Pawnee Montane Skipper Monitoring Study for the Upper South Platte Watershed Protection and Restoration Project
August 2020

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Colorado Natural Heritage Program
Colorado State University
Ft. Collins, Colorado 80523

CNHP's mission is to advance the conservation of Colorado's native species and ecosystems through science, planning, and education for the benefit of current and future generations.

Pawnee Montane Skipper Monitoring Study for the Upper South Platte Watershed Protection and Restoration Project
August 2020

Prepared for

U. S. Forest Service
Pike and San Isabel National Forests
And
Comanche and Cimarron National Grasslands
South Platte Ranger District
30403 Kings Valley Dr., Suite 2-115
Conifer, CO 80433

Prepared by:

John Sovell

Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
1475 Campus Delivery
Fort Collins, CO 80523
(970) 491-7331

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Cover photos clockwise from top left: Pawnee montane skipper (*Hesperia leonardus montana*); Two Pawnee montane skippers nectar at dotted gayfeather (*Liatris punctata*); survey transect 209 in the 2002 treatment area; egg of Pawnee montane skipper on blue grama (*Bouteloua gracilis*). Photos taken by Colorado Natural Heritage Program Staff.

ABSTRACT

Skipper density for both the pooled *Hesperia* and HLM samples in 2020 declined from the previous year, but the density of both samples was still relatively high (12.7 pooled Hesperia/acre and 2.7 HLM/acre). Unlike previous years, the 2004 Treatment Area had the greatest numbers of *Hesperia* skippers, but the Control Area again had the highest density of HLM. Overall, there was a high ratio of Western branded skippers to HLM suggesting that this year's sampling may have occurred prior to the peak flight period of the HLM. Like most previous years, the densities of both the pooled *Hesperia* and HLM samples did not differ statistically among the four forest treatments. This year's flowering dotted gayfeather stem densities decreased dramatically from the previous year, to 61.1 stems per acre for all forest treatments combined (**Table 3**). These values of flowering stem density are lower than for all other years monitored except for the extreme drought year of 2002**.** The GSP this year was dramatically less than that of the previous year, second to only the low GSP of 2002, and dotted gayfeather densities were negatively impacted by this large decrease in precipitation. Dotted gayfeather flowering stem density this year were greatest in the 2000 Treatment Area, although this difference was not significant (**Table 4**). Similar to previous year's, dotted gayfeather density was positively correlated with GSP (r^2=0.43, p=0.002) and the proportion of plants in flower was the lowest on record (60 percent), suggesting that skipper counts were conducted before peak flowering and/or that the drought had compromised plant fitness and flowering. Similar to previous years, the 2004 Treatment Area differed from the other three forest treatments in the environmental variables that significantly influenced skipper density. Like past years, growing season temperature had a positive and significant influence on both HLM and *Hesperia* skipper density and annual temperature had a negative and significant influence on both HLM and *Hesperia* skipper densities at most all forest treatments.

EXECUTIVE SUMMARY

In 2000, the U.S. Forest Service (USFS), in cooperation with the Colorado State Forest Service, Denver Water, and other entities, implemented a program of forest thinning treatments to reduce the risk of large fires that could occur where surface fuels have accumulated and dense forest stands have resulted from past fire management activities. To assist in identifying project effects over the short- and long-term, the USFS and Denver Water sponsored a pilot *Hesperia* monitoring program for the federally threatened Pawnee montane skipper (*Hesperia leonardus montana*; HLM), to evaluate the relative use by skippers of treated and untreated areas. Annual monitoring began in August 2000; this report discusses results of the most recent years monitoring in relation to all previous years.

The primary objective of the monitoring effort is to compare skipper use (measured by the number of adult butterflies seen within a known area) of untreated lower montane forest with butterfly use in lower montane forest that has been thinned to reduce fire danger, which is expected to improve Pawnee montane skipper habitat. A secondary objective made possible by the continued annual monitoring is to document and interpret year-to-year variability in skipper densities in the monitored areas and to monitor skipper response to drought.

