Heavenly Creek SEZ Demonstration Project
2016 Vegetation Monitoring Report

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EXECUTIVE SUMMARY

This report addresses riparian vegetation changes between 2006/2007 (pre-project) and 2016 (9 years post-project) following the 2007 mechanical treatments within the Heavenly Creek SEZ Fuels Reduction Project area. This is one component of a larger monitoring effort as documented in the Heavenly SEZ Fuels Reduction Project Monitoring Plan (Norman 2007). The intent of this component of the monitoring project was to track vegetation response over time at the Heavenly Creek SEZ fuel reduction site. Vegetation conditions were monitored along 12 transects within four treatment units during five monitoring events (pre-project: 2006/2007 and post project: 2008, 2010, 2012, and 2016).

As of 2016, all four project objectives were met. The first objective, to maintain or increase pre-project cover of native herbaceous plants (graminoids and forbs) and native shrubs, was met. As of 2016 native herbaceous plant cover and native shrub cover are not significantly different than pre-project levels. Vegetative cover steadily decreased from an average of 23.72% at pre-project to its lowest point of 7.53% in 2010. In 2012 percent cover began an upward trend increasing to an average 15.58%, not being significantly different from 2008 which averaged 14.22%. In 2016 percent cover increased to 22.64%, returning to pre-project conditions. These results indicate that recovery of herbaceous plant cover began to occur four to five years post-project and has fully recovered to pre-project conditions after six to nine years. Shrub cover in 2016 did not significantly differ from pre-project conditions. Pre-project shrub cover conditions were sustained across all four post-project monitoring events and no year significantly differed from pre-project conditions. Recovery to pre-project levels occurred sooner in wetland and facultative wetland species than in upland favoring species.

The second objective, for no more than a 25% increase in pre-project invasive plant cover, was met. The overall cover of invasive species did not differ in 2016 compared to pre-project conditions. Percent cover of non-native plant cover initially decreased from 2006 to 2010 from 4.99% to 1.13% and began to increase in 2012. Invasive plant cover continued to increase in 2016 but did not significantly differ from pre-project conditions.

The third objective, to maintain or increase the pre-project native plant diversity, was met. Species richness, the total number of species present, did not differ in 2016 compared to pre-project species richness. Evenness, the equality of abundance of all species present, was not significantly different pre- versus post-project when calculated either by presence/absence or percent cover. Beta diversity, a measure of transect diversity relative to whole site diversity, trended (P-value=0.077) towards a significant decrease in 2016 compared to pre-project conditions. This decrease indicates that transect diversity is could be approaching site diversity.

The fourth objective, to maintain or increase the pre-project proportion of obligate wetland and facultative wetland species relative to facultative, facultative upland, and upland species, was met. As of 2016, the combined average cover of obligate and facultative wetland species was 12.44% which was not significantly different from pre-project conditions which averaged 11.11%. In addition, the combined average cover of facultative, facultative upland, and upland species was 9.18% which did not significantly differ from pre-project conditions which averaged 12.38%. This difference did however trend (P-value = 0.063) towards a significant decrease in upland species which could indicated that upland favored species are decreasing in cover. Only obligate cover was different in 2016 compared to pre-project levels. The percent cover of obligate species increased from an average of 3.86% pre-project to 9.15% in 2016.

Overall, while no significant increases in plant cover, diversity, or the distribution of wetland to non-wetland species was observed, there was also no lasting adverse impact from operations. The results from this monitoring report indicate that although there was an initial negative effect on plant cover, recovery began after four to five years and now after nine years, site conditions have returned to pre-project levels.

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INTRODUCTION

A landscape analysis of the south shore of Lake Tahoe (South Shore Landscape Analysis 2004) found that fire suppression practices have affected riparian habitat conditions in stream environment zones (SEZs). The riparian zone and associated buffer zone (25 to 100 feet) of every creek and lake shore in the southern portion of the Lake Tahoe Basin are affected to varying degrees by overly-dense live and dead mixed-conifer forest stands, heavy ground fuels, and thick ladder fuels between the ground and overstory layers. Higher stand density in riparian zones creates higher risk of mortality due to fluctuations in the water table and susceptibility to bark beetles (South Shore Landscape Analysis 2004); in addition, the increased fuel presents an increase in fire hazard. The current condition of SEZs within the Lake Tahoe Basin prompted the Tahoe Regional Planning Agency (TRPA) to amend its ordinances to allow for development and implementation of innovative techniques to reduce fire hazard within SEZs (TRPA Code of Ordinances, 71.4.C, amended 2004).

The USDA Forest Service Lake Tahoe Basin Management Unit (LTBMU) initiated a fuel reduction pilot project in 2007 to determine the feasibility of conducting mechanical fuel treatments in SEZs. The goals of the project were: to demonstrate SEZ treatment methods using low-impact innovative-technology vehicles and techniques, reduce hazardous fuels by treating dead and down trees and fuel ladders and removing material from the project area, and to facilitate a desired vegetation structure and function through conifer thinning and removal. In order to maximize the utility of such methods, managers need to balance fuel treatments with maintaining the diversity and function of the SEZ. riparian zones. These riparian zones are crucial ecosystem components that provide food and habitat for wildlife and macroinvertebrates, act as nutrient filters, provide refuges for regional diversity, and minimize soil erosion through bank stabilization (Naiman & Decamps 1997). Hydrology and interactions with local geomorphology are the most important factors influencing vegetative patterns and succession in riparian zones; plant species also entrap material along low gradient stream reaches which influences channel hydraulics (Naiman & Decamps 1997).

Vegetation monitoring was established in 2006 prior to project initiation in order to quantitatively assess if mechanical fuel treatments cause significant and lasting adverse impacts to non-target vegetation. This effort is one component of a larger monitoring effort for this project as documented in the Heavenly SEZ Fuels Reduction Project Monitoring Plan (Norman 2007). Results related to the soil quality monitoring component of this plan were previously presented in the Heavenly Creek SEZ Demonstration Project 2007 Soil Monitoring Report (Norman et al. 2008). For this study of vegetation, adverse impacts were defined as a reduction of native plant cover and diversity, and/or an increase in invasive species cover. A positive impact of this project was defined as an increase in the number and cover of obligate wetland and facultative wetland species. This report provides information on vegetation response to the SEZ project activities one, three, five, and nine years after project implementation.

Project Objectives for Vegetation

The objectives of vegetation monitoring were to assess the impacts of the fuel treatment project on cover, diversity, and wetland indicator status of native riparian SEZ vegetation and on cover of invasive plant species. Specific project objectives included:

- Maintain or increase the pre-project cover of native herbaceous plants and shrubs.
- Allow no more than a 25% increase in pre-project cover of invasive plant species.
- Maintain or increase the pre-project native plant diversity.
- Maintain or increase the pre-project proportion of obligate wetland and facultative wetland species relative to facultative, facultative upland, and upland species.

METHODS

Site

The Heavenly Creek SEZ Demonstration Project is located on the Lake Tahoe Basin Management Unit of the USDA Forest Service within the city limits of South Lake Tahoe, CA. The project site is located southwest of the intersection of Al Tahoe Boulevard and Pioneer Trail (Appendix 1). Prior to the fuels treatment project, this site had dense lodgepole pine (*Pinus contorta*) stands with high mortality levels within the SEZ and associated SEZ buffers of Heavenly Valley Creek. In December 2002, a wildfire burned through the area leaving standing dead fuels and causing additional tree mortality. The dense forest stands and heavy fuel loads continued to pose a wildfire threat and encroaching conifer vegetation continued to impact non-conifer riparian vegetation communities. For these reasons, this location was chosen as an area to demonstrate low-impact mechanical and manual techniques for vegetation and fuel reduction treatments within SEZs at both burned and unburned sites.

The project consisted of five units totaling 21 acres (Appendix 1). Unit 1 was a mixed conifer stand with both burned (1B) and unburned (1A) portions. Unit 2 was a dense lodgepole pine stand with heavy tree mortality. Unit 3 was a dense lodgepole pine and Jeffrey pine (*Pinus jeffreyi*) stand. Unit 4 was an aspen (*Populus tremuloides*) stand encroached by lodgepole pine and white fir (*Abies concolor*). Unit 5 was comprised of three small sub-units. Sub-units 5a and 5b were located between an open meadow and the road; 5a was treated mechanically and 5b was hand treated. Sub-unit 5c was a very wet area dominated by graminoids and shrubs and was treated by hand because it never met mechanical treatment soil moisture requirements (Table 1). The Unit 5 sub-units were not included in this vegetation assessment, because this monitoring effort was designed to assess the effects of mechanical treatment methods, and 5a was fairly small. Therefore, only four subunits are addressed in this monitoring report.

A primary concern when working in SEZs is to ensure that ground-water levels and soil moisture content are at acceptably low levels. Prior to project implementation, ground-water level was measured in each unit to ensure that it was at least two feet below the ground surface. Soil moisture was also measured prior to project implementation and following storm events during implementation. This was done by collecting a soil sample from a 6-12 inch depth and trying to form a ball by squeezing a handful of soil very firmly. Results were compared to the criteria appropriate for Tahoe Basin soil types (Table 1). No operations took place on soils which exhibited “very moist” or “wet” characteristics. Further details of soil conditions pre- and post-project implementation are presented by Norman et al. (2008).

Table 1. Criteria for soil moisture determination.

Soil Moisture	**Characteristics** (Coarse sands, loamy sands, very fine sands. Sandy loams, fine sandy loams, very fine sandy loams.)
Dry soils	Dry, loose, single grained flows thru fingers, will not form a ball with pressure.
Moist soils	Tends to stick together slightly, sometimes forms a very weak ball, but will shatter into single grains easily when tossed to a few inches height and caught in the hand.
Very moist soils	Forms a weak ball, when tossed in the air may break into smaller chunks but will not shatter easily into single grains.
Wet soils	Upon squeezing, free water may appear. Wet outline is left on hand.

Vegetation Monitoring Design

Thirteen transects were installed prior to project implementation using a stratified random sampling design to ensure SEZ vegetation and soil types were adequately sampled. Two to four 30 to 60 meter transects were established in each mechanical treatment unit (Table 2). Each transect contained 40 to 60 evenly spaced 0.5m^2 measurement plots. The vegetation units were small, which constrained the number of transects that could be established within each unit. Each transect was monitored one time during pre-project monitoring in the fall of either 2006 or 2007. Post-project monitoring occurred 1 year post (2008), 3 years post (2010), five years post (2012), and nine years post (2016). Pre-project monitoring occurred in late August 2006 and late June to mid-July 2007. Monitoring occurred between June through August during peak growing season. In 2008, transect 4-2 could not be relocated, so the data from this transect was excluded from all analyses. In 2012, portions of transects 3-1, 3-2, and 3-3 were covered by large wood piles and wood chips, so the affected plots and line-intercept lengths were excluded from all analyses.

Table 2. Number of vegetation transects and plots analyzed within Heavenly Creek SEZ pilot project and total transect length within each mechanically-treated unit.

Heavenly Creek SEZ Unit	**Number of transects**	**Total transect length in Unit (meters)**	**Number of 0.5m^2 plots**
1A	2	90	40
1B	3	180	60
2	2	120	40
3	4	137.5	34
4	1	60	20
Total:	**12**	**630**	**202**

Ocular cover of each herbaceous species (native and non-native) was recorded in each evenly spaced 0.5m^2 measurement plot along each transect (Table 2). Cover was estimated as the vertical projection of plant foliage and supporting parts as viewed from above, and was recorded as all vegetation covering the ground surface (Elizinga et al. 1998). If a plant was rooted outside the plot but had branches or leaves overhanging the plot then the portion of the plant covering the plot was included in total cover estimates. Average transect cover was calculated by summing the percent cover of all species recorded in an individual plot across all plots along the transect and averaging across all summed plots. Average cover for each invasive plant, wetland category, or herbaceous/graminoid cover type was calculated in the same manner. Invasive plant species were analyzed separately from native plant species to address the management objectives. Invasive species were identified using the 2017 California Invasive Plant Inventory and Watch List (Cal-IPC 2006, updated 2017). Non-native species that were not listed by Cal-IPC as invasive were not included in the analyses of either native herbaceous species or invasive species (Appendix 2).

Shrub cover was monitored using the line-intercept method. The starting point for each shrub was recorded and a continuous closed canopy was assumed unless a gap in vegetation exceeded 5 cm. Percent cover of each species was calculated by summing the total length (in meters) of intercept along the four transects, dividing by total transect length and multiplying by 100 to give growth form percent cover at each transect. No non-native or invasive shrub species occurred in the project area.

Ground cover was calculated post project to use as an explanatory variable by using the four corners of the plot frame as point intercepts, summing the number of point intercepts for each category along each transect, dividing by total number of points per transect, and then multiplying by 100 to give percent cover. This method can provide a more accurate assessment of ground cover than ocular estimates (Keane & Lutes 2006). Ground cover categories were bare ground, basal vegetation, litter (organic material and woody debris <6” diameter), and large woody debris (>6” diameter). Rocky cover and water cover were included in the 2016 protocol but were reclassified as bare ground for the sake of analysis and consistency with previous measurement protocol.

Diversity

Whittaker's (1979) three types of diversity (alpha, gamma, and beta) were calculated for native plant species (herbs and shrubs). Alpha diversity is diversity at each transect, and was calculated using species richness. Species richness is a count of the total number of species per transect. Gamma diversity is site diversity and was calculated as the total species richness of the site. Beta diversity is a measure of transect diversity (alpha) relative to site diversity (gamma), and was calculated for each transect by dividing site richness (gamma) by transect richness (alpha). A beta value closer to one indicates that transect diversity is approaching diversity of the entire site, and larger beta values indicate that transect diversity is less than site diversity. Transect evenness was measured with Pielou's *J* ($J = H'/\log(S)$), where H' is the Shannon-Wiener diversity index ($H' = -\sum p_i \log p_i$), S is species richness, and p_i in the Shannon-Wiener diversity index is the number of species relative to the total number of species. When relative abundance is the same for all species along a transect, Pielou's *J* equals 1; values of *J* closer to zero indicate less evenness in relative abundance along the transect. Both Pielou's J and the Shannon-Wiener diversity index were calculated using the vegan package in R (Oksanen et al. 2017). Evenness can traditionally be calculated using either presence/absence (number of "hits"), or as the percent cover of each species on the transect and results from both methods are presented.

