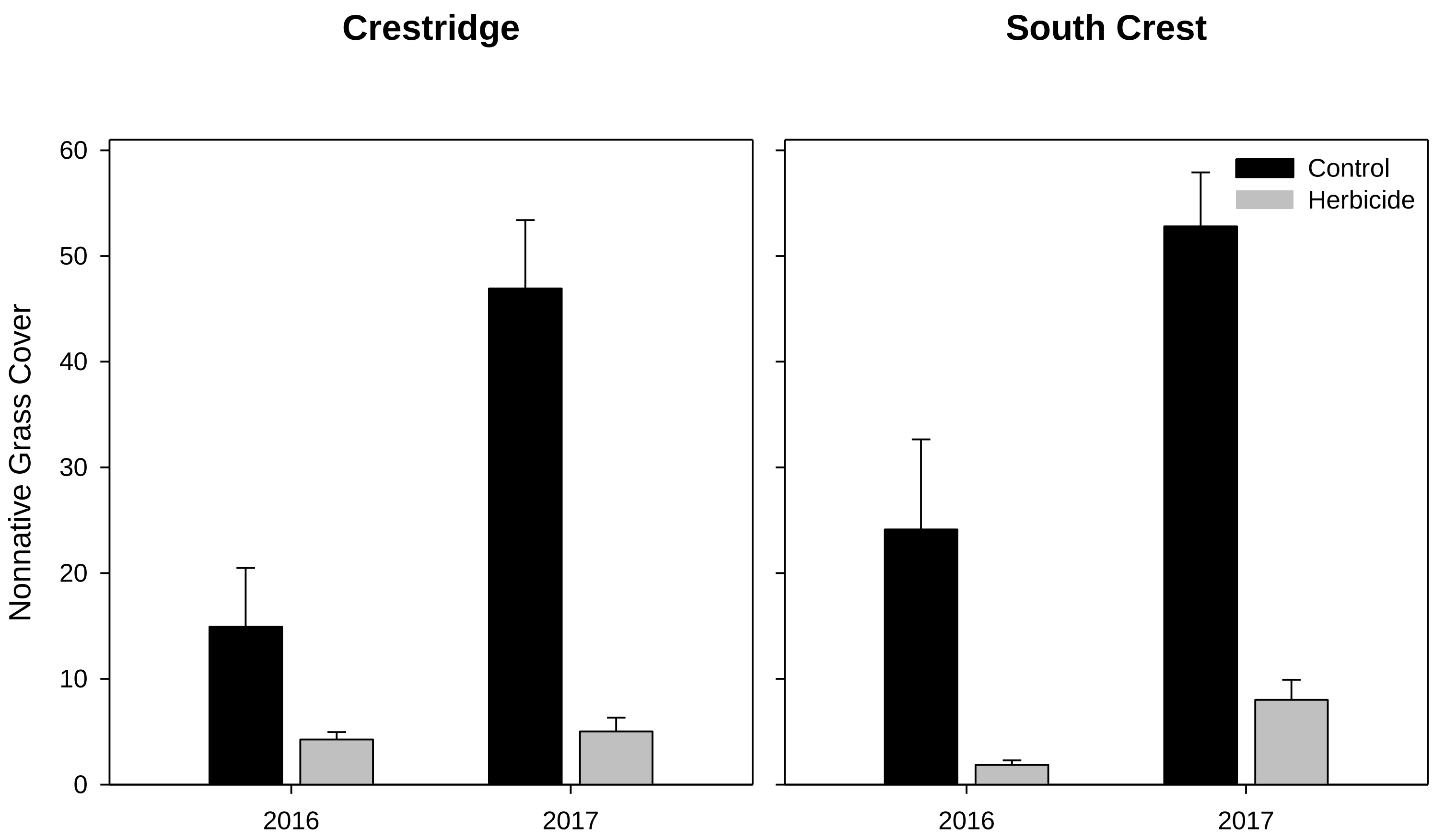
Native Species Richness



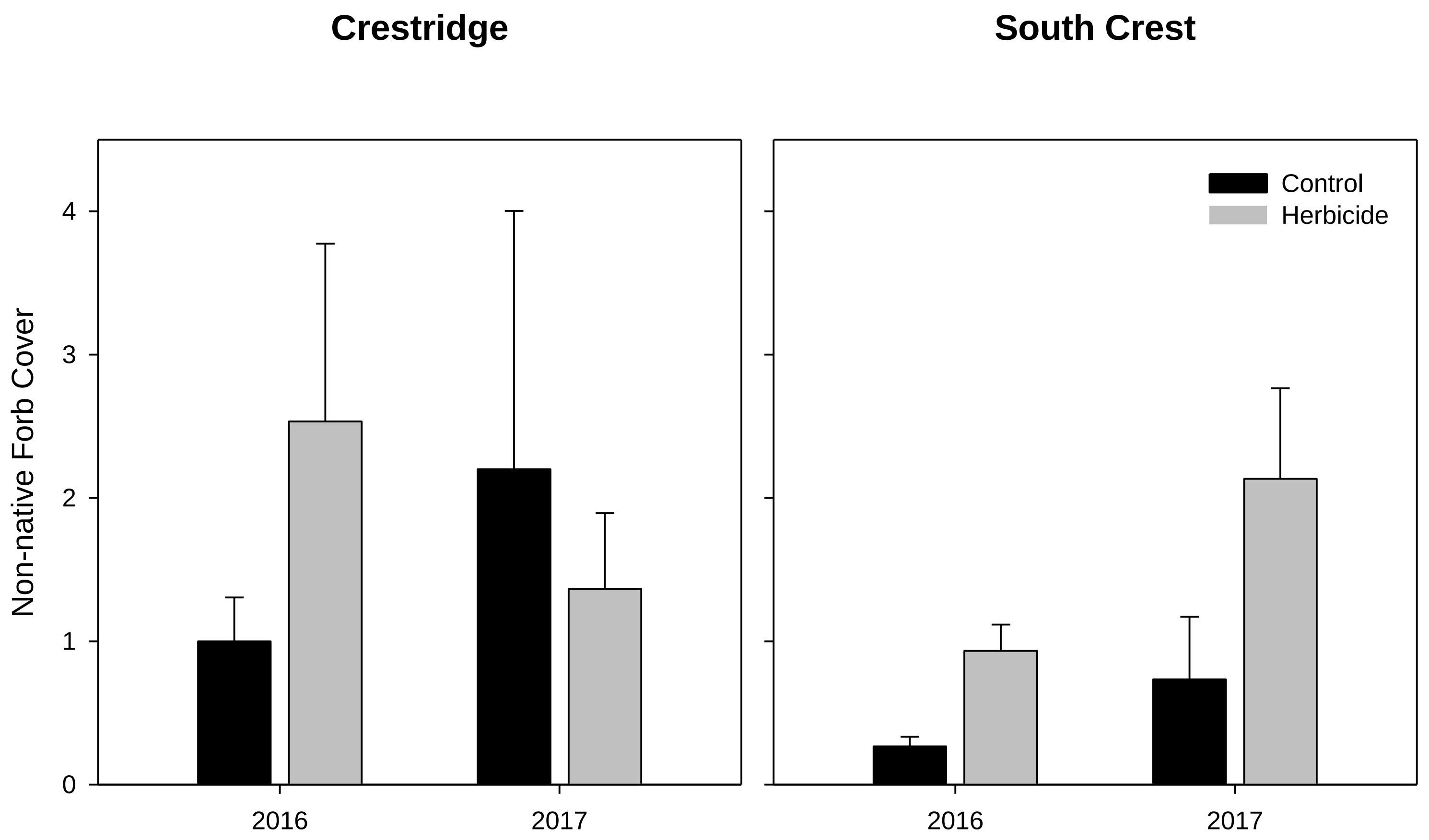
Brachypodium Cover



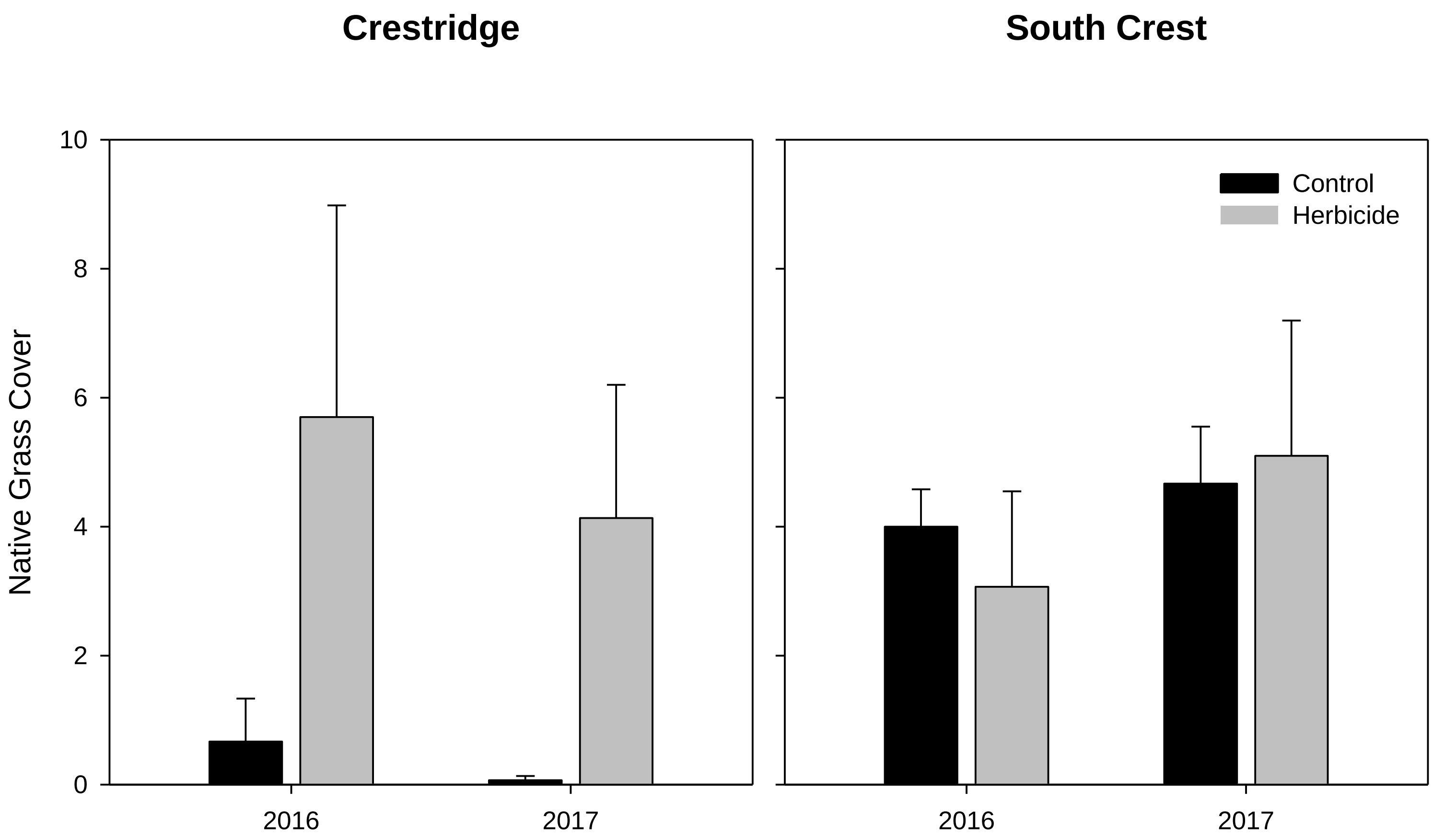
Nonnative Grass Cover



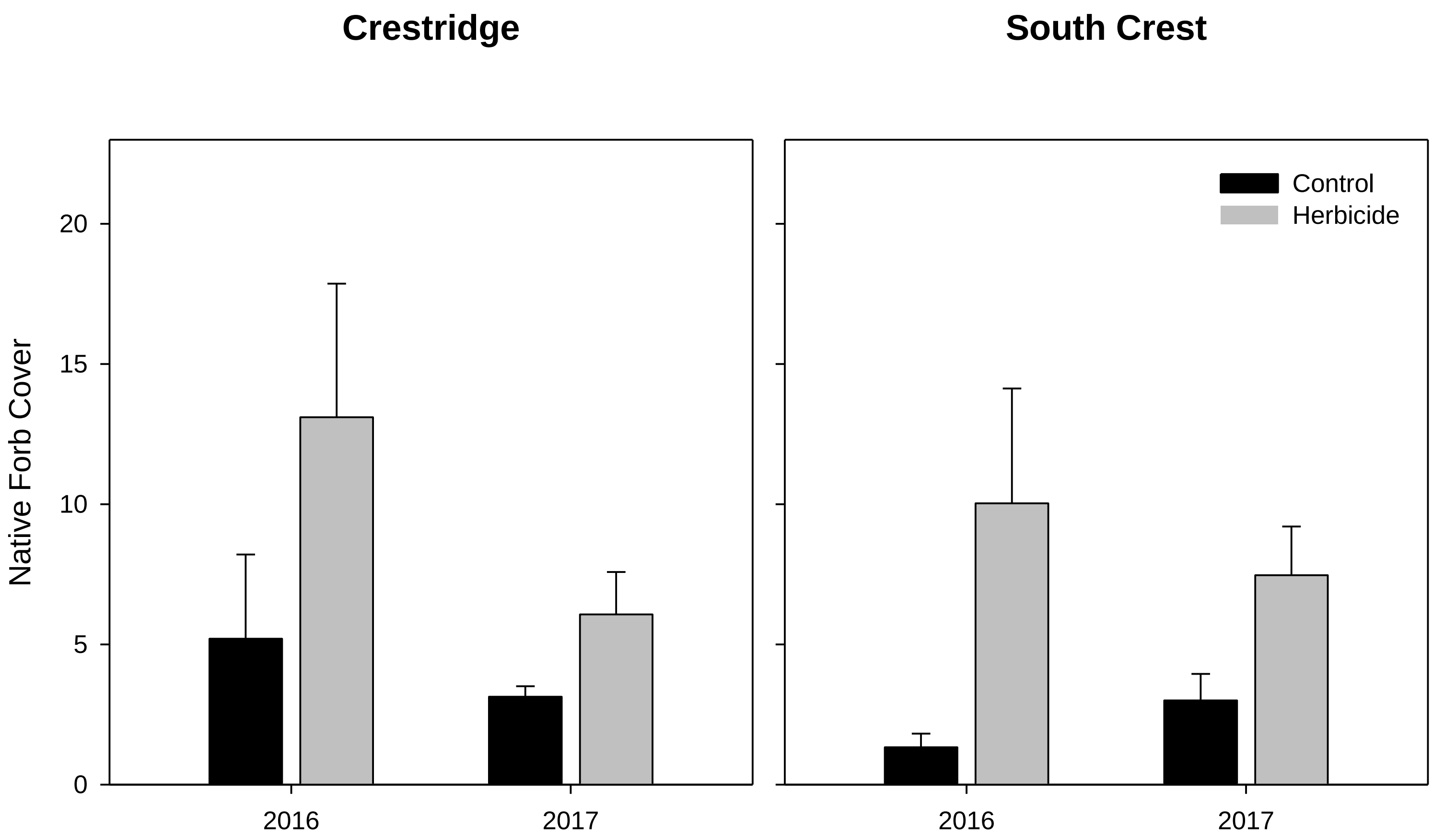
Nonnative Forb Cover



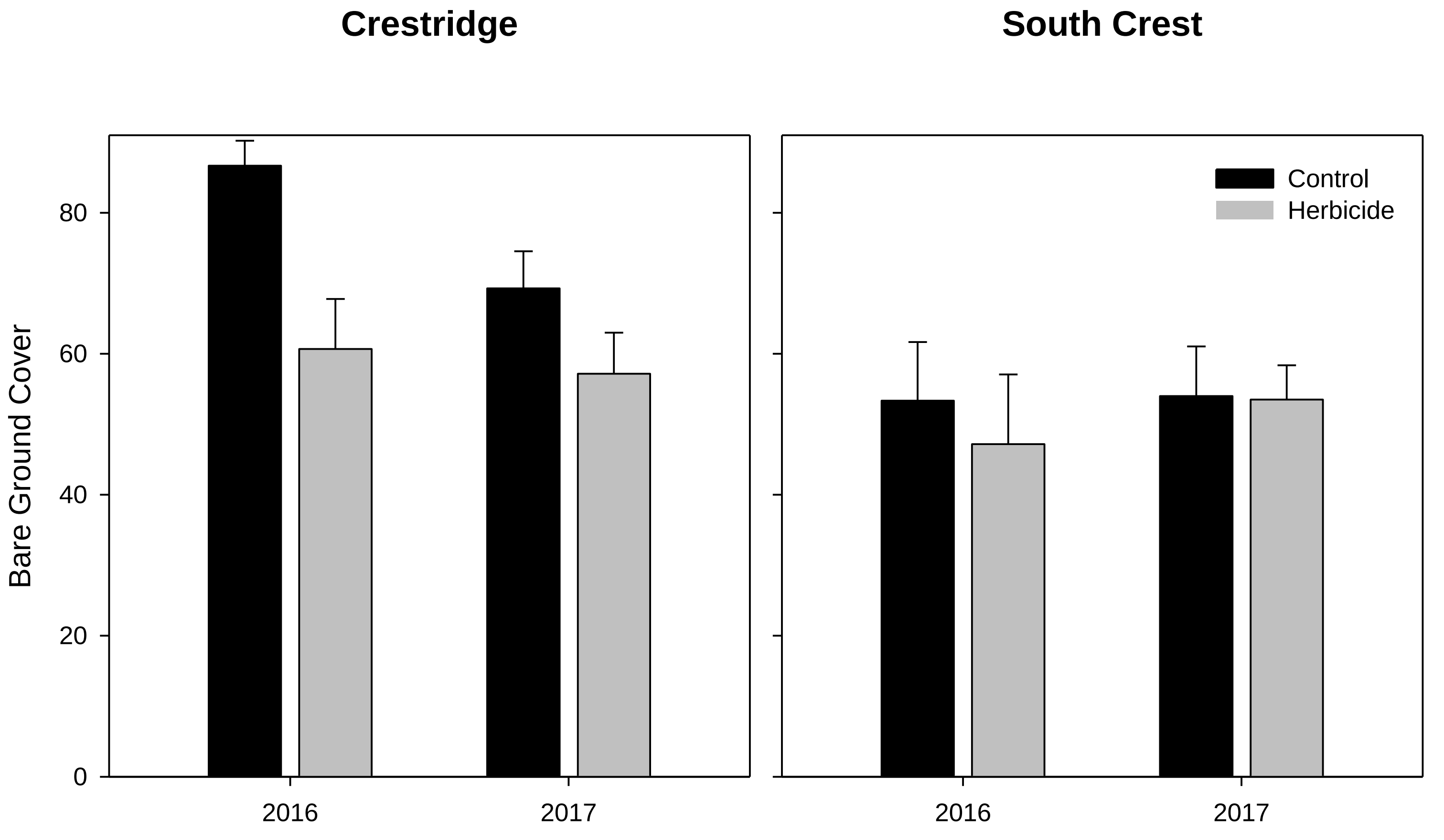
Native Grass Cover



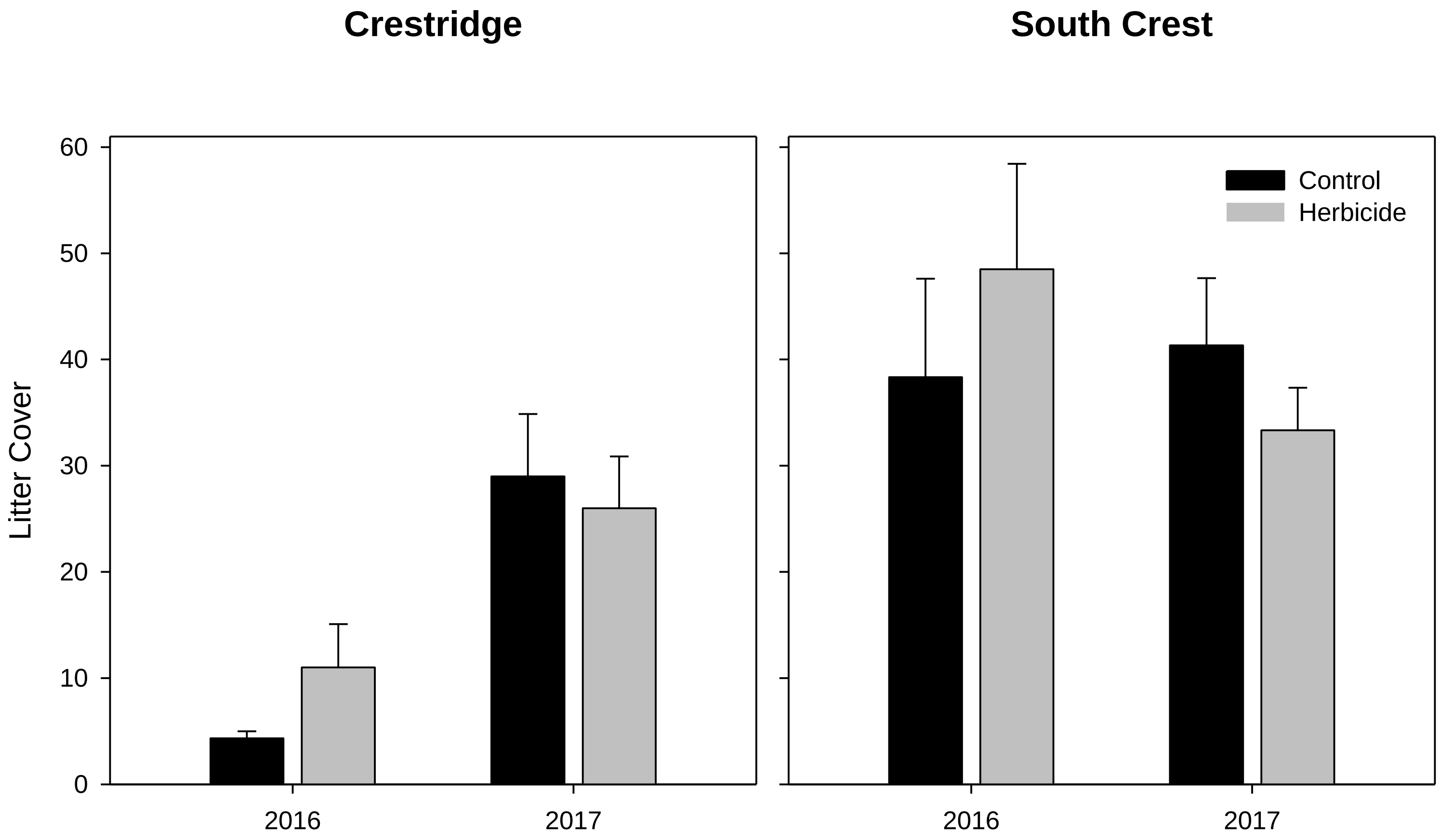
Native Forb Cover



Bare Ground Cover