The monitoring study was designed to compare the number of adult *Hesperia* skippers within four forest treatments including three areas that received substantial thinning in either 2000 (2000 Treatment Area), 2002 (2002 Treatment Area), or 2004 (2004 Treatment Area) and a Control Area. The Control Area approximates optimal skipper habitat characteristics described by the U.S. Fish and Wildlife Service (USFWS 1987, 1998). The monitoring procedure involves counting all *Hesperia* skippers including the HLM and western branded skipper (*H. colorado*). The abundance of the primary adult nectar source (dotted gayfeather, *Liatris punctata*) was measured by counting the number of flowering stems present at each transect, and the abundance of the larval food plant (blue grama, *Bouteloua gracilis*) was measured by noting its presence or absence at subplots within each monitored transect. Annual and growing season (March – August) mean temperature and precipitation were collected from the nearby Cheesman weather station and compared to their 25 year means from 1985-2009.

An analysis of variance was conducted to determine whether there were significant differences in the skipper counts among treatments (Control Area, 2000 Treatment Area, 2002 Treatment Area, and 2004 Treatment Area) within and across the 15 monitored transects. Similar statistical analyses of blooming dotted gayfeather stems were performed and are reported here as well. Multiple regression was also performed to understand how precipitation, temperature and dotted gayfeather are associated with skipper density and how precipitation and temperature are associated with dotted gayfeather density among treatments.

The skipper monitoring data in this study now cover two decades, which, impressive as it is for a study of insect population dynamics, is relatively short in comparison to longer climatic changes, such as drought cycles. Since the beginning of this monitoring effort in 2000, skipper population size in the project area showed evidence of an increasing trend. This is true of both the pooled skipper sample (*H. colorado* and *H. l. montana* combined) and the Pawnee montane skipper sample taken individually (**Figure 4**). This increase in population size has been interrupted by drought in 2002, 2008 and by an extended drought occurring from 2011 to 2012 and again in 2014 through 2016.

Populations of *Hesperia* skippers on transects of the Trumbull forest treatment continued the increase in density initiated during the previous year. The current year estimates of skipper density do not correspond with increased precipitation or increased density of the primary nectar plant dotted gayfeather, but do correspond to above average temperatures. These are all environmental factors that tend to increase butterfly population size (Luppi et al. 2018, Curtis et al. 2015, Radchuk et al. 2013, Stefanescu et al. 2004).

Low growing season rainfall has consistently resulted in low flowering densities of the butterflies preferred nectar source, dotted gayfeather, on the monitored transects (**Figures 2 and 5**). The current densities in HLM have not tracked simultaneous declines in dotted gayfeather density. Increases in HLM densities may be the result of elevated temperatures during the larval development period enhancing larval survival and rates of pupation, or other unknown factors.

The HLM is particularly dependent on their primary nectar plant as well as their larval host plant, blue grama. Consequently, the objective of vegetation management for HLM conservation is to provide habitat conditions that maintain, expand, or add to the mosaic of dotted gayfeather and blue grama in ponderosa pine forest. The following management considerations for the HLM draws upon the discussion found in Sovell (2014). Forest restoration prescriptions to improve habitat for the HLM should mimic those found on the Control Area and 2000 Treatment Area for overstory structure including DBH, crown width, canopy cover, tree height, and basal area (see Table 6 in Sovell 2014). Forest restoration treatments should attempt to recreate historic forest conditions by promoting a variety of tree size classes in a clumpy spatial arrangement (see Figure 4 in Sovell 2014). Variability of the forest structure should be promoted by creating a mosaic of forested patches with openings of approximately 0.1 acre in average size. Treatment should focus on reducing the continuity of surface and ladder fuels, while simultaneously seeking a broader ecosystem response with more forest openings inducing the growth of blue grama and dotted gayfeather in the understory, thus benefiting both the HLM and forest hydrologic function (Lowe 2005).