Wetland Species

In 1996, the US Fish and Wildlife Service prepared a national list of species that occur in wetlands and determined wetland indicator status for each of the species; the list and definitions were updated in 2012 (Table 3). This list categorizes species by their likelihood to occur in a wetland. Obligate wetland species are typically hydrophyte species which are any plants that grow in water or in soils that are saturated for at least part of the year (Tiner 1991). However, the presence of an obligate wetland species does not necessarily indicate the degree of wetness in a system as many obligates occur in permanently flooded wetlands but can also occur in seasonally flooded wetlands (Reed 1997). On the opposite end of the list are upland species which are very rarely hydrophytes and almost exclusively grow in uplands. The proportion of obligate wetland, facultative wetland, facultative, facultative upland, and upland species was compared for each of the monitoring visits. Wetland indicator status of each species was obtained from the USDA Plants Database (http://plants.usda.gov/wetland.html). If a regional rating was not available the national rating was used. When a wetland rating was not available for a species it was excluded from the analysis. If a plant had only been identified to genus (with the exception of *Carex*) it was excluded from the analysis. If the species was unknown for *Carex* it was considered to be a facultative wetland species.

Table 3. Explanation of categories identified by the US Fish and Wildlife Service to describe Wetland Indicator Status of plant species.

Wetland Type	Indicator Code	Definition
Obligate Wetland	OBL	Almost always is a hydrophyte, rarely in uplands
Facultative Wetland	FACW	Usually is a hydrophyte but occasionally found in uplands
Facultative	FAC	Commonly occurs as either a hydrophyte or non-hydrophyte
Facultative Upland	FACU	Occasionally is a hydrophyte but usually occurs in uplands
Obligate Upland	UPL	Rarely is a hydrophyte, almost always in uplands
No Indicator	NI	Insufficient information was available to determine an indicator status.

Climate

Climate was evaluated as an additional explanatory variable to address vegetation response to project activities. Snow water equivalent data and historical precipitation data was downloaded from the Heavenly Valley NRCS SNOTEL station (#518) located approximately 3.75 km east from the center of the Heavenly Creek SEZ Demonstration project. The Palmer Drought Severity Index (PDSI) was collected for California Climate Division 3. Palmer Drought Severity Index values between 0.49 and -0.49 are defined as “near normal,” negative values below this threshold indicate increasing drought conditions, and positive values above this threshold indicate progressively wetter than normal conditions. This index takes into consideration, soil type, evapotranspiration demand, and soil water capacity in addition to the amount of precipitation (Palmer 1965). Because PDSI is on such a course scale its values should be taken in a regional context.

The 30-year average total annual precipitation for Heavenly Creek Valley is approximately 32.54 in calculated across the calendar year. The 30-year average maximum snow water equivalent is 26.01 inches calculated from January through June (USDA Natural Resource Conservation Service Heavenly Valley #518. The 30-year average PDSI for climate division 3 is -0.91 (http://www1.ncdc.noaa.gov/pub/data/cirs/climdiv/, accessed February 2017).

Data Analysis

Changes in the total native herbaceous, native shrub, and invasive plant cover were analyzed by comparing pre-project data (2006/2007) to the latest post-project data (2016). Summary statistics (mean, standard deviation, minimum, maximum, and median values) were calculated for each transect and for the entire project site. The Shapiro-Wilk test was used to determine if a set of data was normally distributed. A paired t-test was used for all pre-post pairwise comparisons on normally distributed data. If the data did not follow a normal distribution the Wilcoxon Signed-Rank test was used. All descriptive statistics were calculated in Microsoft Excel 2010 and all statistical tests were conducted using R Studio 3.3.1 (R Core Team 2016). Repeated measure analyses of variance (ANOVA) with post hoc analyses were used to perform multiple pairwise comparisons to take into account the covariance of repeated measures. Before performing an ANOVA and in order to satisfy the linear modeling assumptions of constant variance and normally distributed data, and to reduce heteroscedasticity in the residuals, all data that was not normally distributed was appropriately transformed and the model with the lowest Akaike information criterion (AIC) was chosen. The nlem package (Pinheiro et al. 2016) was used for all repeated measures on normally transformed data. When values could not be transformed to normality, the Quade test was used. This is a non-parametric test similar to the Friedman test which allows for repeated measures in ANOVAs, but is more robust with lower levels of replication such as in this project. All multiple comparisons were calculated using the multcomp package (Hothorn et al. 2008). All tests were considered significant at $\alpha \leq 0.05$.

RESULTS

Climate

From January 2005, one year prior to project implementation, to December 2016, average annual precipitation was 33.03 in. The highest recorded amount of precipitation was 52.4 in in 2010, while the lowest amount of precipitation was 15.9 in in 2013(Figure 1A). The average maximum snow water equivalent from 2005 to 2016 was 23.37 in. The highest recorded average maximum snow water equivalent was 44.4 in in 2011, while the lowest amount of maximum snowpack was 7.3 in in 2015. Average yearly values of PDSI ranged from -4.08 in 2014 to 1.94 in 2011. Average yearly values of PDSI indicated 7 years of drought ranging from incipient to extreme with only 5 years ranging from near normal to slightly wetter than normal conditions (Figure 1B). These results show that monitoring events predominantly occurred during drought years.

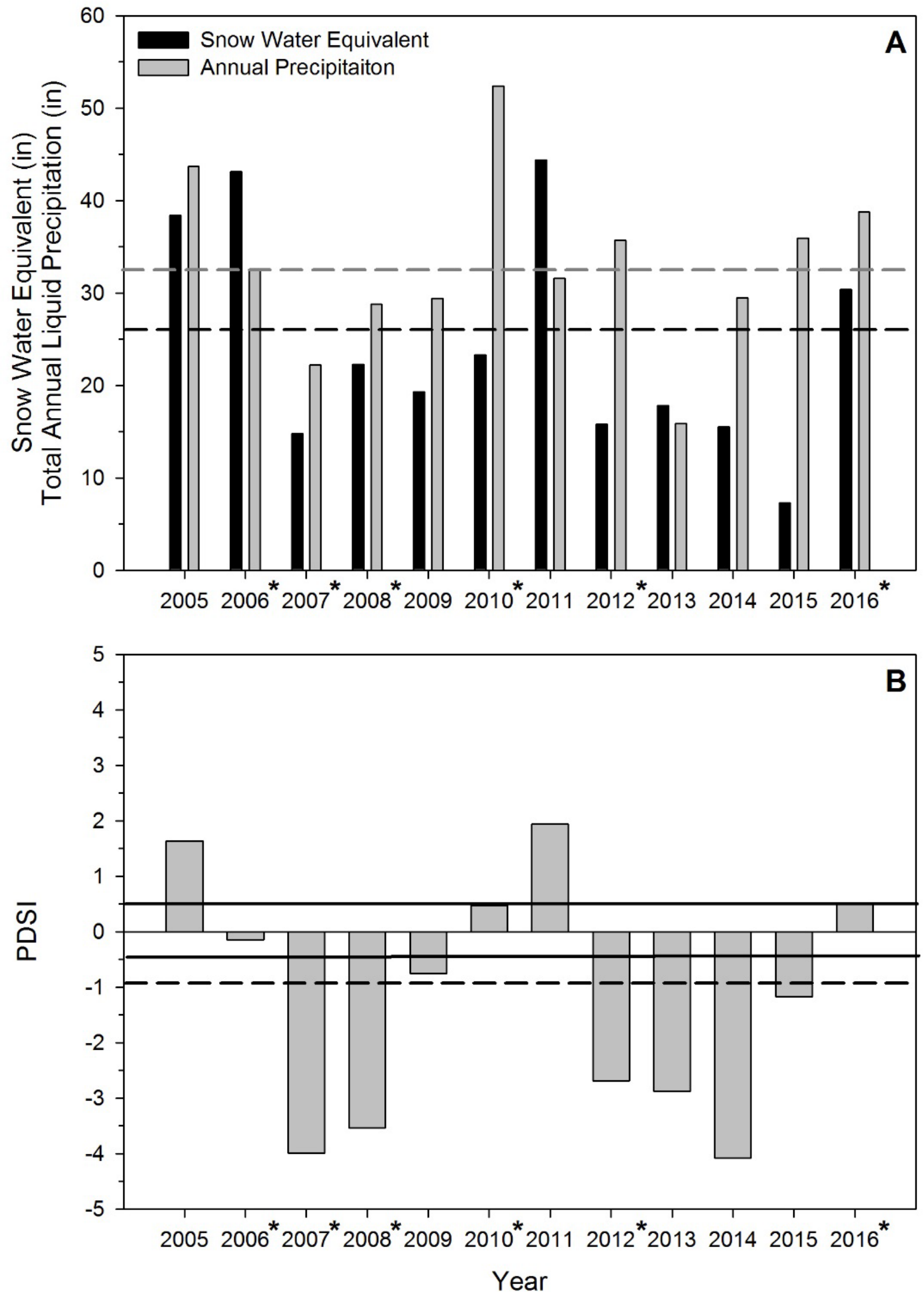

Figure 1. (A)Annual total precipitation and yearly maximum snow water equivalent from 2005 to 2016. Dashed lines indicate 30-year averages. (B) Yearly average Palmer Drought Severity Index (PDSI) from 2005 to 2016. Dashed line indicates 30-year average yearly PDSI, solid lines at 0.45 and -0.45 indicate “near normal” condition threshold values. Values below this threshold indicate drought conditions and values above this threshold indicate wetter than normal conditions. Asterisks indicate monitoring years.

Native Herbaceous Cover

As of 2016, native herbaceous plant cover did not significantly differ from pre-project conditions. In 2006/2007 native herbaceous plant cover averaged 23.72% across all transects and averaged 22.64% in 2016 across all transects (Table 4; Figure2). Percent cover steadily decreased from pre-project conditions from 2006/2007 to 2010 where it reached a minimum cover of 7.53%. In 2012 percent cover began to increase where it reached conditions that were not significantly different than 2008 conditions. Percent cover continued to rise in 2016 (Figure 3). By individual transects in 2016, three transects continued to be significantly lower than pre-project conditions, eight did not differ, and one transect was significantly higher in percent cover (Table 4). The transects that had significantly lower cover than pre-project conditions were both located in the mixed coniferous stand and the transect with higher cover was located in the Aspen stand. These observations were primarily due herbaceous forb cover.

Neither graminoid cover nor herbaceous forb cover significantly differed from pre-project conditions. In 2006/2007 native graminoid cover averaged 12.77% across all transects and averaged 14.03% in 2016 across all transects. By individual transects, ten transects did not significantly differ from pre-project conditions and two transects showed an increase while no transects were observed to be lower in percent cover (Table 5; Figure 4). In 2006/2007 percent cover of native herbaceous forb cover averaged 10.92% across all transects and averaged 8.43% in 2016 across all transects. By individual transect, three transects continued to be significantly lower than pre-project conditions, eight did not differ, and one transect was significantly higher in percent cover (Table 6; Figure 5).

Table 4. Summary statistics for native herbaceous plant cover (%) at the Heavenly Creek SEZ Demonstration Project in five monitoring years. Paired t-tests were used to test for a significant difference in pre-project cover and post-project cover as of 2016. If data were not normally distributed the Wilcoxon Signed-Rank test was used indicated by an asterisk. Bold values indicate a significant difference at α ≤ 0.05.