Litter Cover



RANOVA

NONNATIVE GRASSLAND TREATMENT: DETHATCH + SEED+ HERBICIDE (D+S+H) V. CONTROL

Herbicide and Seed in NNGL

variance decomposition

	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	38%	9%	43%	33%	67%	86%	0%	7%	35%	17%	16%	22%
SITE	0%	3%	1%	1%	12%	0%	0%	30%	27%	46%	2%	42%
SITE*FULL_TREATMENT	28%	14%	26%	5%	2%	3%	31%	0%	2%	14%	5%	15%
YEAR	0%	0%	0%	20%	6%	4%	2%	0%	0%	2%	5%	3%
YEAR*FULL_TREATMENT	3%	12%	0%	1%	1%	0%	11%	1%	4%	0%	1%	0%
YEAR*SITE	0%	3%	0%	0%	1%	1%	0%	1%	3%	0%	8%	1%
YEAR*SITE*FULL_TREATMENT	0%	3%	0%	3%	0%	0%	15%	2%	0%	0%	0%	0%
Tot. Var. Exp.	70%	45%	71%	65%	89%	94%	59%	41%	70%	80%	37%	84%

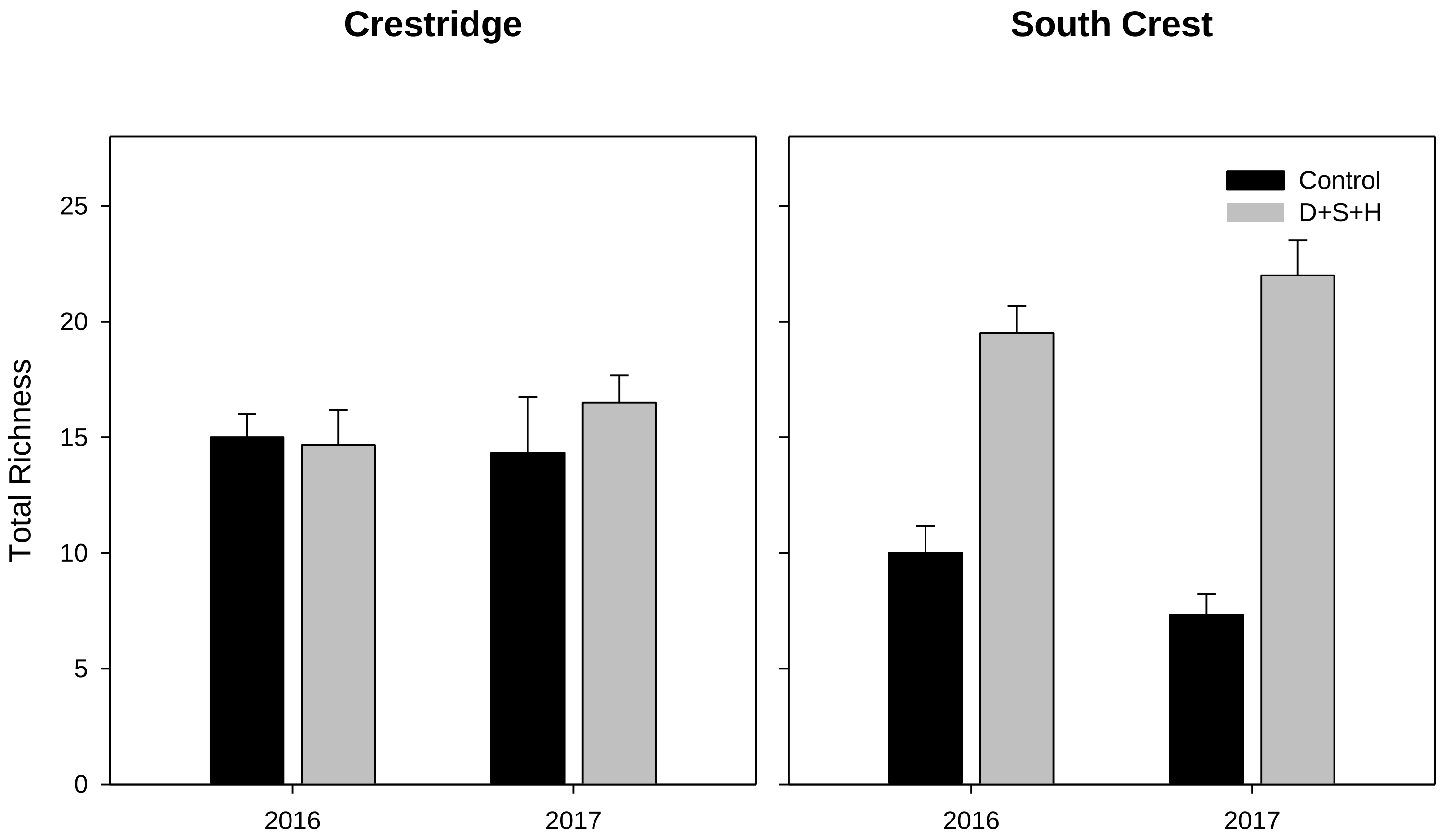
P-values

	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	0	0.11	0	0	0	0	0.686	0.13	0	0	0.064	0
SITE	0.76	0.312	0.327	0.35	0	0.812	0.661	0.006	0.001	0	0.474	0
SITE*FULL_TREATMENT	0.001	0.054	0	0.08	0.057	0.005	0	0.818	0.24	0	0.258	0
YEAR	0.76	0.225	0.495	0	0.001	0	0.259	0.918	0.592	0.138	0.01	0.035
YEAR*FULL_TREATMENT	0.031	0.755	0.495	0.291	0.262	0.274	0.017	0.469	0.037	0.973	0.296	0.836
YEAR*SITE	0.684	0.058	0.495	0.594	0.215	0.121	0.743	0.529	0.077	0.736	0.002	0.249
YEAR*SITE*FULL_TREATMENT	0.419	0.876	0.819	0.077	0.777	0.65	0.007	0.248	0.973	0.519	0.77	0.454