The densities of the pooled skipper sample on transects of the Trumbull treatment area also continued to increase at all forest treatments in 2019. The greater densities estimated for the pooled skipper sample might also be attributed to elevated temperatures as discussed for the HLM. The management actions recommended for maintaining viability of the HLM population are also relevant for sustaining the overall *Hesperia* community present at the monitoring site.

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INTRODUCTION

The U. S. Forest Service (USFS) is directed to conserve and manage for species listed under the Endangered Species Act (ESA) (Forest Service Manual 2670). The Pawnee montane skipper (*Hesperia leonardus montana*; HLM) is listed as threatened under the ESA. The primary objective of this study is to compare skipper use (measured by the number of adult butterflies seen within a known area) of untreated ponderosa pine forest with skipper use at three sites where ponderosa pine forest was thinned to reduce fire danger and treatments were expected to improve HLM habitat. A secondary objective, made possible by the continued annual monitoring of this species, is to document and interpret year-to-year variability in skipper densities in the monitored areas. Additional objectives include examining the population effects of forest thinning activities on blue grama (*Bouteloua gracilis*) and dotted gayfeather (*Liatris punctata*) and to compare the annual variation in the abundance of HLM, blue grama, and dotted gayfeather populations to annual changes in precipitation and temperature.

In 2000, the USFS, Colorado State Forest Service, Denver Water, and other entities outlined a program to restore lower montane forests in the South Platte River drainage. The proposed Upper South Platte Watershed Protection and Restoration Project (USPWPRP) included timber harvesting, understory thinning, prescribed burning, revegetation of burned areas, obliteration and reclamation of unnecessary roads, and trail improvements. The U. S. Forest Service initiated formal consultation with the U.S. Fish and Wildlife Service (USFWS) in June 2000 to review actions proposed by the USPWPRP for their potential effects on species listed under the ESA including the HLM. The USFWS prepared a Biological Opinion (BO), which has been updated three times, to evaluate the effects of the proposed actions on listed species (U. S. Fish and Wildlife Service 2001, 2003, 2009). The BO identified specific thinning and rehabilitation measures, and monitoring programs for lands to be treated. Project implementation has been ongoing annually since 2000.

The U. S. Forest Service works with Colorado State University – Colorado Natural Heritage Program (CSU-CNHP) to evaluate USPWPRP project effects over the short- and long-term on populations of HLM within suitable habitat of the South Platte River Valley. During the flight season in August 2000, the USFS and Denver Water sponsored a pilot skipper monitoring program for both HLM and western branded skipper (*Hesperia colorado*) to evaluate relative use by skippers of treated and untreated areas. Monitoring work has continued since then as called for in the BO. This report describes the results from adult skipper monitoring conducted during the 2020 flight season and provides comparisons with sampling completed annually since 2000.

STUDY AREA

The study area is in Douglas and Jefferson counties in central Colorado approximately 1.5 miles north of Deckers on State Highway 67 (**Figure 1**). Most of the study site is on Pike National Forest land (80 percent) with the remainder on Denver Water Board property.

The project area covers approximately 1,400 acres and ranges in elevation from approximately 6,400 feet near the South Platte River to a maximum elevation of 6,760 feet above mean sea level in the 2002 treatment area. Additional background information for the project site is presented in the Pawnee Montane Skipper Monitoring Study for the Upper South Platte Watershed Protection and Restoration Project: August 2017 (Sovell 2018).