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
1A-1	2006/2007	37.50	7.42	1.00	117.00	30.00	**0.005***
	2008	15.65	2.43	0.00	35.00	13.25	
	2010	5.30	0.81	2.00	17.00	4.25	
	2012	16.93	2.70	1.00	55.00	15.50	
	2016	22.38	3.82	2.00	65.50	20.00	
1A-2	2006/2007	18.48	3.30	0.00	54.00	14.00	0.702
	2008	10.95	2.09	0.00	26.00	9.50	
	2010	6.03	1.22	1.00	25.50	4.75	
	2012	12.23	2.10	1.50	43.00	12.00	
	2016	20.13	2.34	1.50	36.00	18.50	
1B-1	2006/2007	41.75	5.56	5.00	85.50	41.50	**0.012***
	2008	25.43	3.12	0.00	60.00	23.50	
	2010	9.23	1.44	3.00	30.00	7.25	
	2012	19.40	2.62	2.00	50.50	16.50	

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
	2016	23.80	4.45	1.50	88.00	18.75	
1B-2	2006/2007	30.38	3.42	7.00	63.00	26.50	0.106
	2008	15.73	2.01	2.50	32.00	14.50	
	2010	9.30	1.78	1.00	35.00	7.00	
	2012	17.70	2.61	3.00	52.50	15.50	
	2016	22.90	2.87	1.00	54.50	21.25	
1B-3	2006/2007	13.70	3.44	0.00	45.00	6.50	**0.041***
	2008	12.78	4.18	0.00	60.50	3.00	
	2010	2.70	0.58	0.50	9.00	2.00	
	2012	6.55	2.45	0.00	43.50	2.25	
	2016	5.80	1.69	0.00	30.50	2.50	
2-1	2006/2007	37.78	6.53	5.00	83.00	35.00	0.681*
	2008	33.40	5.60	3.00	75.00	27.50	
	2010	9.53	1.49	2.50	25.00	7.50	
	2012	22.88	4.59	2.00	75.00	17.75	
	2016	37.95	6.16	1.00	88.00	31.50	
2-2	2006/2007	19.53	4.76	0.00	78.00	12.00	0.257*
	2008	8.28	2.64	0.00	50.00	5.00	
	2010	10.80	2.31	0.00	36.00	6.75	
	2012	21.05	4.63	0.00	65.00	18.00	
	2016	30.78	6.64	0.00	95.00	24.25	
3-1	2006/2007	30.96	8.49	0.00	94.50	39.50	0.727
	2008	12.00	3.43	0.00	36.50	6.00	
	2010	12.15	2.87	0.50	37.50	9.50	
	2012	14.38	3.72	0.00	44.50	15.00	
	2016	26.54	4.39	2.00	50.00	25.50	
3-2	2006/2007	28.56	5.67	0.00	50.00	30.00	0.633
	2008	12.28	4.25	0.00	43.50	10.00	
	2010	7.67	2.43	0.50	23.50	7.50	
	2012	21.56	8.25	0.50	80.00	11.50	
	2016	24.33	7.72	0.00	80.00	17.00	
3-3	2006/2007	8.40	4.55	0.00	25.00	6.50	0.826
	2008	12.80	4.99	0.00	25.00	17.00	
	2010	3.20	1.57	0.00	9.00	2.50	
	2012	3.20	1.16	0.00	6.00	4.00	
	2016	9.50	3.15	2.00	20.50	10.00	
3-4	2006/2007	9.36	6.95	0.00	50.00	1.00	0.529*
	2008	3.64	2.95	0.00	21.00	0.00	
	2010	5.14	1.50	0.00	9.50	7.50	
	2012	4.71	1.99	0.00	15.00	4.00	

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
	2016	12.93	3.82	0.00	24.00	14.00	
4-1	2006/2007	8.25	3.66	0.00	50.00	0.00	**0.003***
	2008	7.78	2.76	0.00	35.00	0.00	
	2010	9.28	2.61	0.00	33.00	2.00	
	2012	26.33	7.80	0.00	90.00	5.75	
	2016	33.43	7.75	0.00	110.00	23.50	
All transects	2006/2007	23.72	3.55	8.25	41.75	24.04	0.729
	2008	14.22	2.32	3.64	33.40	12.53	
	2010	7.53	0.87	2.70	12.15	8.45	
	2012	15.58	2.17	3.20	26.33	17.31	
	2016	22.64	2.74	5.80	37.95	23.35	

Table 5. Summary statistics for native graminoid cover (%) at the Heavenly Creek SEZ Demonstration Project in five monitoring years. Wilcoxon Signed-Rank tests were used to test for a significant difference in pre-project cover and post-project cover as of 2016 as data were not normally distributed. Bold values indicate a significant difference at $\alpha \leq 0.05$.

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
1A-1	2006/2007	13.95	3.49	0.00	55.00	10.00	0.344
	2008	8.88	1.96	0.00	32.00	6.25	
	2010	1.50	0.28	0.00	4.50	1.00	
	2012	5.40	0.99	0.00	15.00	4.50	
	2016	10.75	3.16	0.00	59.00	6.50	
1A-2	2006/2007	11.18	3.44	0.00	50.00	5.00	0.176
	2008	6.70	1.87	0.00	25.00	2.50	
	2010	3.98	1.25	0.50	25.00	2.25	
	2012	8.30	2.11	0.00	40.00	5.25	
	2016	13.43	2.76	0.00	36.00	8.00	
1B-1	2006/2007	17.90	5.37	0.00	80.00	8.50	0.104
	2008	2.93	1.55	0.00	30.00	0.00	
	2010	1.80	0.33	0.00	5.50	1.50	
	2012	6.63	1.62	0.00	30.50	4.75	
	2016	7.00	1.88	0.00	25.00	2.00	
1B-2	2006/2007	4.45	1.38	0.00	20.00	0.50	0.478
	2008	7.18	1.45	0.50	23.00	5.25	
	2010	1.53	0.46	0.00	8.00	1.00	
	2012	4.65	1.13	0.00	15.50	2.50	
	2016	6.65	1.84	0.00	30.50	3.75	
1B-3	2006/2007	5.80	2.56	0.00	40.00	0.00	0.345
	2008	8.18	3.52	0.00	55.00	0.25	

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
	2010	1.13	0.38	0.00	8.00	1.00	
	2012	2.30	1.32	0.00	25.50	0.25	
	2016	3.65	1.61	0.00	30.00	0.00	
2-1	2006/2007	36.00	6.31	5.00	83.00	30.00	0.955
	2008	27.30	4.88	0.00	70.00	25.00	
	2010	8.95	1.56	2.00	25.00	7.25	
	2012	22.48	4.54	2.00	75.00	17.50	
	2016	35.95	5.91	1.00	88.00	31.00	
2-2	2006/2007	5.33	3.75	0.00	76.00	0.75	**0.011**
	2008	6.75	2.70	0.00	50.00	1.50	
	2010	8.18	2.30	0.00	35.00	5.00	
	2012	19.60	4.68	0.00	65.00	15.00	
	2016	29.48	6.72	0.00	95.00	22.50	
3-1	2006/2007	24.38	8.33	0.00	92.50	2.50	0.273
	2008	9.38	2.98	0.00	35.00	5.00	
	2010	5.62	2.48	0.00	32.00	3.00	
	2012	11.50	2.92	0.00	33.00	14.00	
	2016	10.57	3.03	0.00	31.00	6.75	
3-2	2006/2007	19.67	6.10	0.00	50.00	15.00	0.944
	2008	10.44	4.01	0.00	40.00	9.00	
	2010	5.39	1.94	0.50	20.00	4.50	
	2012	19.67	8.45	0.50	80.00	8.00	
	2016	19.33	8.17	0.00	80.00	14.00	
3-3	2006/2007	3.30	1.26	0.00	6.00	5.00	0.584
	2008	4.80	2.67	0.00	15.00	2.00	
	2010	1.30	0.37	0.00	2.00	1.50	
	2012	2.50	1.14	0.00	5.50	1.00	
	2016	3.90	1.25	0.00	6.50	5.00	
3-4	2006/2007	3.43	2.78	0.00	20.00	1.00	0.789
	2008	2.36	1.96	0.00	14.00	0.00	
	2010	1.21	0.45	0.00	3.50	1.00	
	2012	1.14	0.66	0.00	5.00	0.50	
	2016	2.36	1.49	0.00	11.00	1.00	
4-1	2006/2007	8.25	3.66	0.00	50.00	0.00	**0.004**
	2008	6.65	2.63	0.00	35.00	0.00	
	2010	6.95	2.41	0.00	32.00	0.75	
	2012	24.23	7.95	0.00	90.00	1.50	
	2016	25.25	6.18	0.00	80.00	15.00	
All transects	2006/2007	12.77	2.91	3.30	36.00	9.71	1.000

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
	2008	8.46	1.85	2.36	27.30	6.96	
	2010	3.96	0.85	1.13	8.95	2.89	
	2012	10.70	2.46	1.14	24.23	7.46	
	2016	14.03	3.19	2.36	35.95	10.66	

Table 6. Summary statistics for native herbaceous forb cover (%) at the Heavenly Creek SEZ Demonstration Project in five monitoring years. Wilcoxon Signed-Rank tests were used to test for a significant difference in pre-project cover and post-project cover as of 2016 as data were not normally distributed. Bold values indicate a significant difference at $\alpha \leq 0.05$.

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
1A-1	2006/2007	23.55	5.73	0.00	101.50	18.50	**0.040**
	2008	6.78	1.60	0.00	22.00	5.00	
	2010	3.80	0.75	1.00	15.00	3.00	
	2012	11.53	2.40	0.00	50.50	10.25	
	2016	11.63	2.96	0.50	53.00	6.25	
1A-2	2006/2007	7.30	1.49	0.00	25.00	5.00	0.763
	2008	4.25	1.24	0.00	20.00	2.00	
	2010	2.05	0.61	0.00	11.50	1.00	
	2012	3.93	1.04	0.00	17.00	1.75	
	2016	6.70	1.75	0.00	28.50	3.00	
1B-1	2006/2007	23.85	4.49	1.00	71.00	17.75	0.263
	2008	22.50	3.01	0.00	60.00	20.25	
	2010	7.43	1.48	0.50	29.00	6.50	
	2012	12.78	2.38	2.00	47.00	8.50	
	2016	16.80	4.14	1.00	73.00	8.50	
1B-2	2006/2007	25.93	3.18	7.00	60.00	24.00	**0.029**
	2008	8.55	1.49	0.50	26.00	8.50	
	2010	7.78	1.73	1.00	34.00	5.75	
	2012	13.05	2.29	0.00	41.50	12.75	
	2016	16.25	2.89	1.00	54.50	19.75	
1B-3	2006/2007	7.90	2.19	0.00	31.00	4.50	0.070
	2008	4.60	1.67	0.00	25.00	1.00	
	2010	1.58	0.44	0.00	8.00	1.00	
	2012	4.25	2.18	0.00	42.50	1.75	
	2016	2.10	0.57	0.00	8.50	1.00	
2-1	2006/2007	1.78	1.34	0.00	25.50	0.00	0.262
	2008	6.10	3.74	0.00	70.00	0.00	
	2010	0.58	0.21	0.00	3.00	0.00	
	2012	0.40	0.24	0.00	4.00	0.00	

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
	2016	2.00	0.78	0.00	12.00	0.25	
2-2	2006/2007	14.20	3.72	0.00	56.00	8.50	**0.001**
	2008	1.53	0.68	0.00	13.50	0.50	
	2010	2.63	0.66	0.00	11.50	2.00	
	2012	1.45	0.51	0.00	9.50	0.75	
	2016	1.15	0.58	0.00	10.00	0.00	
3-1	2006/2007	6.58	3.16	0.00	41.50	3.00	0.056
	2008	2.62	0.71	0.00	7.00	1.50	
	2010	6.54	1.78	0.00	21.00	5.00	
	2012	2.88	0.93	0.00	11.50	2.00	
	2016	15.15	2.88	1.00	35.00	16.50	
3-2	2006/2007	8.89	4.54	0.00	35.00	0.00	0.674
	2008	1.83	0.82	0.00	7.00	1.00	
	2010	2.28	1.06	0.00	10.00	1.50	
	2012	1.89	0.81	0.00	7.00	1.50	
	2016	5.00	1.80	0.00	14.00	5.00	
3-3	2006/2007	5.10	3.84	0.00	20.00	0.50	0.855
	2008	8.00	3.39	0.00	15.00	10.00	
	2010	1.90	1.31	0.00	7.00	1.00	
	2012	0.70	0.58	0.00	3.00	0.00	
	2016	5.60	2.48	0.00	14.00	4.00	
3-4	2006/2007	5.93	4.27	0.00	30.00	0.00	0.402
	2008	1.29	0.99	0.00	7.00	0.00	
	2010	3.93	1.30	0.00	8.00	4.00	
	2012	3.57	1.39	0.00	10.00	3.00	
	2016	10.57	3.60	0.00	23.00	9.00	
4-1	2006/2007	0.00	0.00	0.00	0.00	0.00	**0.014**
	2008	1.13	0.76	0.00	15.00	0.00	
	2010	2.33	1.49	0.00	25.00	0.00	
	2012	2.10	1.51	0.00	30.00	0.00	
	2016	8.18	4.01	0.00	60.00	0.00	
All transects	2006/2007	10.92	1.81	0.00	25.93	7.60	0.301
	2008	5.76	1.70	1.13	22.50	4.43	
	2010	3.57	0.69	0.58	7.78	2.48	
	2012	4.88	1.37	0.40	13.05	3.23	
	2016	8.43	1.62	1.15	16.80	7.44	

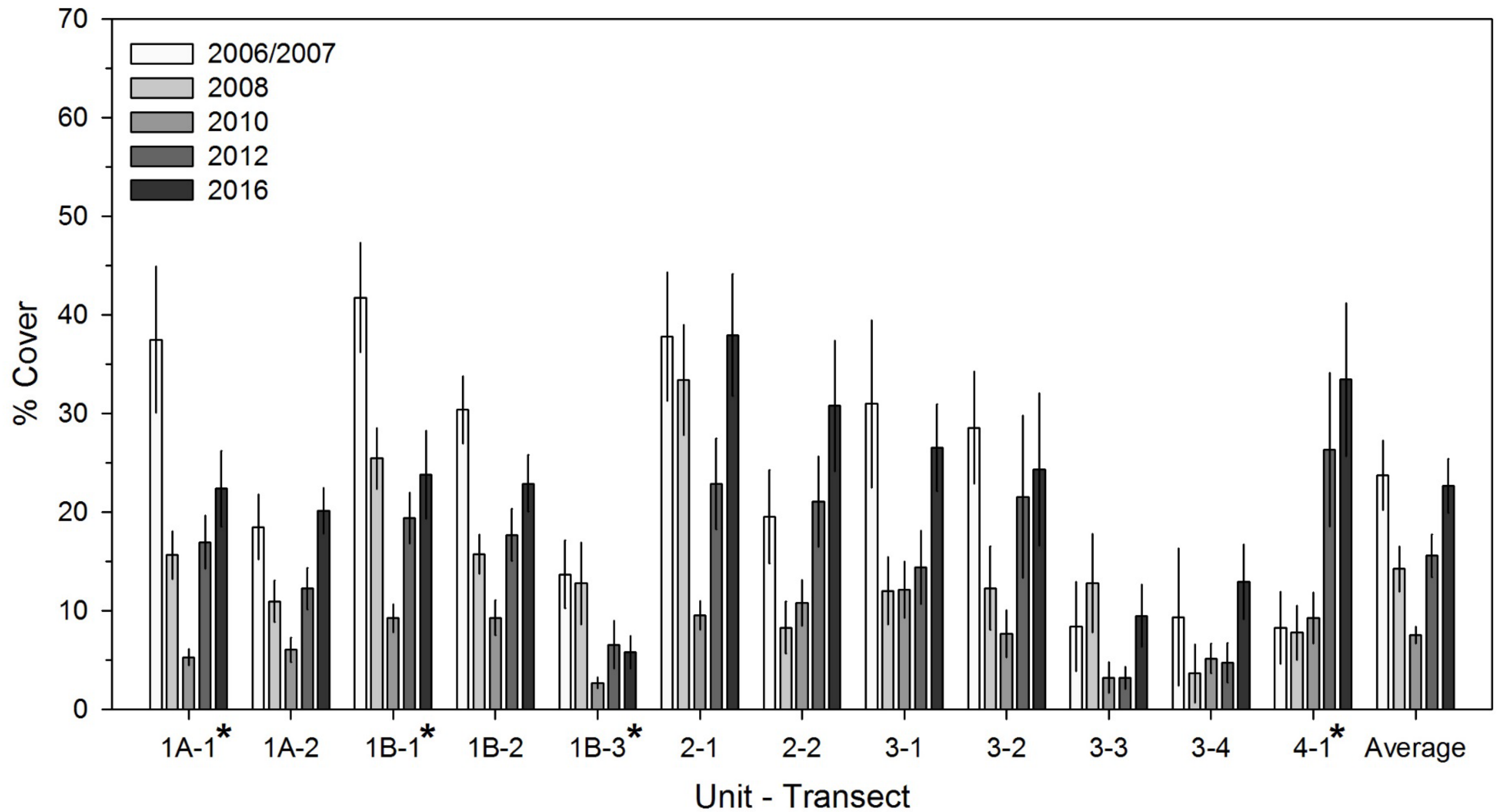

Figure 2. Mean ± SE native herbaceous cover by transect and averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. Asterisks indicate a significant difference between pre (2006/2007) and post (2016) percent cover.