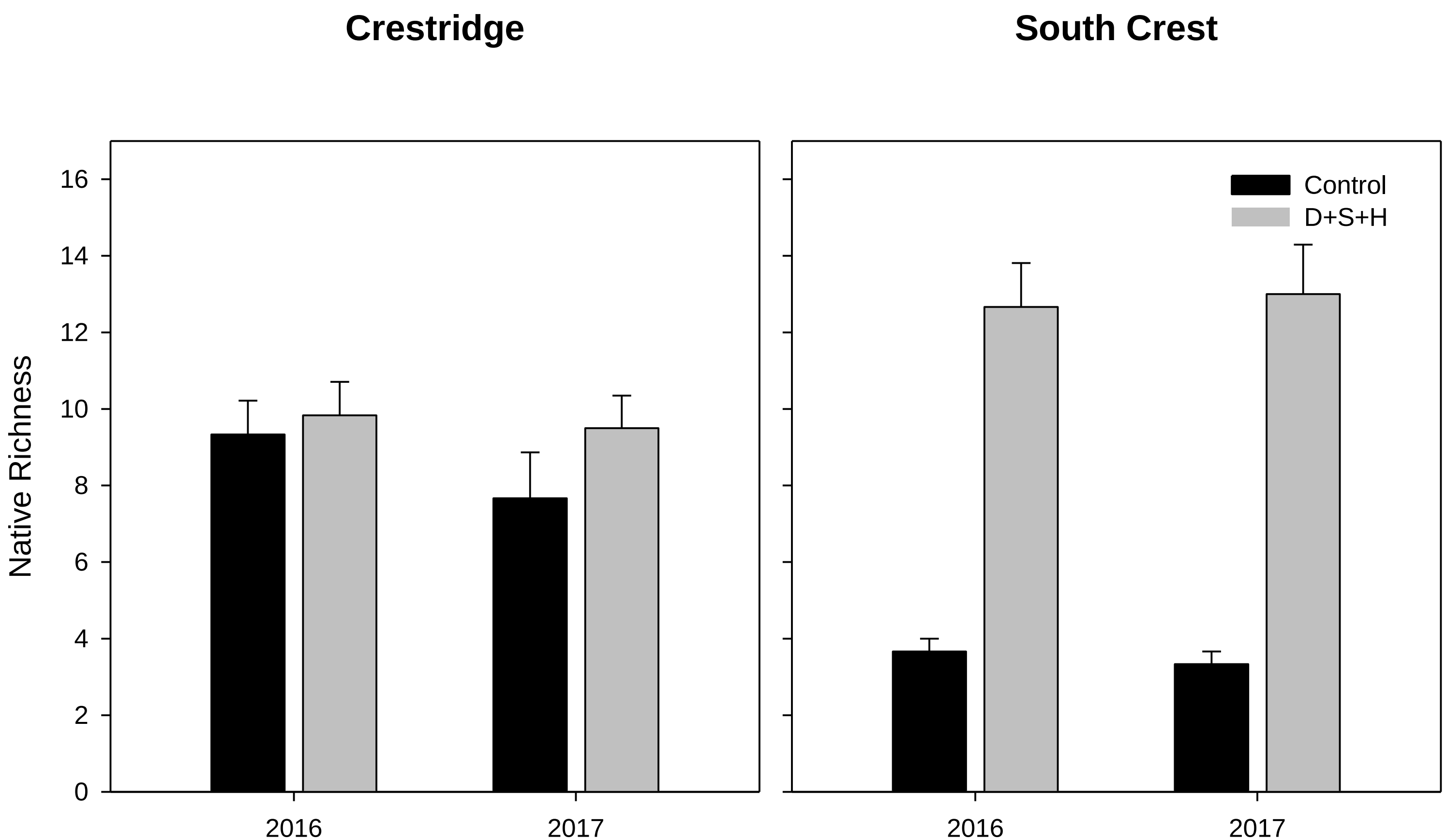
Variance decomp+ P-value

	Total Richness	NN Richness	Native Richness	Total Cover	Bradis Cover	NNG Cover	NNF Cover	NG Cover	NF Cover	Bare Ground	Rock	Litter
FULL_TREATMENT	**38%**	9%	**43%**	**33%**	**67%**	**86%**	0%	7%	**35%**	**17%**	16%	**22%**
SITE	0%	3%	1%	1%	**12%**	0%	0%	**30%**	**27%**	**46%**	2%	**42%**
SITE*FULL_TREATMENT	**28%**	14%	**26%**	5%	2%	**3%**	**31%**	0%	2%	**14%**	5%	**15%**
YEAR	0%	0%	0%	**20%**	**6%**	**4%**	2%	0%	0%	2%	**5%**	**3%**
YEAR*FULL_TREATMENT	**3%**	12%	0%	1%	1%	0%	**11%**	1%	**4%**	0%	1%	0%
YEAR*SITE	0%	3%	0%	0%	1%	1%	0%	1%	3%	0%	**8%**	1%
YEAR*SITE*FULL_TREATMENT	0%	3%	0%	3%	0%	0%	**15%**	2%	0%	0%	0%	0%
Tot. Var. Exp.	70%	45%	71%	65%	89%	94%	59%	41%	70%	80%	37%	84%