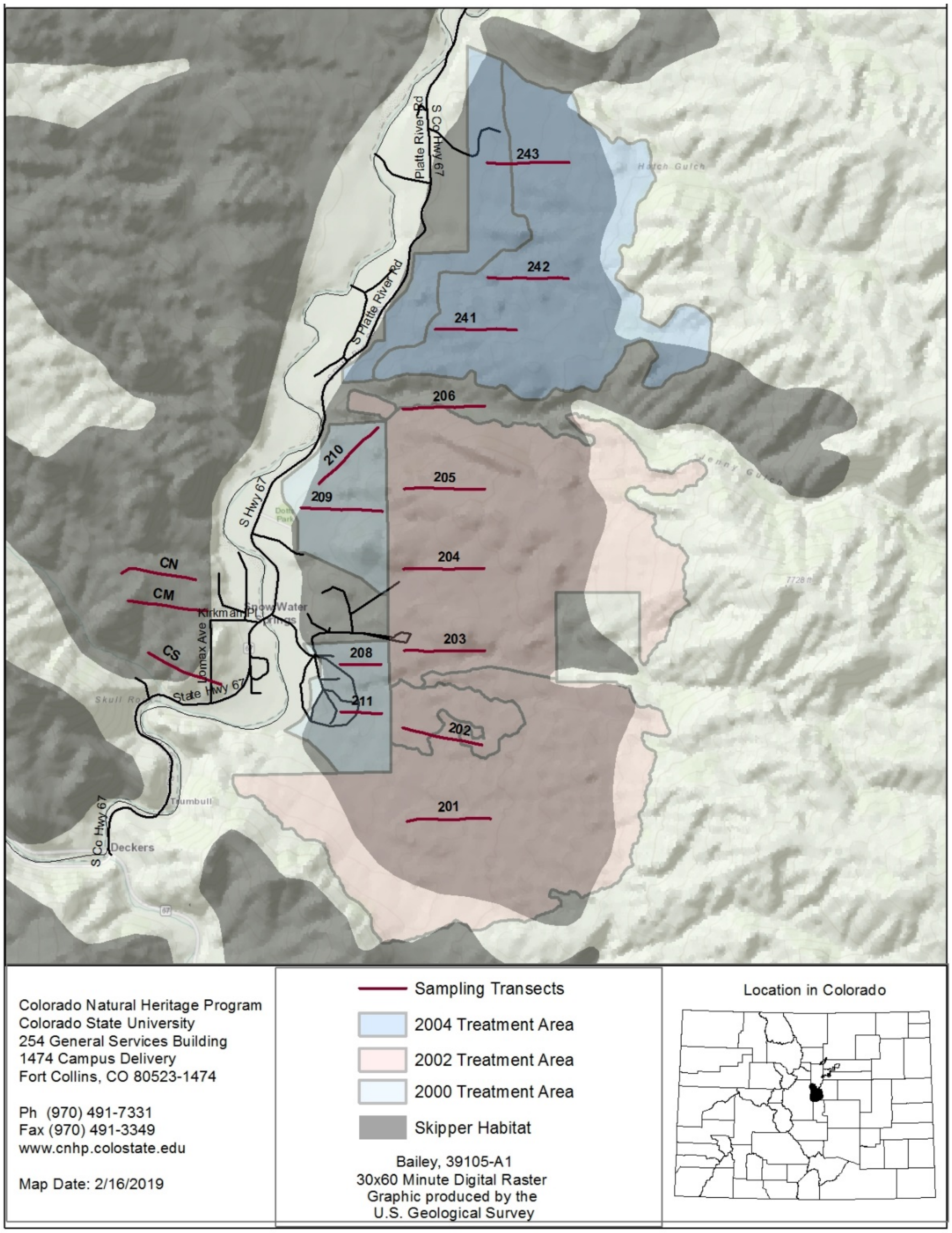

Figure 1. Location of Pawnee montane skipper (*Hesperia leonardus montana*) monitoring transects.

METHODS

In this report, to simplify the represented analyses, the analysis of variance for the skipper butterfly (*Hesperia* spp. and HLM) and dotted gayfeather were restricted to data from the past decade (2010 -2020). Otherwise, the methods for this year's monitoring were the same as those used in the monitoring effort of previous years. For a detailed discussion of these methods refer to Appendix A**.**

RESULTS

Field reconnaissance of the Trumbull area prior to initiation of fieldwork was conducted by personnel from the USFS to determine the period of peak dotted gayfeather flowering and skipper activity. Based on the condition of dotted gayfeather and skipper activity at the time, the annual monitoring effort appeared to coincide with an average year's schedule as determined by previous studies (Environmental Research Technology 1986,1988, and 1989; ENSR 2003a, and b; Drummond 2005).