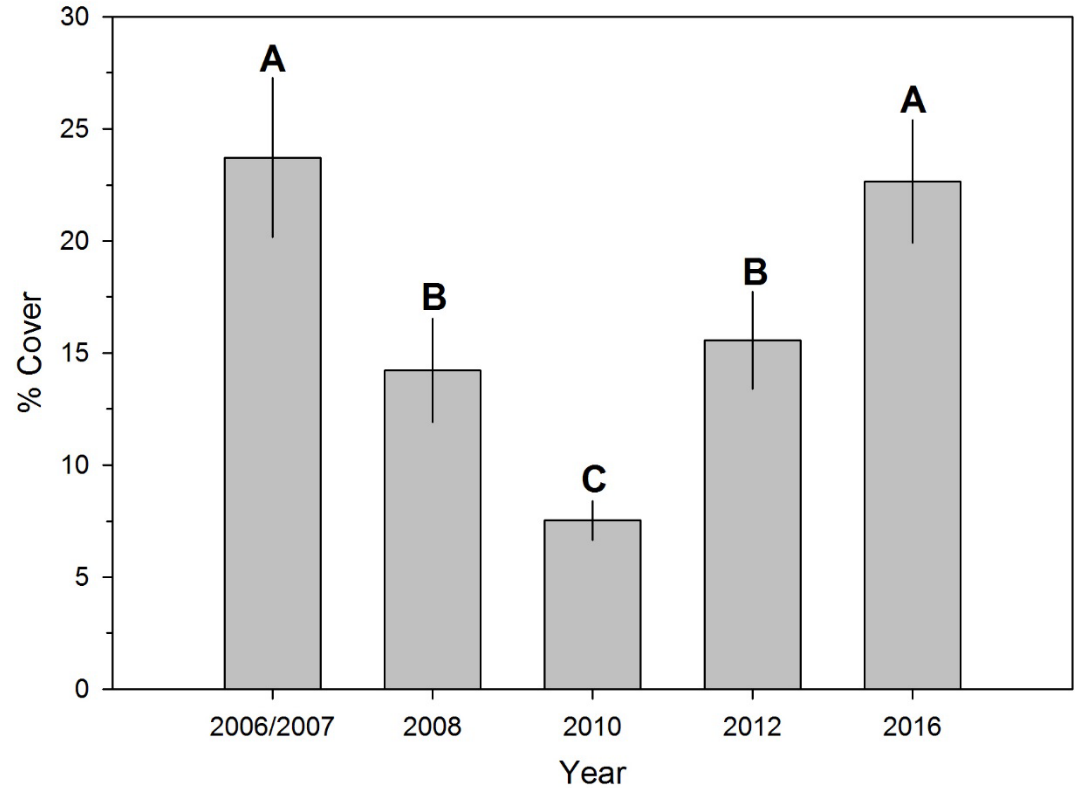

Figure 3. Mean ± SE native herbaceous cover by year averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. Letters above each year are post hoc Tukey letters which indicate significant difference between years at $\alpha \leq 0.05$. Years that share a letter indicate no significant difference.

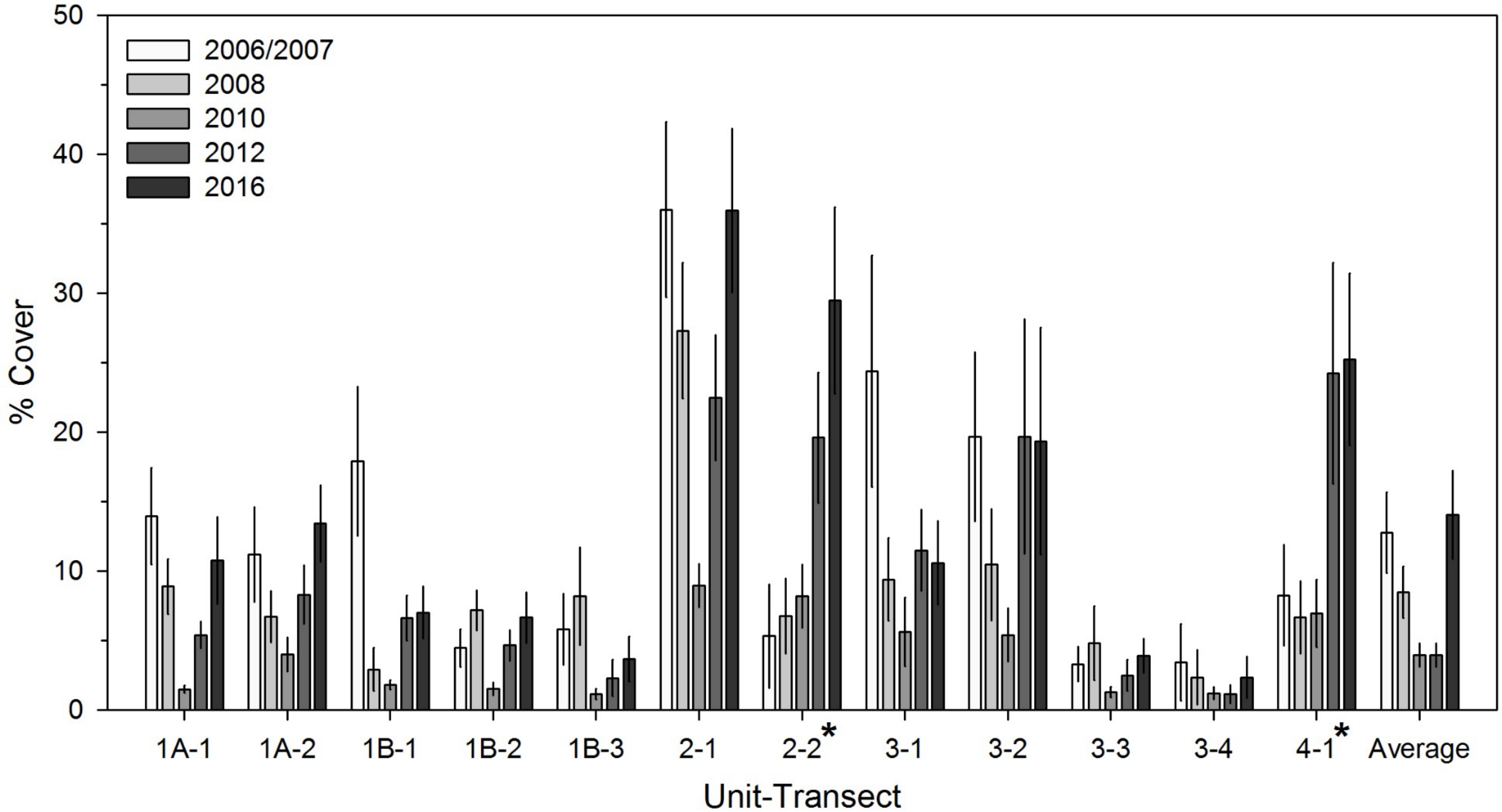

Figure 4. Mean ± SE native graminoid cover by transect and averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. Asterisks indicate a significant difference between pre (2006/2007) and post (2016) percent cover.

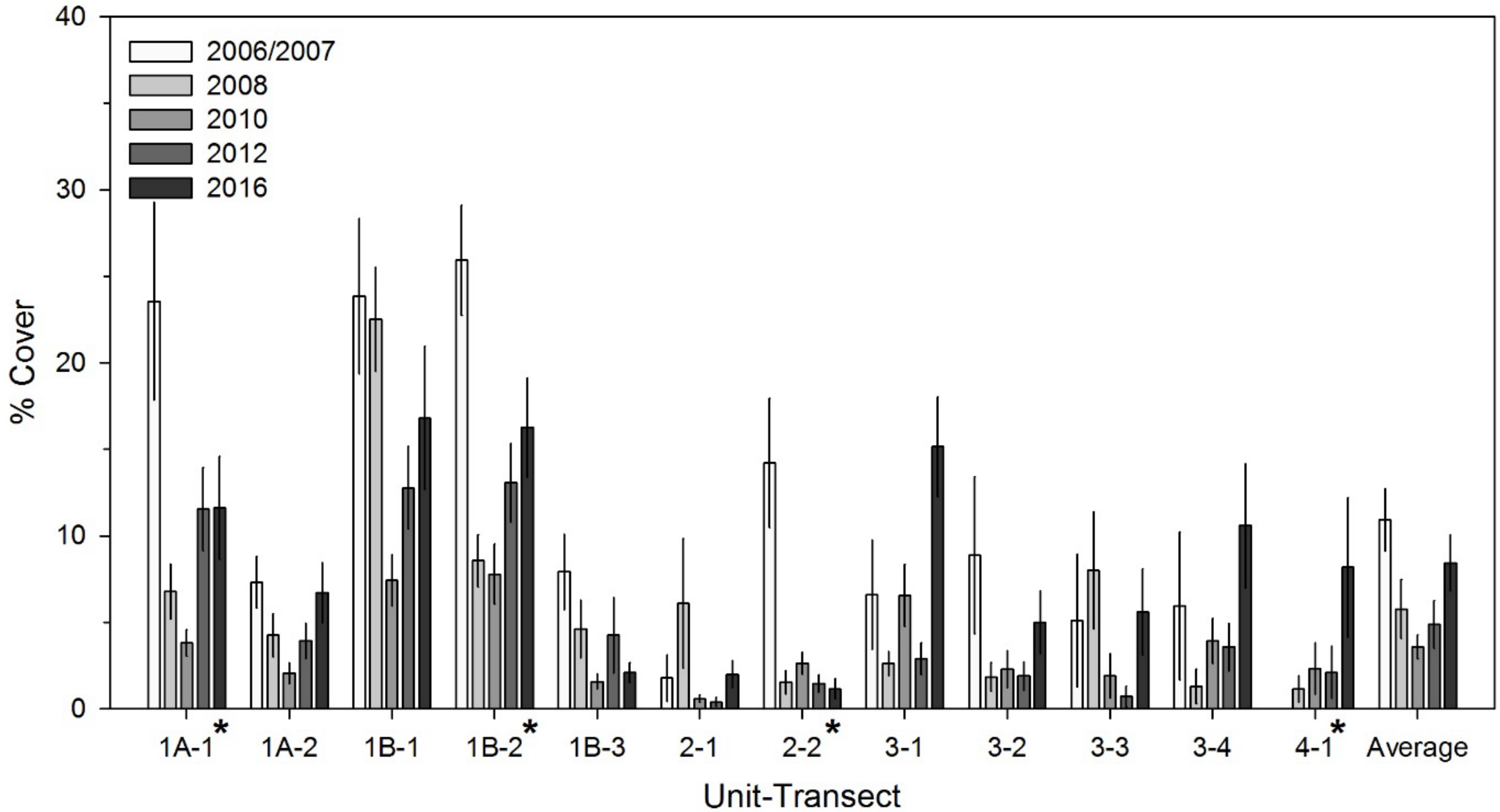

Figure 5. Mean ± SE native herbaceous forb cover by transect and averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. Asterisks indicate a significant difference between pre (2006/2007) and post (2016) percent cover.

Native Shrub Cover

As of 2016, native shrub cover did not significantly differ from pre-project conditions. In 2006/2007 percent cover of native shrubs averaged 8.71% across all transects and averaged 11.80% in 2016 across all transects (Table 7; Figure 6). Percent cover remained relatively stable across all monitoring years and no post hoc pair-wise comparisons with repeated measures showed significant differences.

Table 7. Summary statistics for native shrub cover (%) at the Heavenly Creek SEZ Demonstration Project in five monitoring years. A Wilcoxon Signed-Rank test was used to test for a significant difference in pre-project cover and post-project cover as of 2016 as data were not normally distributed.