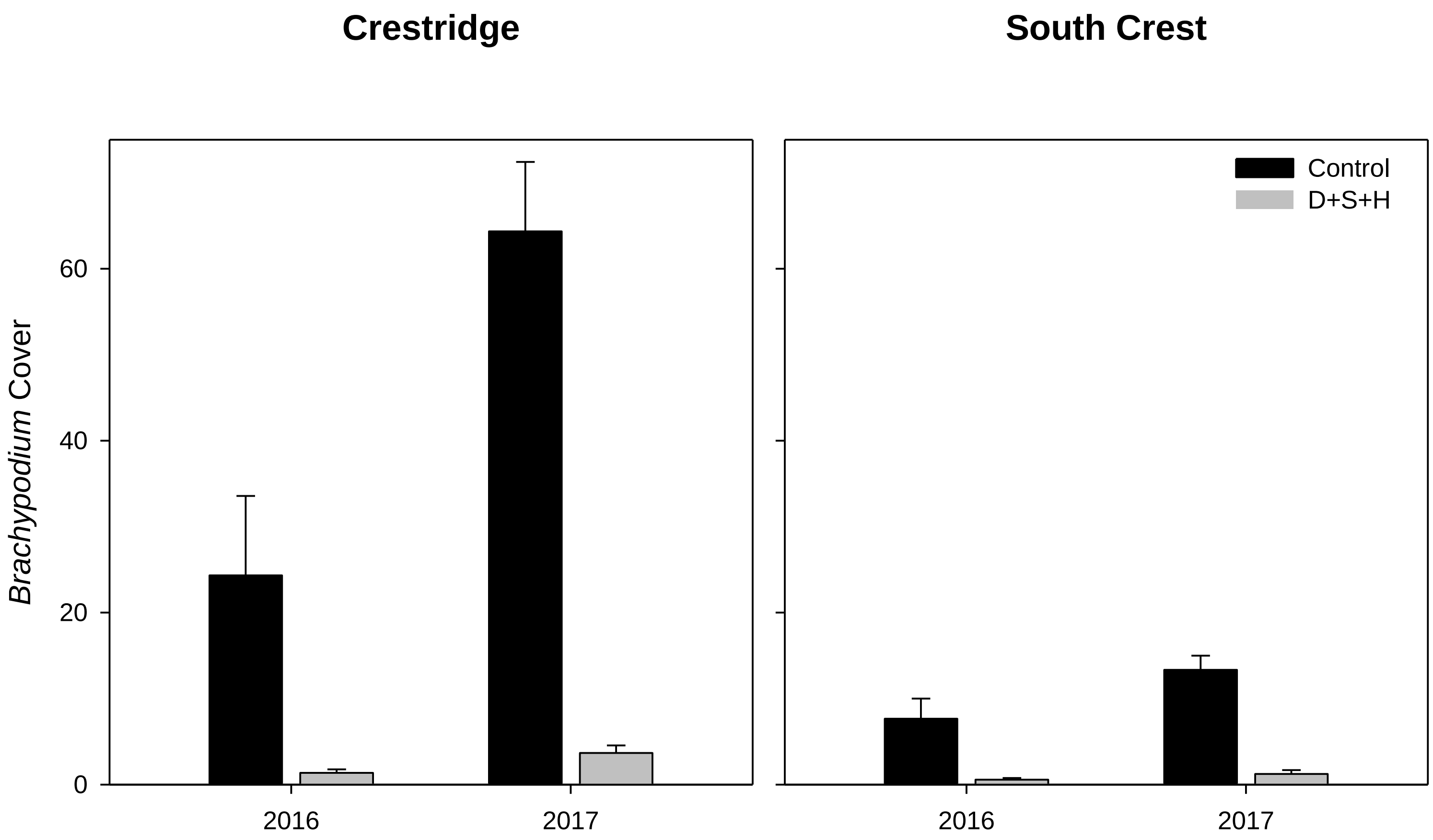
Total Species Richness



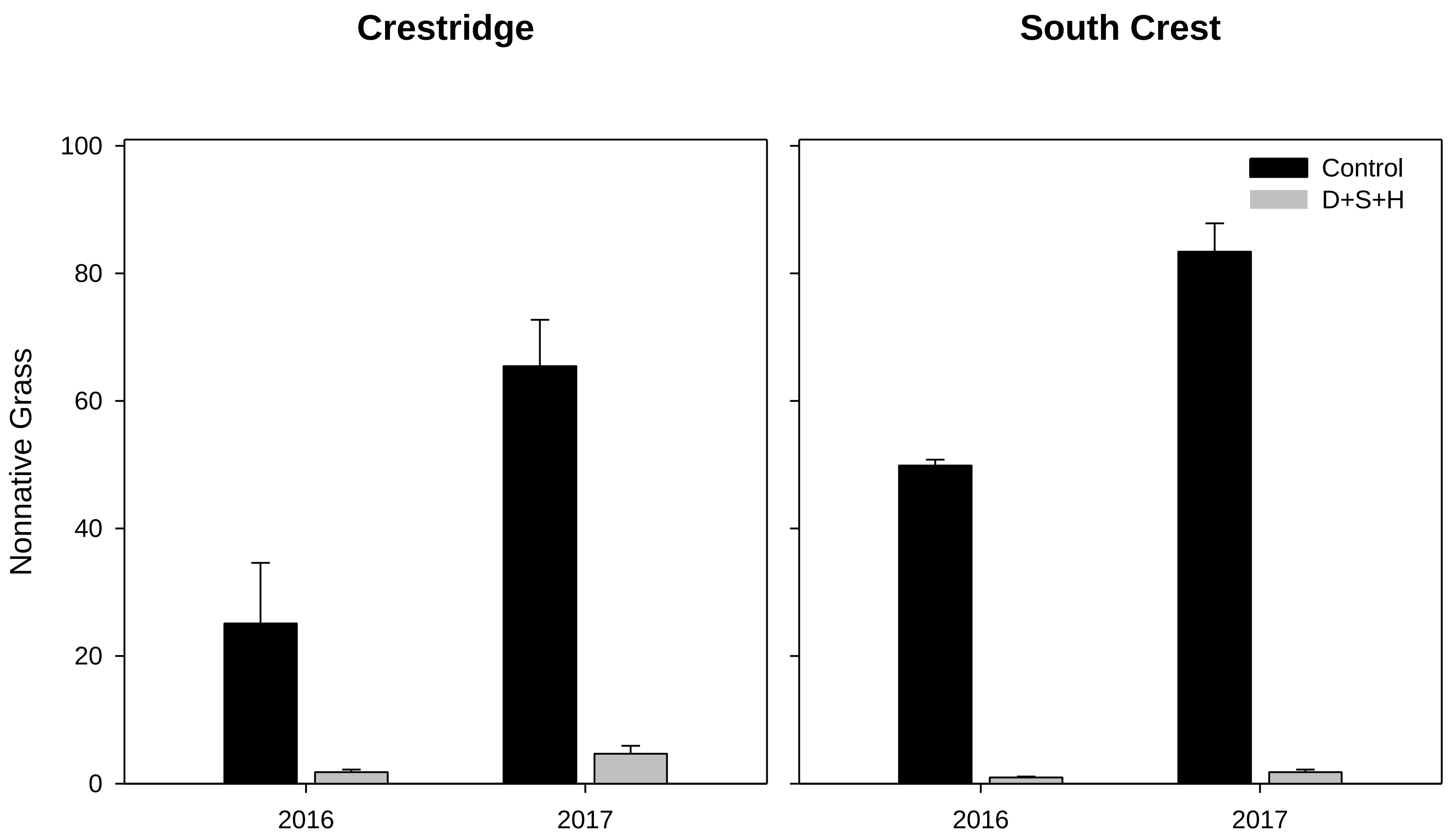
Native Species Richness