Sampling for this year was conducted from August 24 to August 27, 2020. Surveys started at approximately 10:00 am each day with start temperatures ranging from 71^0 to 76^0F. Temperatures rose steadily each morning reaching highs by 1:00-3:00 pm that ranged from 91^0 to 94^0F. Cloud cover each day started out 30% or less, but usually increased as the day progressed. Survey work halted during rainstorms, and if a survey had to be cancelled it was completed with favorable weather in the following days.

Annual counts were led by John Sovell (CNHP), Mikele Painter, and Christine Sandbach (USFS); and assisted by David Rude, Angela Tackett, and Debbie Yoo (USFS); Kristen Salamack (USFWS/CDOT); Chelsea Beebe, Michelle Desrosiers, Angel Flores, Jordan Laughlin, Tanner Marshall, Joel Neitzke, Lexi Sorenson, Matt Svejnoha, and Joe Zamboldi (Jeffco Open Space); and Ariel Demarest, Kaylin Medina, and Abby Voorhis (Volunteers).

August 24: Painter, Sorenson, and Voorhis (204, 205, 206, 209, 210); Sandbach, Demarest, and Medina (201,202,203,208/211, 243) Sovell, Laughlin, and Zamboldi (CM, CN, CS, 241, 242).

August 25: Painter, Neitzke, and Yoo (204, 205, 206, 209, 210); Sandbach, Laughlin, and Tackett (CM, CN, CS, 241, 242); Sovell, Desrosiers, and Svejnoha (201,202,203,208/211, 243).

August 26: Painter, Desrosiers, and Marshall (CM, CN, CS, 241, 242); Sandbach, Rude, and Salamack (201,202,203,208/211, 243) Sovell, Beebe, and Flores (204, 205, 206, 209, 210).

August 27: Painter, Tackett, and Voorhis (203); Painter, Sandbach, Tackett, and Voorhis (243) Sovell, and Sandbach (208/211).

Study Area Conditions

The study uses a 25 year mean for both precipitation and temperature based on data from 1985-2009 recorded at the nearby Cheesman Weather Station for both the year in total and for the growing season precipitation (GSP: March-August) (Western Regional Climate Center 2020). Precipitation measured at the Cheeseman Reservoir weather station was 5.9 inches below the 25 year mean for the calendar year.

During the important growing season period, precipitation was 0.89 inches below the 25-year mean (**Figure 2a**). The variation in GSP over the monitoring period shows that GSP has been below normal for most years sampled (16 of the 21 sample years). There has been a statistically insignificant decreasing trend in GSP since 2000 (r^2=0.0008, p=0.9). If the outlier value for GSP in 2002 is removed, when precipitation was 1.26 inches below the 25-year mean, then a greater portion of variation in the decline in GSP is explained by time (r^2=0.05), although it still insignificant (p=0.4). Annual precipitation was 0.55 inches below the 25-year mean (**Figure 2b**). The variation in AP over the monitoring period shows that AP has been below normal for most years sampled (15 of the 21 sample years). There has been a statistically insignificant decreasing trend in GSP since 2000 (r^2=0.003, p=0.8)

Temperature measured at the Cheesman Reservoir weather station was 5.2 degrees above the 25-year mean for the calendar year (Western Regional Climate Center 2020). During the important growing season period (GST: March-August), temperature was 5.1 degrees above the 25-year mean (**Figure 3a**). The values of GST over the monitoring period have been above normal for most years sampled (19 of the 21 sample years). Temperatures have been trending up since 2000 and this increase is statistically significant (r^2=0.4, p=0.005) (**Figure 3a**). The values of AT over the monitoring period have been above normal for most years sampled (18 of the 21 sample years). Temperatures have been trending up since 2000 and this increase is statistically significant (r^2=0.5, p=0.0006) (**Figure 3b**).