Unit-Transect	Year	Mean	SE	Min	Max	Median	P-value
All transects	2006/2007	8.71	4.61	0.00	55.08	2.10	0.359
	2008	6.91	3.27	0.00	38.92	0.80	
	2010	9.72	4.09	0.00	48.92	2.92	
	2012	8.95	2.98	0.00	28.50	3.17	
	2016	11.80	4.73	0.00	52.50	3.49	

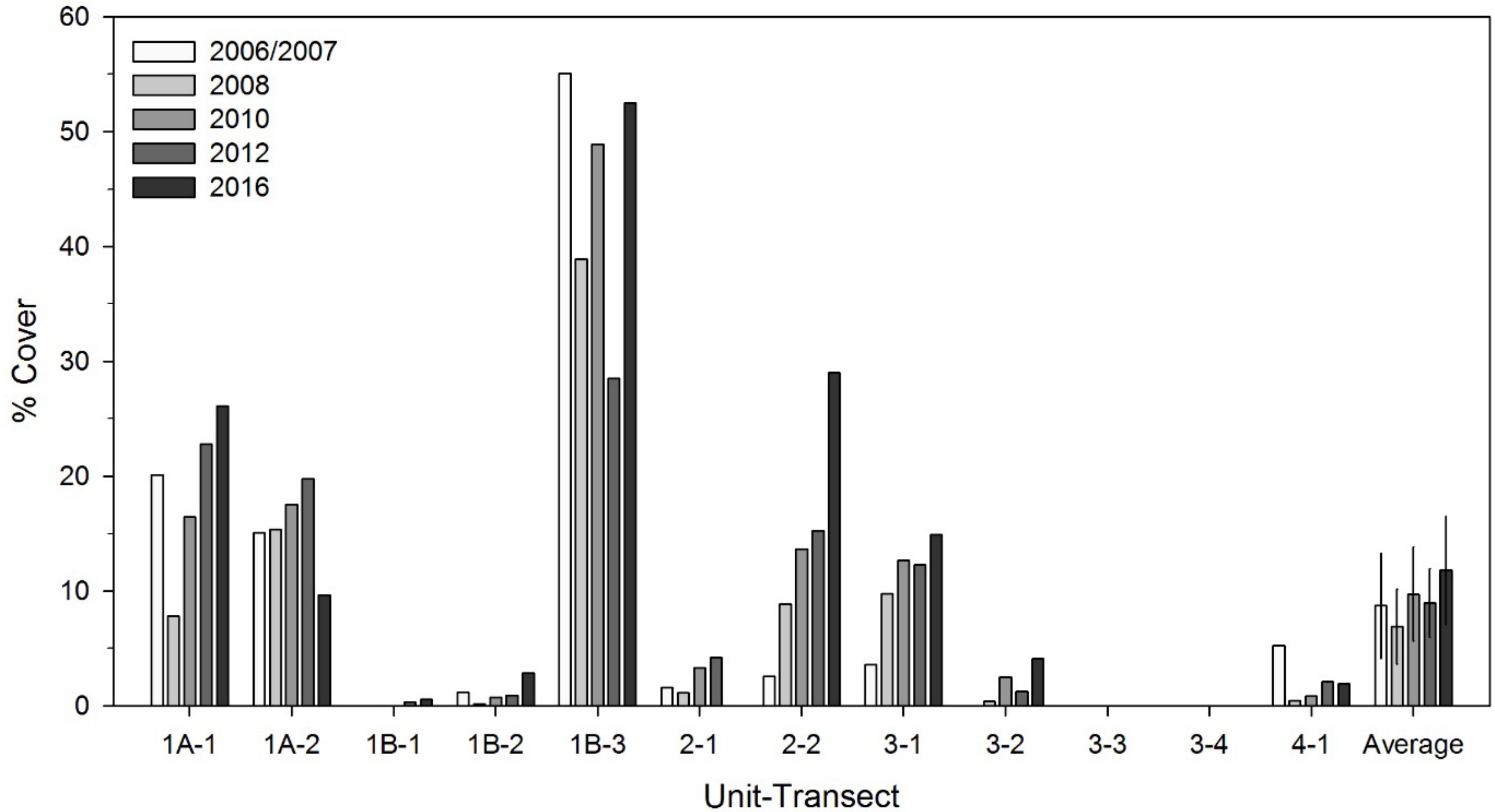

Figure 6. Mean native shrub cover by transect and averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits.

Non-native Invasive Plant Species

As of 2016, non-native plant cover did not significantly differ from pre-project conditions. In 2006/2007 percent cover of non-native plant cover averaged 4.99% across all transects and averaged 4.50% in 2016 across all transects (Table 8; Figure 6). Percent cover significantly decreased from pre-project conditions from 2006/2007 to 2008 where it reached a minimum cover of 0.80% on average across all transects. Percent cover began to increase in 2012 where it was no longer significantly different than pre-project conditions. This increasing pattern continued through 2016 (Figure 8). By individual transect, no transects were significantly lower than pre-project conditions, ten did not differ, and two transects were significantly higher in percent cover (Table 8). One of the transects with significantly higher cover was located in the lodgepole stand and one was located in the aspen stand.

The previous interim report found that the cover of six invasive species (*Bromus tectorum, Dactylis glomerata, Phleum pratense, Poa pratensis, Rumex acetosella,* and *Tragopogon dubius*) decreased between pre-project and 2012. As of 2016, *Bromus tectorum* and *Tragopogon dubius* appear to have (not statistically tested) surpassed pre-project conditions and *Poa pratensis* appears to have returned to pre-project conditions. The percent cover of *Rumex acetosella* and *Taraxacum officinalis* are still lower compared to pre-project conditions. Lastly, *Agrostis stolonifera* and *Rumex crispus* were not found during pre-project monitoring but were found in post-project monitoring.

Table 8. Summary statistics for not-native vegetation cover (%) at the Heavenly Creek SEZ Demonstration Project in five monitoring years. Wilcoxon Signed-Rank tests were used to test for a significant difference in pre-project cover and post-project cover as of 2016 as data were not normally distributed. Bold values indicate a significant difference at $\alpha \leq 0.05$.

Unit-Transect	Year	Number of Species	Mean	SE	Min	Max	Median	P-value
1A-1	2006/2007	1	2.70	1.32	0.00	25.00	0.00	0.243
	2008	0	0.00	0.00	0.00	0.00	0.00	
	2010	3	0.48	0.25	0.00	5.00	0.00	
	2012	2	0.73	0.24	0.00	4.00	0.50	
	2016	2	0.45	0.16	0.00	3.00	0.25	
1A-2	2006/2007	2	4.45	2.18	0.00	31.00	0.00	0.107
	2008	1	1.95	0.87	0.00	10.00	0.00	
	2010	1	1.80	0.66	0.00	10.00	0.50	
	2012	2	4.25	1.71	0.00	25.00	0.75	
	2016	1	0.50	0.18	0.00	3.00	0.00	
1B-1	2006/2007	4	8.95	3.93	0.00	70.00	1.00	0.219
	2008	3	2.60	2.04	0.00	40.00	0.00	
	2010	3	0.65	0.17	0.00	2.00	0.50	
	2012	2	2.73	0.84	0.00	14.00	1.00	
	2016	1	1.53	0.40	0.00	6.00	0.75	
1B-2	2006/2007	4	1.60	0.63	0.00	10.00	0.00	0.570

Unit-Transect	Year	Number of Species	Mean	SE	Min	Max	Median	P-value
	2008	4	0.65	0.26	0.00	4.00	0.00	
	2010	4	1.90	1.23	0.00	25.00	0.50	
	2012	5	1.38	0.50	0.00	8.00	0.25	
	2016	3	2.20	1.49	0.00	30.00	0.00	
1B-3	2006/2007	4	4.03	1.67	0.00	25.00	0.00	0.286
	2008	2	0.10	0.07	0.00	1.00	0.00	
	2010	2	1.00	0.24	0.00	4.00	0.75	
	2012	4	1.70	0.49	0.00	8.00	1.00	
	2016	3	1.33	0.99	0.00	20.00	0.00	
2-1	2006/2007	3	15.10	4.89	0.00	70.00	0.00	0.813
	2008	2	3.40	1.31	0.00	20.00	0.00	
	2010	3	2.83	0.94	0.00	15.00	0.50	
	2012	1	7.73	3.44	0.00	60.00	0.00	
	2016	2	16.30	5.16	0.00	80.00	6.00	
2-2	2006/2007	0	0.00	0.00	0.00	0.00	0.00	**0.004**
	2008	3	0.18	0.11	0.00	2.00	0.00	
	2010	5	2.03	1.05	0.00	15.00	0.00	
	2012	3	6.83	4.23	0.00	80.00	0.00	
	2016	3	14.23	6.03	0.00	96.00	0.75	
3-1	2006/2007	1	5.77	2.64	0.00	30.00	0.00	0.360
	2008	0	0.00	0.00	0.00	0.00	0.00	
	2010	2	1.62	0.79	0.00	10.50	0.50	
	2012	1	0.46	0.22	0.00	3.00	0.00	
	2016	2	4.04	2.45	0.00	31.00	0.50	
3-2	2006/2007	1	11.11	6.55	0.00	50.00	0.00	0.400
	2008	2	0.44	0.33	0.00	3.00	0.00	
	2010	1	0.61	0.29	0.00	2.00	0.00	
	2012	1	2.72	1.45	0.00	12.00	0.00	
	2016	1	1.22	0.49	0.00	4.00	0.50	
3-3	2006/2007	0	0.00	0.00	0.00	0.00	0.00	1.000
	2008	0	0.00	0.00	0.00	0.00	0.00	
	2010	0	0.00	0.00	0.00	0.00	0.00	
	2012	0	0.00	0.00	0.00	0.00	0.00	
	2016	1	0.10	0.10	0.00	0.50	0.00	
3-4	2006/2007	1	3.57	3.57	0.00	25.00	0.00	0.855
	2008	0	0.00	0.00	0.00	0.00	0.00	
	2010	1	0.29	0.15	0.00	1.00	0.00	
	2012	1	1.14	0.55	0.00	3.00	0.00	
	2016	1	2.00	1.00	0.00	6.00	0.00	
4-1	2006/2007	3	2.60	2.13	0.00	42.00	0.00	**0.028**

Unit-Transect	Year	Number of Species	Mean	SE	Min	Max	Median	P-value
	2008	2	0.30	0.25	0.00	5.00	0.00	
	2010	2	0.35	0.21	0.00	4.00	0.00	
	2012	1	0.25	0.20	0.00	4.00	0.00	
	2016	2	10.10	4.43	0.00	60.00	0.00	
All transects	2006/2007	8	4.99	1.32	0.00	15.10	3.80	0.424
	2008	8	0.80	0.34	0.00	3.40	0.24	
	2010	8	1.13	0.25	0.00	2.83	0.83	
	2012	6	2.49	0.74	0.00	7.73	1.54	
	2016	7	4.50	1.65	0.10	16.30	1.76	

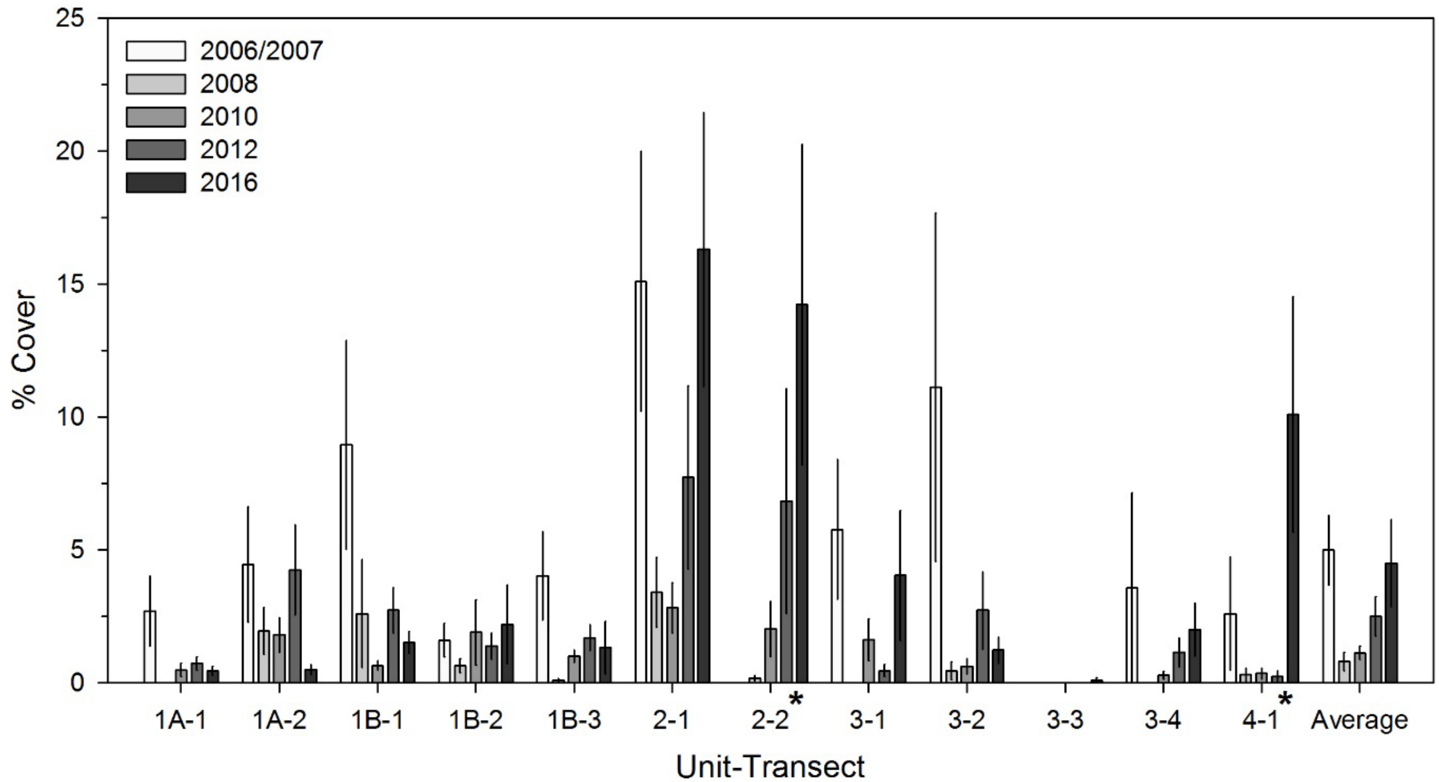

Figure 7. Mean ± SE non-native vegetation cover by transect and averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. Asterisks indicate a significant difference between pre (2006/2007) and post (2016) percent cover.