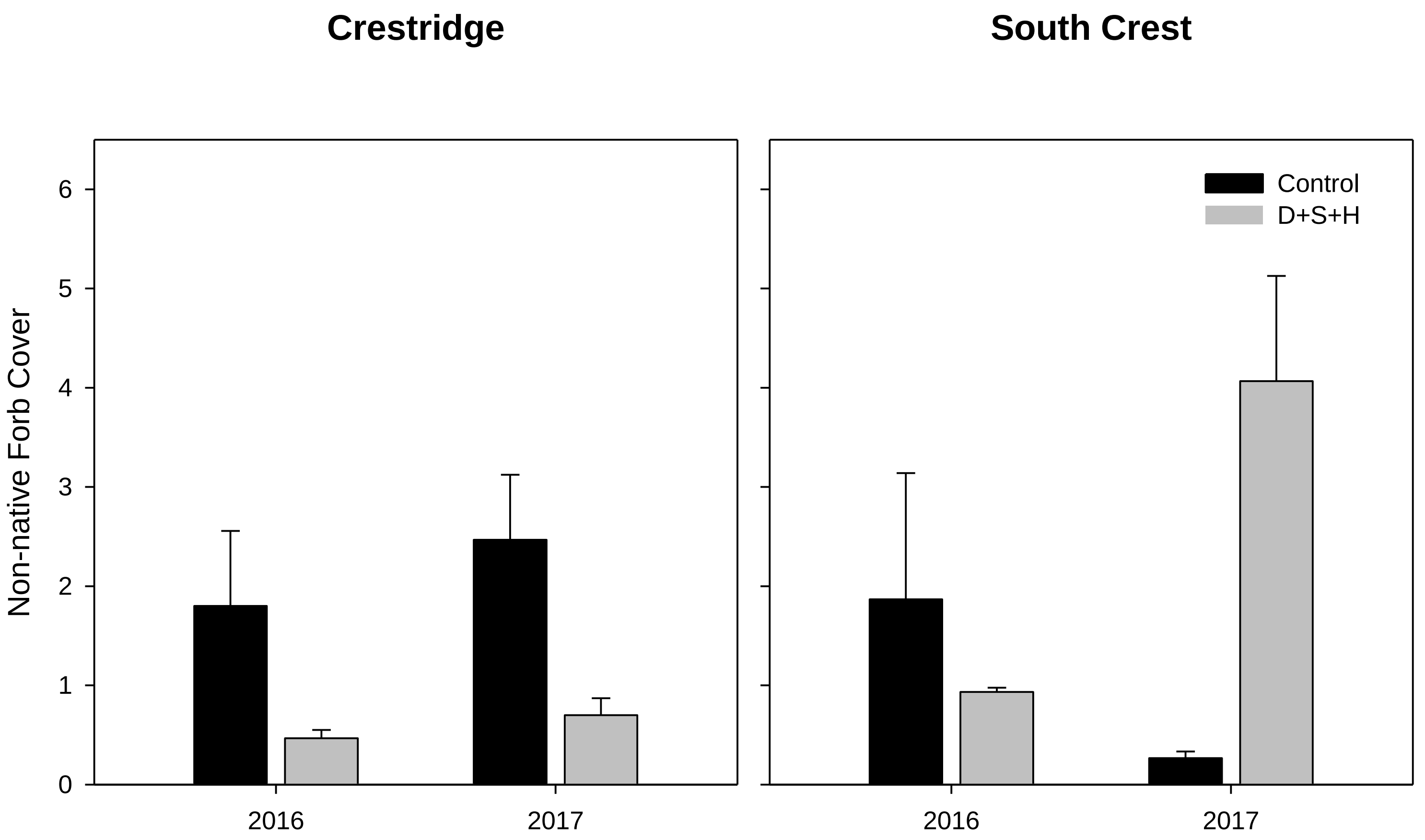
Brachypodium Cover



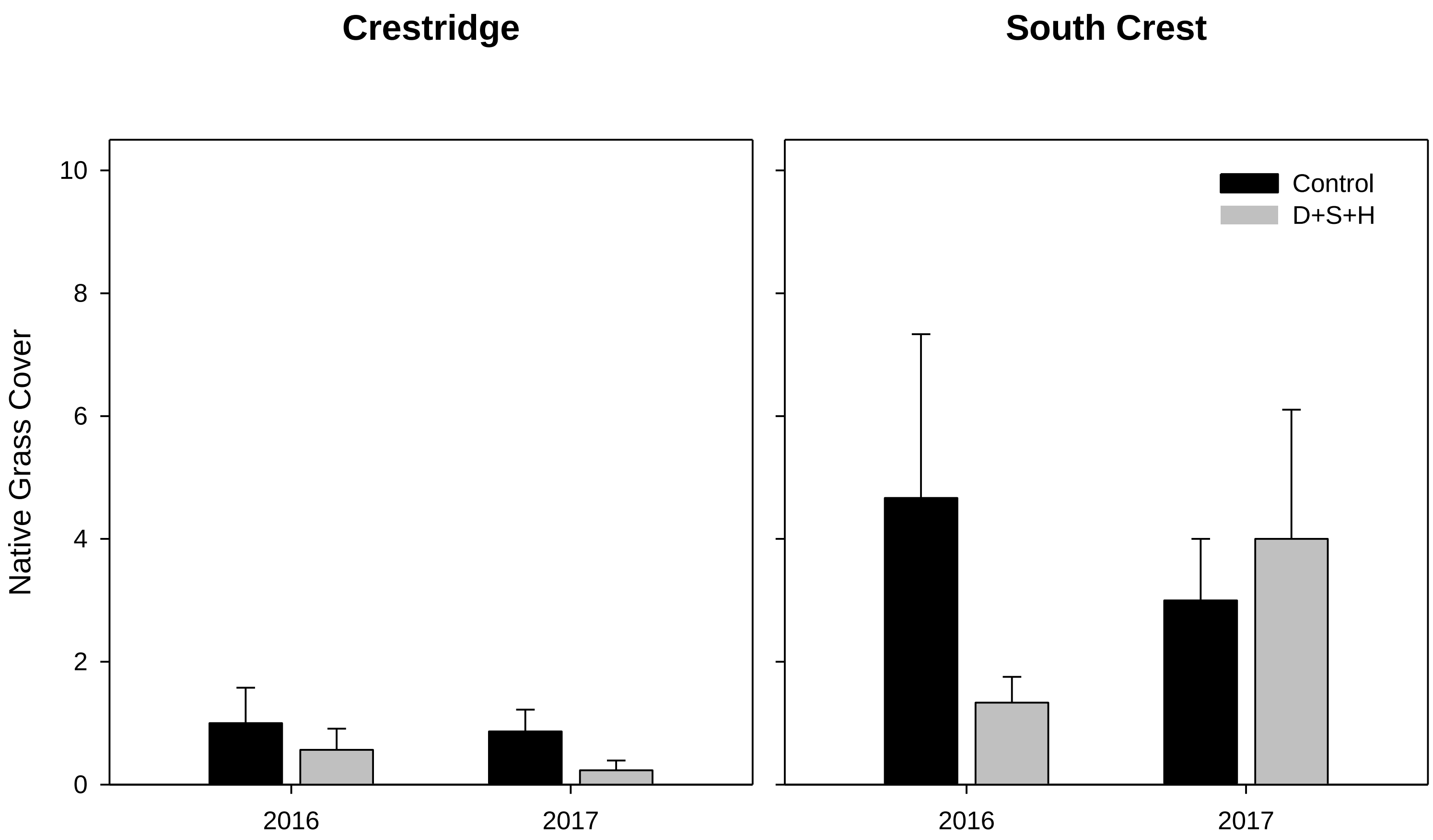
Nonnative Grass Cover



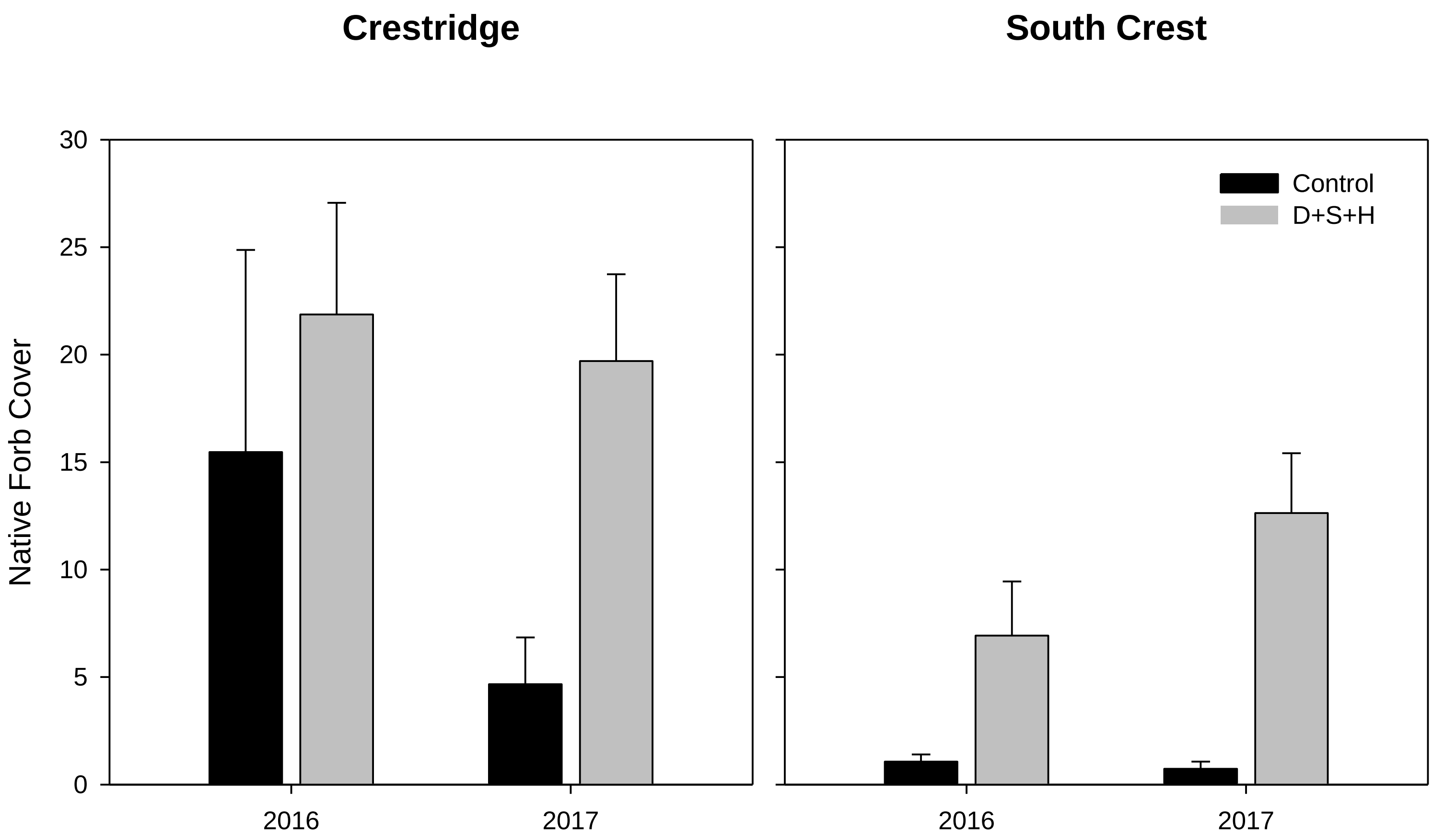
Nonnative Forb Cover



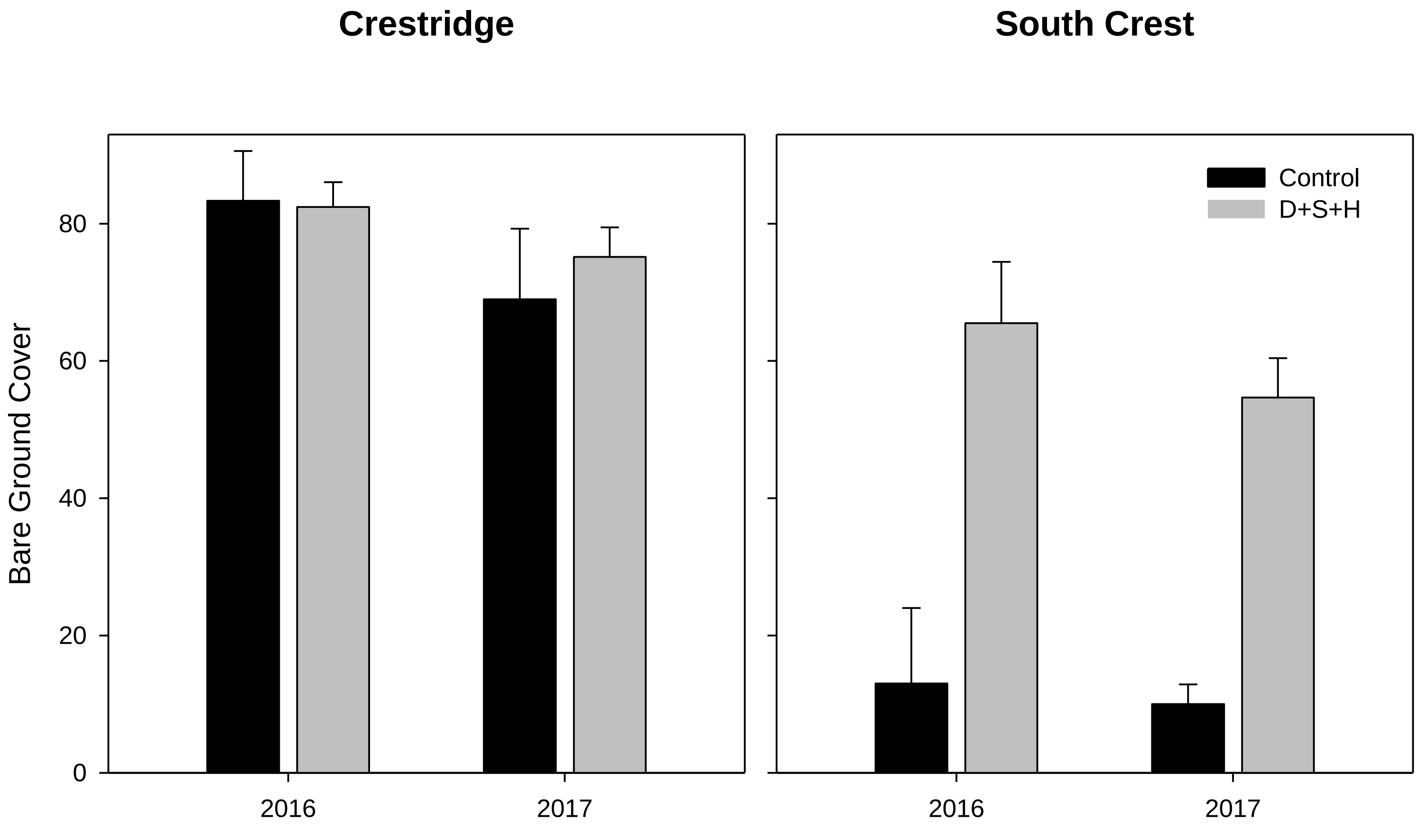
Native Grass Cover



Native Forb Cover



Bare Ground Cover



Litter Cover