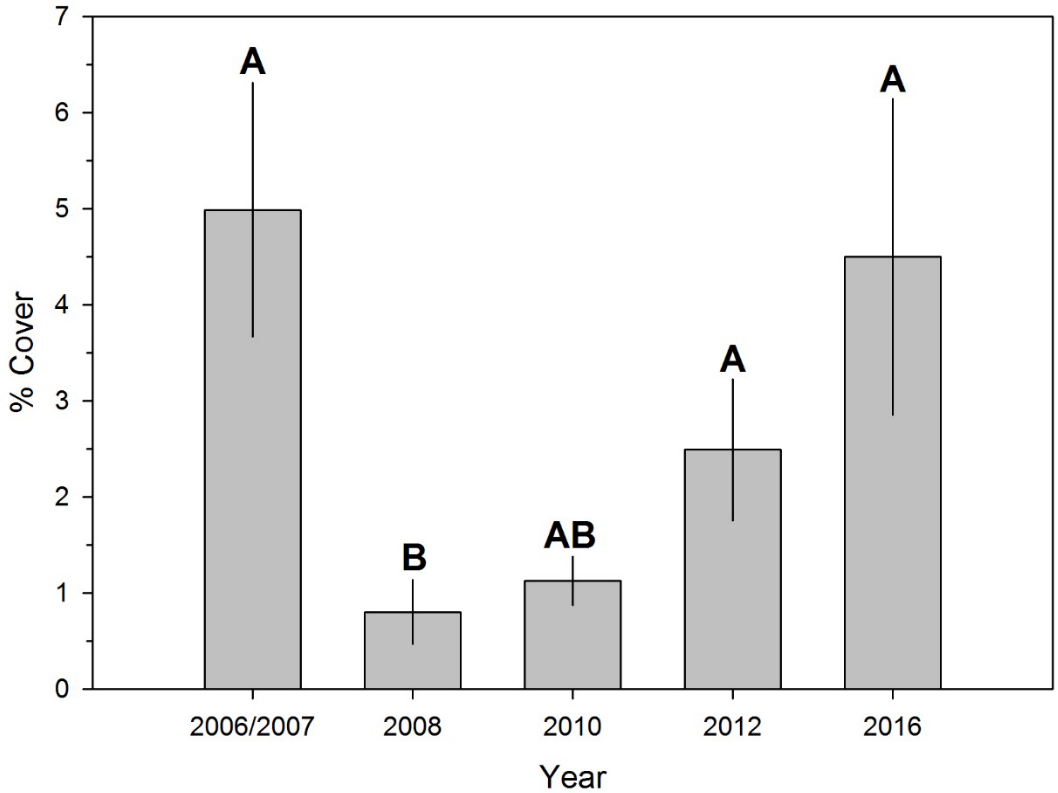

Figure 8. Mean ± SE non-native herbaceous cover by year averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. Letters above each year are post hoc Tukey letters which indicate significant difference between years at $\alpha \leq 0.05$. Years that share a letter indicate no significant difference.

Native Plant Diversity

As of 2016, native plant species richness across the project site did not significantly differ from pre-project conditions. In 2006/2007 61 unique species were observed across the site and in 2016 63 species were observed. The average number of species per transect in 2006/2007 was 12.6 species whereas the average number of species per transect in 2016 was 13.9. In addition, neither evenness calculated as number of hits (presence/absence) nor evenness calculated as a proportion of percent covers significantly differed from pre-project conditions. Lastly, beta diversity trended towards a significant decrease in 2016 (P-value =0.077) indicating that transect diversity could be approaching site diversity (Table 9A; Table 9B).

Table 9A. Alpha diversity (species richness), evenness calculated based on the number of “hits” (presence/absence) and based on percent cover, and beta diversity of native plant species at Heavenly Creek SEZ demonstration project in five monitoring years. These values exclude native shrubs.

Unit-Transect	Year	Species Richness	Evenness ("Hits")	Evenness (%Cover)	Beta Diversity
1A-1	2006/2007	14	0.90	0.76	4.36
	2008	13	0.85	0.71	4.46
	2010	16	0.88	0.76	4.25
	2012	15	0.92	0.81	4.73
	2016	16	0.84	0.74	3.94
1A-2	2006/2007	21	0.92	0.77	2.90
	2008	13	0.83	0.78	4.46
	2010	16	0.81	0.66	4.25
	2012	25	0.86	0.69	2.84
	2016	16	0.88	0.79	3.94
1B-1	2006/2007	18	0.84	0.59	3.39
	2008	14	0.82	0.65	4.14
	2010	25	0.85	0.77	2.72
	2012	21	0.84	0.72	3.38
	2016	17	0.91	0.81	3.71
1B-2	2006/2007	14	0.86	0.60	4.36
	2008	20	0.86	0.80	2.90
	2010	26	0.87	0.68	2.62
	2012	25	0.84	0.71	2.84
	2016	24	0.87	0.77	2.63
1B-3	2006/2007	14	0.87	0.71	4.36
	2008	17	0.91	0.64	3.41
	2010	16	0.89	0.83	4.25
	2012	15	0.90	0.66	4.73
	2016	16	0.85	0.77	3.94
2-1	2006/2007	11	0.70	0.41	5.55
	2008	8	0.58	0.36	7.25
	2010	17	0.84	0.52	4.00
	2012	9	0.76	0.49	7.89
	2016	15	0.83	0.33	4.20
2-2	2006/2007	17	0.81	0.49	3.59
	2008	18	0.94	0.69	3.22
	2010	21	0.86	0.69	3.24
	2012	15	0.83	0.42	4.73
	2016	11	0.86	0.50	5.73

Unit-Transect	Year	Species Richness	Evenness ("Hits")	Evenness (%Cover)	Beta Diversity
3-1	2006/2007	22	0.95	0.58	2.77
	2008	16	0.94	0.67	3.63
	2010	27	0.95	0.75	2.52
	2012	28	0.92	0.71	2.54
	2016	21	0.96	0.85	3.00
3-2	2006/2007	9	0.89	0.57	6.78
	2008	9	0.86	0.49	6.44
	2010	13	0.90	0.59	5.23
	2012	13	0.94	0.36	5.46
	2016	14	0.90	0.54	4.50
3-3	2006/2007	3	0.99	0.85	20.33
	2008	3	0.99	0.84	19.33
	2010	6	0.91	0.74	11.33
	2012	3	0.87	0.96	23.67
	2016	4	0.86	0.59	15.75
3-4	2006/2007	5	0.93	0.68	12.20
	2008	9	0.97	0.80	6.44
	2010	14	0.95	0.85	4.86
	2012	11	0.96	0.85	6.45
	2016	8	0.92	0.82	7.88
4-1	2006/2007	3	0.72	0.68	20.33
	2008	8	0.83	0.50	7.25
	2010	12	0.90	0.58	5.67
	2012	11	0.84	0.22	6.45
	2016	5	0.85	0.48	12.60
All transects	2006/2007	61	0.86 (0.02)	0.64 (0.04)	7.58 (1.87)
	2008	58	0.87 (0.03)	0.66 (0.04)	6.08 (1.29)
	2010	68	0.88 (0.01)	0.70 (0.03)	4.58 (0.68)
	2012	71	0.87 (0.02)	0.63 (0.06)	6.31 (1.65)
	2016	63	0.88 (0.01)	0.67 (0.05)	5.98 (1.19)

Table 9B. Alpha diversity (species richness), evenness calculated based on the number of "hits" (presence/absence) and based on percent cover, and beta diversity of native plant species at Heavenly Creek SEZ demonstration project in five monitoring years. These values exclude native shrubs. Paired t-tests were used to test for a significant difference in pre-project and post-project results as of 2016. If data were not normally distributed the Wilcoxon Signed-Rank test was used indicated by an asterisk.

Unit-Transect	Year	Species Richness		Evenness (hits)		Evenness (cover)		Beta Diversity	
All transects	2006/2007	61	0.307	0.86 (0.02)	0.324	0.64 (0.04)	0.599	7.58 (1.87)	0.077*
	2008	58		0.87 (0.03)		0.66 (0.04)		6.08 (1.29)	
	2010	68		0.88 (0.01)		0.70 (0.03)		4.58 (0.68)	
	2012	71		0.87 (0.02)		0.63 (0.06)		6.31 (1.65)	
	2016	63		0.88 (0.01)		0.67 (0.05)		5.98 (1.19)	

Wetland Indicator Status

As of 2016, the combined average cover of obligate and facultative wetland herbaceous species did not significantly differ from that of pre-project conditions. The combined cover of obligate and facultative wetland herbaceous species averaged 11.11% in 2006/2007 across all transects and averaged 12.44% in 2016. The combined average cover of facultative, facultative upland, and upland herbaceous species trended towards (P-value 0.063) a significant decrease from pre-project conditions. The combined cover of facultative, facultative upland, and upland herbaceous species averaged 12.38% in 2006/2007 across all transects and averaged 9.18% in 2016. Although not statistically tested, the proportion of obligate and facultative herbaceous species to total herbaceous species appears to be increasing and is higher than pre-project conditions. By individual indicator status, only the percent cover of obligate wetland herbaceous species was significantly different than pre-project conditions which increased from an average of 3.86% across all transects in 2006/2007 to 9.15% to 2016 (Table 10 Figure 9). The combined average percent cover of obligate and facultative wetland herbaceous species decreased slightly in 2008 but was only significantly lower than pre-project conditions in 2010, before returning to pre-project conditions in 2012. A similar trend was found in the combined average of facultative, facultative upland, and upland herbaceous species. The combined average percent cover of these species was lowest in 2010; however, percent cover did not significantly differ from 2010 to 2012 and percent cover did not return to pre-project conditions until 2016 (Table 10; Figure 10).

Table 10. Number of and percent cover of native herbaceous species in each category of wetland indicator status at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. OBL = Obligate, FACW = Facultative Wetland, FAC = Facultative, FACU = Facultative Upland, UPL = Upland. No Info indicates that no wetland status is available or accepted by USDA Plants database. Bold values indicate significance at $\alpha \leq 0.05$. "-"indicates that a statistical test was purposefully not performed. All values exclude native shrubs. The Wilcoxon Signed-Rank test was used with non-normally distributed data indicated by an asterisk.

	Number of Species					Percent Cover					
	2006/2007	**2008**	**2010**	**2012**	**2016**	**2006/2007**	**2008**	**2010**	**2012**	**2016**	**P-Value**
OBL	7	9	8	10	6	3.86 (2.61)	3.46 (2.14)	2.97 (0.75)	9.08(2.50)	9.15 (2.91)	**0.021***
FACW	12	10	13	15	15	7.25 (2.15)	3.23 (1.02)	0.42 (0.14)	0.82 (0.47)	3.29 (1.87)	0.103*
FAC	7	6	7	8	7	1.19 (0.95)	0.83 (0.48)	0.60 (0.22)	0.40 (0.13)	0.98 (0.51)	0.839*
FACU	15	10	15	13	13	7.09 (2.24)	3.57 (1.49)	1.71 (0.43)	3.70 (0.91)	5.41 (1.14)	0.380*
UPL	10	11	13	14	7	2.54 (0.86)	2.30 (0.92)	1.47 (0.40)	1.46 (0.40)	3.53 (0.84)	0.170*
No Info	0	1	1	3	2	0.00	<0.01	<0.01	0.02 (0.01)	0.01 (0.01)	-
OBL + FACW	19	19	21	25	21	11.11 (2.98)	6.69 (2.00)	3.39 (0.77)	9.21 (2.32)	12.44 (3.32)	0.850*
FAC+FACU+UPL	32	27	35	35	27	12.38 (2.13)	7.22 (1.91)	4.07 (0.61)	5.70 (1.32	9.18 (1.78)	0.063

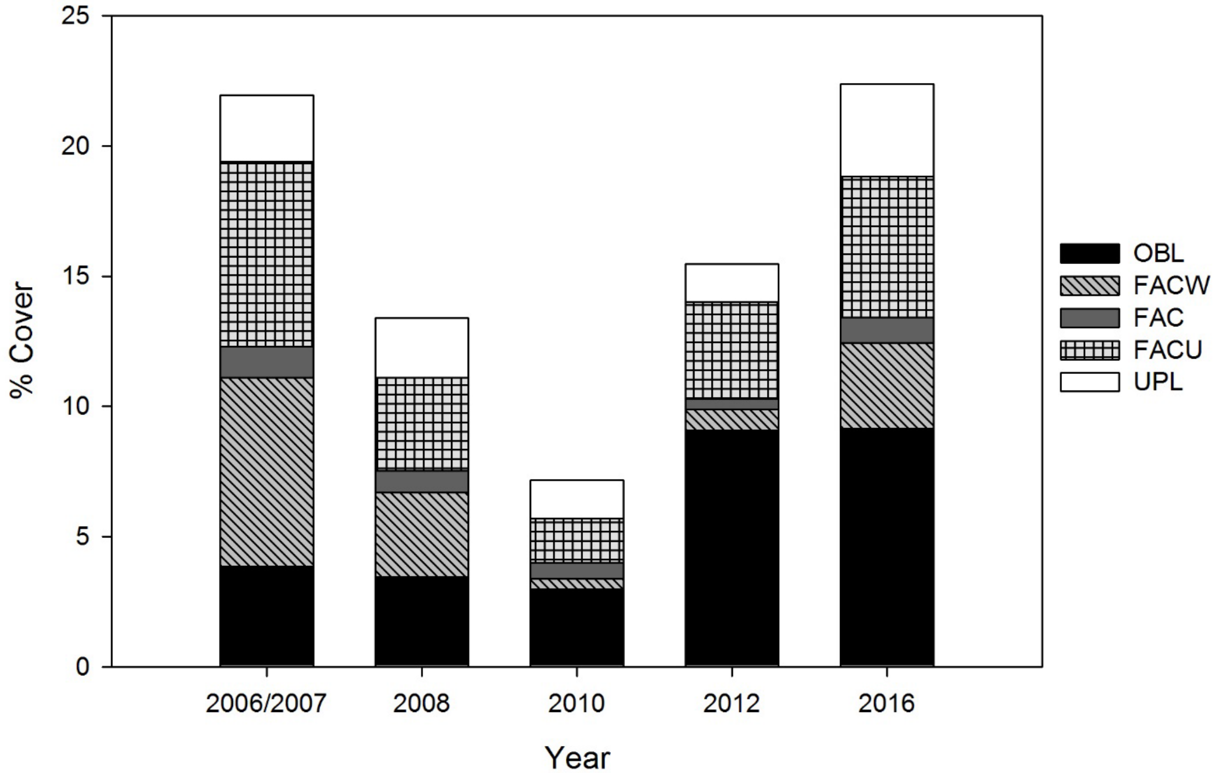

Figure 9 Percent cover of native herbaceous species in each category of wetland status at the Heavenly Creek SEZ Demonstration project during five monitoring visits. OBL = Obligate, FACW = Facultative Wetland, FAC = Facultative, FACU = Facultative Upland, UPL = Upland.

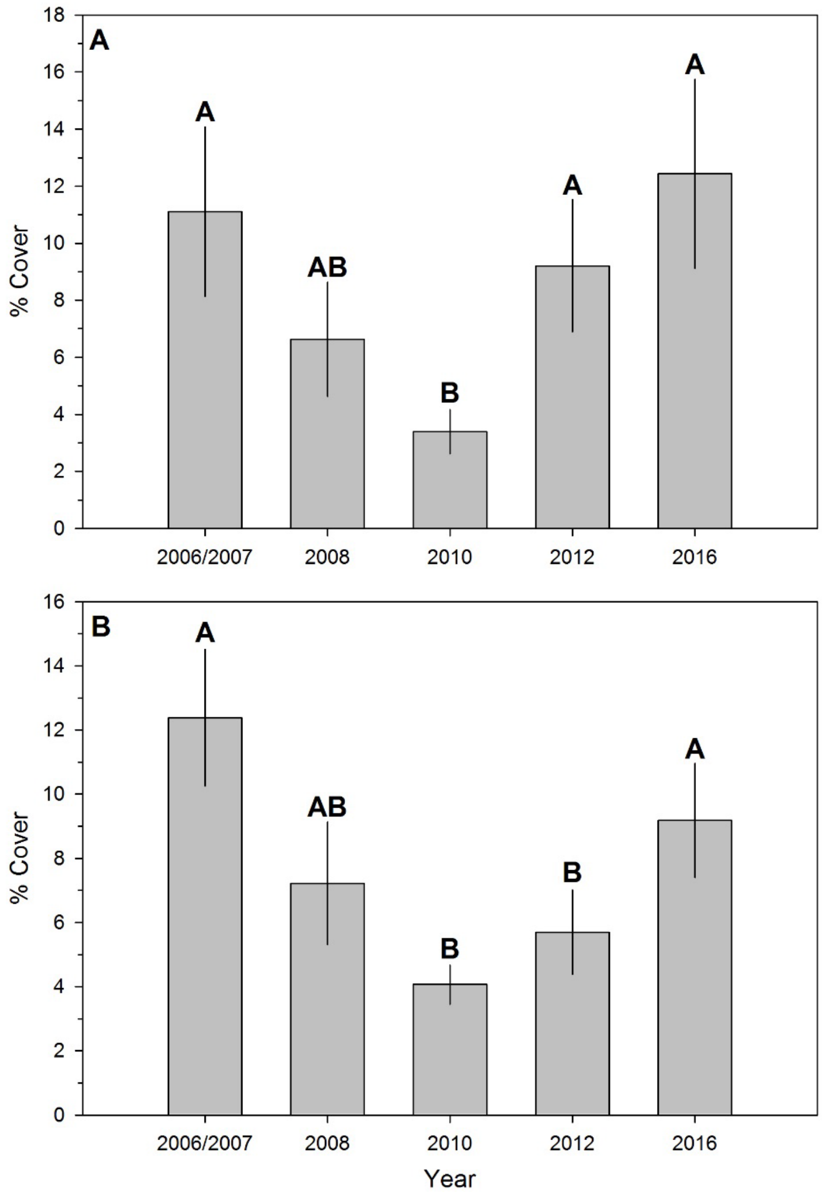

Figure 10. Mean ± SE species cover by year averaged across all transects at the Heavenly Creek SEZ Demonstration Project during five monitoring visits. (A) combined average of OBL and FACW; (B) combined average of FAC, FACU, and UPL. Letters above each year are post hoc Tukey letters which indicate significant difference between years at $\alpha \leq 0.05$. Years that share a letter indicate no significant difference.

Ground Cover

As of 2016, basal vegetation significantly decreased. The other three ground categories (bare ground, litter, and large woody debris) did not significantly differ from 2008 conditions. In 2008 basal vegetation averaged 3.53% across all transects and averaged 1.90% in 2016 across all transects (Figure 11). Pre-project ground cover monitoring did not follow the same protocol and thus could not be compared to post-project conditions. Due to observer error, transects 1A-1, 1B-

1, 1B-2, 2-1, and 2-2 were not measured in 2008 and percent covers are based on the remaining transects for that year. In addition, water and rock substrate types were added into the monitoring protocol in 2016 while these were not included in previous years. Water and Rock substrate types were incorporated into the bare ground covers for 2016.

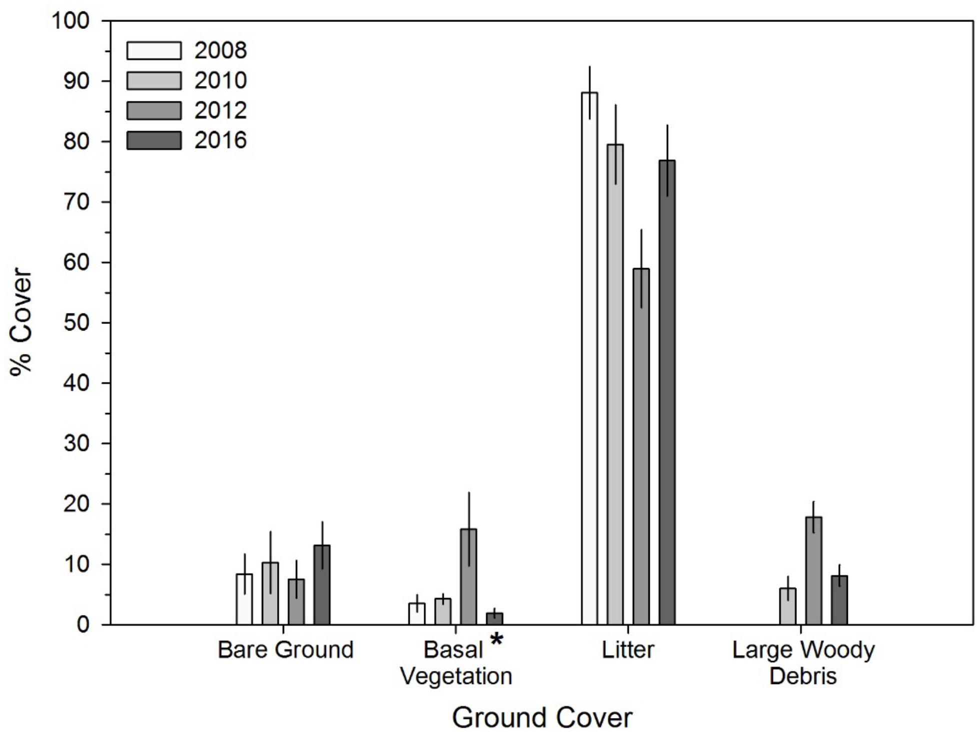

Figure 11 Mean ± SE percent ground cover at the Heavenly Creek SEZ Demonstration project in four monitoring years. In 2006/2007 ground cover protocols differed from post-project monitoring and is excluded.

DISCUSSION

Riparian communities experience frequent disturbances due to seasonal variations in water levels, floods, erosion, abrasion, drought, and freezing; therefore the majority of riparian species are disturbance-adapted (Naiman & Decamps 1997). In order to detect plant community response to disturbance or habitat manipulations, it is important to provide adequate time to allow the response. This report addresses responses in native and non-native plant communities 9 years after fuel reduction activities disturbance to the area. Vegetation responses can occur gradually over many years or progress slowly until a large disturbance event occurs.

Native herbaceous cover was initially observed to decline in 2008, and that trend continued into 2010 where it appeared to reach its minimum cover. Native herbaceous cover began to recover in 2012 (five years post disturbance) and continued to recover in 2016 where it reached a level that was not statistically different from pre-project conditions (nine years post disturbance). Vegetation response to riparian restoration activities can occur rapidly (within one growing season) or exhibit substantial lag times (Loheide & Gorelick 2006, Katz et al. 2009). The initial decrease in native herbaceous plant cover was to be expected based on the amount of disturbance that fuel reduction operations can cause. However, the increase in cover from 2010 to 2016 and the return to pre-project conditions suggests that the herbaceous vegetation was not permanently reduced and that recovering from project disturbances such as these could be reasonably expected to occur within six to nine years.

Nine years after project implementation there was no significant change in native shrub cover. While this lack of difference between pre-project conditions does meet the objective of this project, it is worth noting that post hoc pair wise comparisons and repeated measures indicated that shrub cover was relatively stable across all monitoring years and did not significantly differ between any monitoring year. These results are similar to those reported in previous interim reports. Therefore, project implementation does not appear to have had an adverse impact on native shrub cover and any anticipated beneficial effects of project implementation, have not yet been observed.

When using ocular measurements of percent cover there are always inherent differences in observations which can be attributed to observer differences. Studies have shown that changes in cover greater than 20-25% of the mean must be observed before the change can be attributed to factors other than observer bias (Hope-Simpson 1940, Greig-Smith 1983, Kennedy & Addison 1987). All significant differences in post hoc pairwise comparisons exceeded this threshold indicating that the significant differences that were observed were likely true difference.

The climate from 2006 to the latest monitoring event in 2016 was characterized predominantly by periods of incipient to extreme drought with only five years of normal to slightly wetter than normal conditions according to the PDSI for California climate division 3. In 2007, 2008, and in 2014, Climate Division 3 experienced two periods of severe drought and one of extreme drought which was the worst drought on recent 30-year record of PDSI. In addition, from 2007 to 2010 and from 2012 to 2016 the Heavenly Creek Valley SNOTEL station reported snow water equivalent that was well below the 30-year average. This snow pack supplies water during the late growing season months which are typically characterized by having low amounts of liquid precipitation. Despite these drought conditions herbaceous plant cover was able to recover and native shrub vegetation cover remained relatively stable. This suggests that precipitation may have less influence than site conditions in affecting herbaceous plant establishment and/or persistence. Although drought likely played a role in delaying recovery, the vegetation responses over several years in this report may represent true management responses and not climate effects.

The number of invasive species at the project site initially decreased significantly from pre-project conditions coinciding with the decrease in herbaceous plant cover. Invasive plant cover began to increase sooner than native herbaceous cover, beginning a significant increase in percent cover in 2010. The overall percent cover of non-native species has not increased past pre-project levels, indicating that the management objective has continued to be met as per previous interim reports. However, there were two individual transects in 2016 which had higher than pre-project levels which could indicate an emerging trend, that overtime, there may be an increase in invasive cover compared to pre-project coniditions. *Cirsium vulgare* (bull thistle) was the only invasive observed during monitoring that is treated by LTBMU staff. This species has been treated at least once a year from 2006 to the present and while initial decreases in cover were observed as of 2012, in 2016 it appears that the cover of bull thistle has approximately returned to pre-project levels. In addition there are two known infestations of *Cirsium arvense* (Canada thistle) which occur within the project area but were not found directly on any transects. These sites are relatively small and are chemically treated regularly by LTBMU staff with the goal of eradication. The initial decrease in invasive species cover does not appear to be attributable solely to the treatment efforts. While overall invasive species cover remains below pre-project conditions, two species (*Bromus tectorum* and *Tragopogon dubius*) increased which may be attributed to management actions. *Bromus tectorum* for example, is easily spread by vehicles and equipment. Observationally, drier stands dominated by mixed conifers had lower invasive species cover while wetter stands dominated by *Pinus contorta* and *Populus tremuloides* had higher invasive species cover.

As of 2016, native plant species richness across the project site did not significantly differ from pre-project conditions. Species richness initially decline in 2008 coinciding with the decrease in overall herbaceous plant cover. Following the initial decline in species richness, the number of species found increased in 2010 and 2012. Species richness increased significantly between pre-project and 2012, both along individual transects and across the entire site. Species evenness calculated either by presence/absence or percent cover were not significantly different pre- versus post-project. Beta diversity trended towards a decrease, indicating that transect diversity could be approaching site diversity.

Nine years after project implementation there was no significant difference between combined obligate and facultative wetland cover. As 2016 however, there was a significant increase in the percent cover of obligate wetland species. This increase could in part be due to the decreasing trend that was observe in the combined average of facultative, facultative upland, and upland species percent cover. In general, both wetland and upland oriented species decreased in cover following the same decrease that was observed in overall native herbaceous species cover. Recovery to pre-project levels occurred sooner in wetland and facultative wetland species than in upland favoring species. Wetland species cover was not significantly different than pre-project conditions starting in 2012, while upland species did not recover to pre-project conditions until 2016 This response could be due in part to rhizomatous reproduction strategy of many wetland species especially *Carex* spp. which made up the largest proportion of wetland species. These rhizome reproducing species would already have an established root system that is able to better access dwindling water supply and store carbohydrates in the observed drought conditions. In addition, having an already established reproduction method would not need to rely solely on seed dispersal as many herbaceous upland species require.

Due to the lack of pre-project ground cover data, it is difficult to make definitive conclusions regarding the mechanisms for changes in ground cover composition and whether there is a relationship with the pre- to post-project decrease in herbaceous vegetation. Post-project changes in ground cover do not appear to be related to post-project changes in native herbaceous vegetation. The previous 2012 interim monitoring report found that basal vegetation cover, increased along with native herbaceous cover between 2010 and 2012. As of 2016, Basal vegetation has decreased below pre-2008 conditions. The amount of post-project bare ground has not changed and remains low, therefore erosion is not a concern at this time. Although not significantly different, the increase in litter cover between 2012 and 2016 could be due to increased herbaceous cover.

CONCLUSIONS

As of 2016, all four project objectives were met. Although no positive impacts have been found resulting from this fuel reductions project, no lasting detrimental effects have been found either. Nine years after the completion of the fuels thinning operation, native herbaceous plant and shrub cover are not statistically different than pre-project conditions. In addition, although some individual transects have experienced an increase in non-native plant cover, the overall cover of invasive species did not differ in 2016 compared to pre-project conditions. While the overall cover of invasive species did not increase, two individual species (*Bromus tectorum* and *Tragopogon dubius*) did increase in cover. Diversity of species and the evenness of their distribution has not significantly been impacted by project disturbance. The distribution of wetland obligate and facultative wetland plants did not significantly differ, however there was a small significant increase in the percent cover of obligate species. According to the results of this monitoring report, recovery from disturbance on herbaceous plant cover after an initial decrease began to occur after four to five years with full recovery occurring after six to nine years. This recovery occurred despite extremely drought stricken conditions, however recovery may have been delayed due to these conditions.

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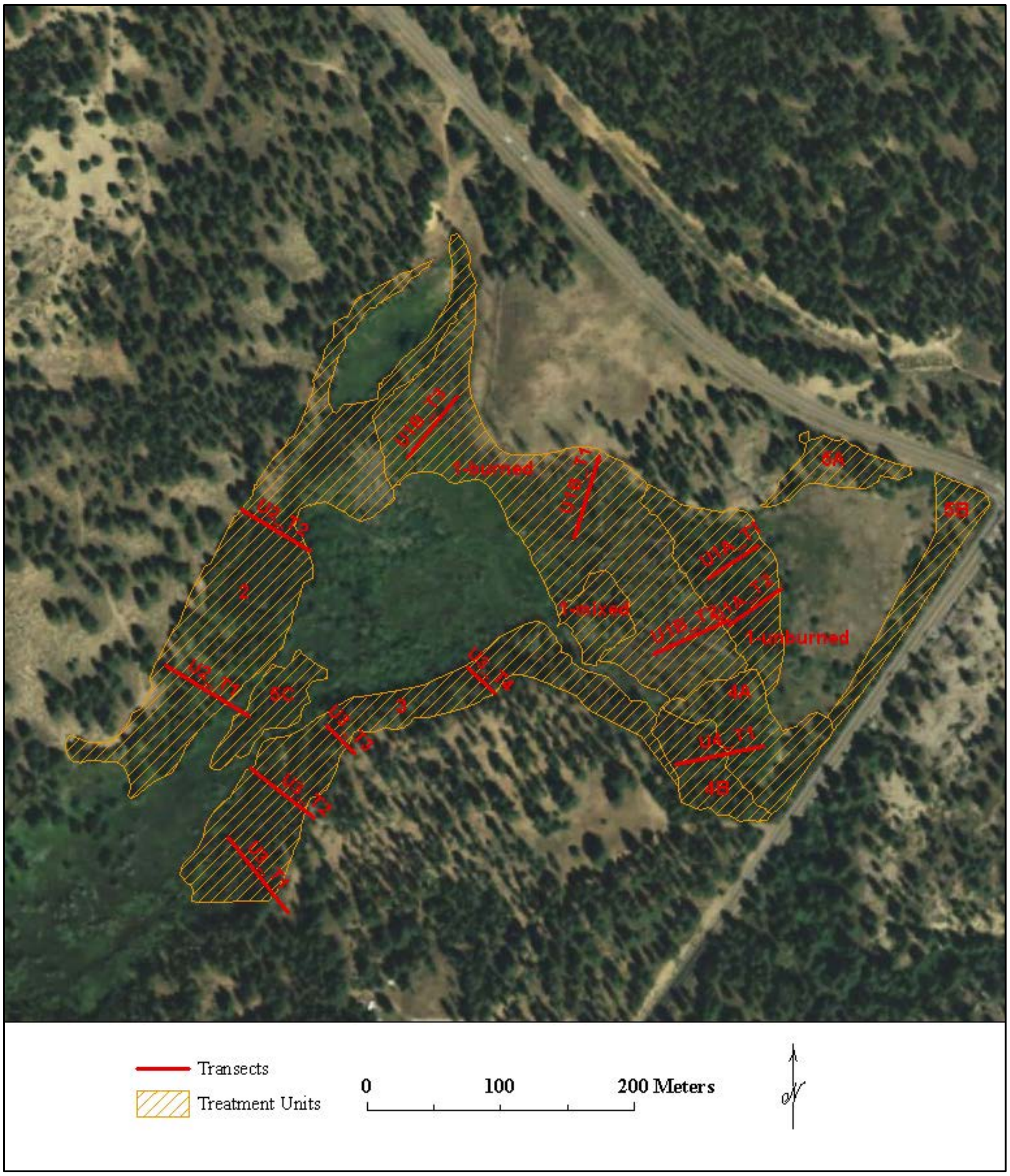
APPENDIX 1. Heavenly Creek SEZ Demonstration Project: Treatment Unit Boundaries and Vegetation Monitoring Transects



Appendix 2. Species present along transects at the Heavenly Creek SEZ Demonstration Project during three survey visits.

Species	Pre-project	2008	2010	2012	2016	Wetland Status[1]	Native/Invasive (Rating)[2]
Achillea millefolium	x	x	x	x	x	FACU	N
Achnatherum occidentale	x	x	x	x	x	UPL	N
Achnatherum lemmonii				x		NO INFO	N
Agoseris retrorsa		x	x	x		UPL	N
Agrostis pallens				x	x	FACU	N
Agrostis sp.	x	x	x	x		FACU	N
Agrostis stolonifera			x	x	x	FACW	I (Limited)
Allophyllum gilioides		x	x			UPL	N
Arnica chamissonis	x	x	x	x	x	FACW	N
Artemisia tridentata			x	x		UPL	N
Aster occidentalis	x	x	x	x	x	UPL	N
Bromus carinatus	x	x	x	x		UPL	N
Bromus tectorum	x	x	x	x	x	UPL	I (High)
Calamagrostis sp.	x					FACW	N
Calyptridium umbellatum				x		UPL	N
Carex aquatilis			x	x	x	OBL	N
Carex athrostachya	x					FACW	N
Carex canescens		x	x	x	x	OBL	N
Carex lanuginosa	x		x	x	x	OBL	N
Carex lasiocarpa		x				OBL	N
Carex lenticularis		x				OBL	N
Carex microptera			x			FACU	N
Carex multicostata			x	x	x	FACW	N
Carex nebrascensis	x	x	x	x	x	OBL	N
Carex phaeocephala		x				UPL	N
Carex sp. 1	x	x	x	x		FACW	N
Carex sp. 2	x	x	x	x		FACW	N
Carex sp. 3	x	x		x		FACW	N
Carex utriculata	x		x			OBL	N
Cerastium sp.		x				NO INFO	N
Chenopodium album		x		x		FAC	I (Not Listed)[3]
Circaea alpina	x					FAC	N
Cirsium andersonii			x	x	x	UPL	N
Cirsium vulgare	x	x	x	x		FACU	I (Moderate)
Claytonia perfoliata	x		x			FAC	N
Claytonia rubra ssp *rubra*					x	NO INFO	N
Collinsia sp.		x	x			NO INFO	N

Species	Pre-project	2008	2010	2012	2016	Wetland Status[1]	Native/Invasive (Rating)[2]
Collomia sp.	x	x				UPL	N
Cryptantha sp.	x	x	x	x		UPL	N
Dactylis glomerata	x					FACU	I (Limited)
Danthonia sp.		x				UPL	N
Elymus elymoides	x	x	x	x	x	FACU	N
Elymus glaucus			x	x	x	FACU	N
Elymus trachycaulus			x	x	x	FAC	N
Epilobium angustifolium	x	x	x	x	x	FACU	N
Epilobium ciliatum	x	x	x	x	x	FACW	N
Equisetum arvense	x	x	x	x	x	FAC	N
Erigeron sp.	x					UPL	N
Eriogonum spergulinum			x	x		UPL	N
Festuca idahoensis	x	x	x	x	x	FACU	N
Fragaria virginiana	x	x	x	x	x	FACU	N
Galium aparine	x	x	x	x	x	FACU	N
Galium palustre	x		x	x	x	FACU	N
Gayophytum diffusum	x	x	x	x	x	UPL	N
Geranium richardsonii			x	x		FACW	N
Geum macrophyllum	x	x	x	x	x	FAC	N
Glyceria elata		x	x	x		OBL	N
Hieracium albiflorum	x	x		x		UPL	N
Hordeum brachyantherum	x	x	x	x	x	FACW	N
Juncus arcticus	x	x	x	x	x	FACW	N
Juncus ensifolius	x					FACW	N
Juncus nevadensis				x	x	FACW	N
Juncus orthophyllus			x	x	x	FACW	N
Lathyrus lanzwertii		x	x			FACU	N
Lonicera conjugialis		x	x	x		FAC	N
Lotus purshianus	x					UPL	N
Lupinus breweri	x	x	x	x	x	UPL	N
Lupinus fulcratus	x	x	x	x	x	UPL	N
Lupinus grayi			x			UPL	N
Lupinus lepidus			x	x		UPL	N
Luzula comosa		x		x		FAC	N
Mimulus guttatus	x	x		x	x	OBL	N
Mimulus primuloides	x			x		OBL	N
Muhlenbergia filiformis	x	x	x			FACW	N
Orthilia secunda	x					FACU	N
Osmorhiza chilensis	x	x	x	x		FACU	N
Paeonia brownii				x		UPL	N

Species	Pre-project	2008	2010	2012	2016	Wetland Status[1]	Native/Invasive (Rating)[2]
Penstemon rydbergii	x	x	x			FACU	N
Phacelia hastata	x	x	x	x		UPL	N
Phleum pratense	x					FACU	I (Watch List)
Phlox gracilis			x	x		FACU	N
Poa pratensis	x	x	x	x	x	FAC	I (Limited)
Poa secunda	x	x			x	FACU	N
Poaceae sp. 1	x		x	x		NO INFO	N
Poaceae sp. 2			x			NO INFO	N
Polemonium californicum			x			NO INFO	N
Polygonum douglasii	x		x	x	x	FACU	N
Potentilla glandulosa	x	x	x	x	x	FAC	N
Potentilla gracilis	x			x	x	FAC	N
Prunella vulgaris	x					FACU	N
Pseudostellaria jamesiana				x		NO INFO	N
Ranunculus occidentalis			x	x		FACW	N
Ribes nevadense	x	x				FAC	N
Ribes roezlii	x	x	x	x		UPL	N
Ribes montigenum					x	NO INFO	N
Rorippa nasturtium-aquaticum	x	x	x			OBL	N
Rosa woodsii		x	x	x		FACU	N
Rumex acetosella	x	x	x	x	x	FACU	I (Moderate)
Rumex crispus		x	x		x	FAC	I (Limited)
Salix lemmonii	x	x	x	x		FACW	N
Salix lucida	x	x	x	x		FACW	N
Senecio integerrimus	x		x			FACU	N
Senecio triangularis					x	FACW	N
Sidalcea oregana	x	x	x	x	x	FACW	N
Silene lemmonii		x				NO INFO	N
Sisyrinchium idahoensis			x	x		FACW	N
Smilacina stellata		x	x	x	x	FAC	N
Solidago canadensis				x	x	FACU	N
Spergularia rubra				x		FAC	I (Not listed)[3]
Stellaria longipes	x	x	x	x	x	FACW	N
Taraxacum officinale	x	x	x	x	x	FACU	I (Watch List)
Tragopogon dubius	x		x		x	NO INFO	I (Watch List)
Trifolium longipes	x	x	x	x	x	FAC	N
Trisetum spicatum	x					UPL	N
Verbascum thapsus		x				FACU	I (Limited)
Veronica peregrina		x		x		OBL	N

Species	Pre-project	2008	2010	2012	2016	Wetland Status[1]	Native/Invasive (Rating)[2]
Viola glabella	**x**					FAC	N
Viola macloskeyi	**x**	**x**	**x**	**x**	**x**	OBL	N

[1] Wetland Status follows the US Fish & Wildlife 2012 National Wetland Plant List as of December 2012.
[2]Rating follows the California Invasive Plant Council Invasive Plant Inventory as of December 2012.
[3]Not included in analyses but were observed along transects