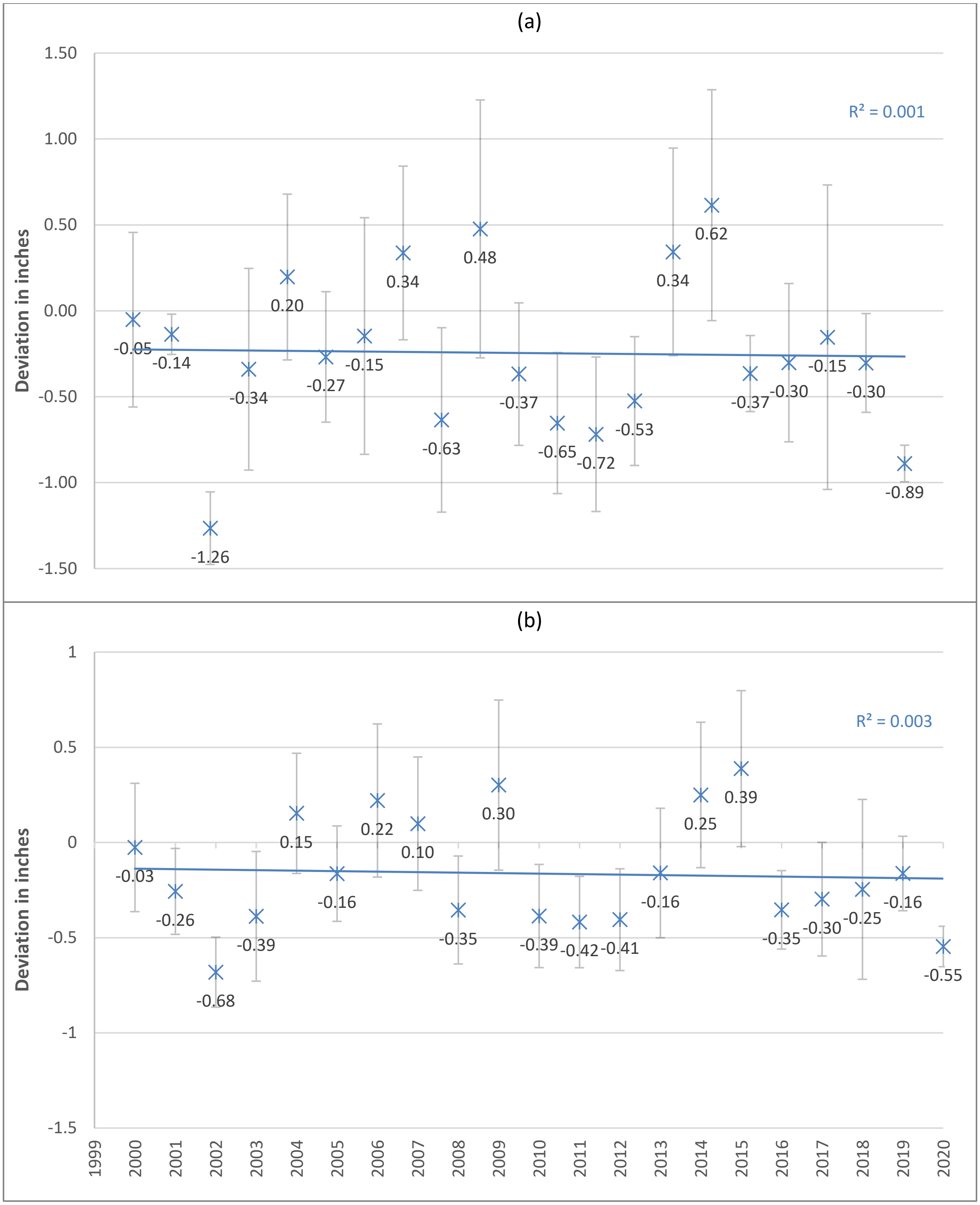

Figure 2. Deviations from mean values of (a) growing season precipitation (inches + 1 SE) and (b) annual precipitation (inches + 1 SEdegrees F + 1 SE) with the 25-year mean shown on each graph as 0.00. The linear trend lines over the entire study period for both growing season and annual precipitation are displayed.

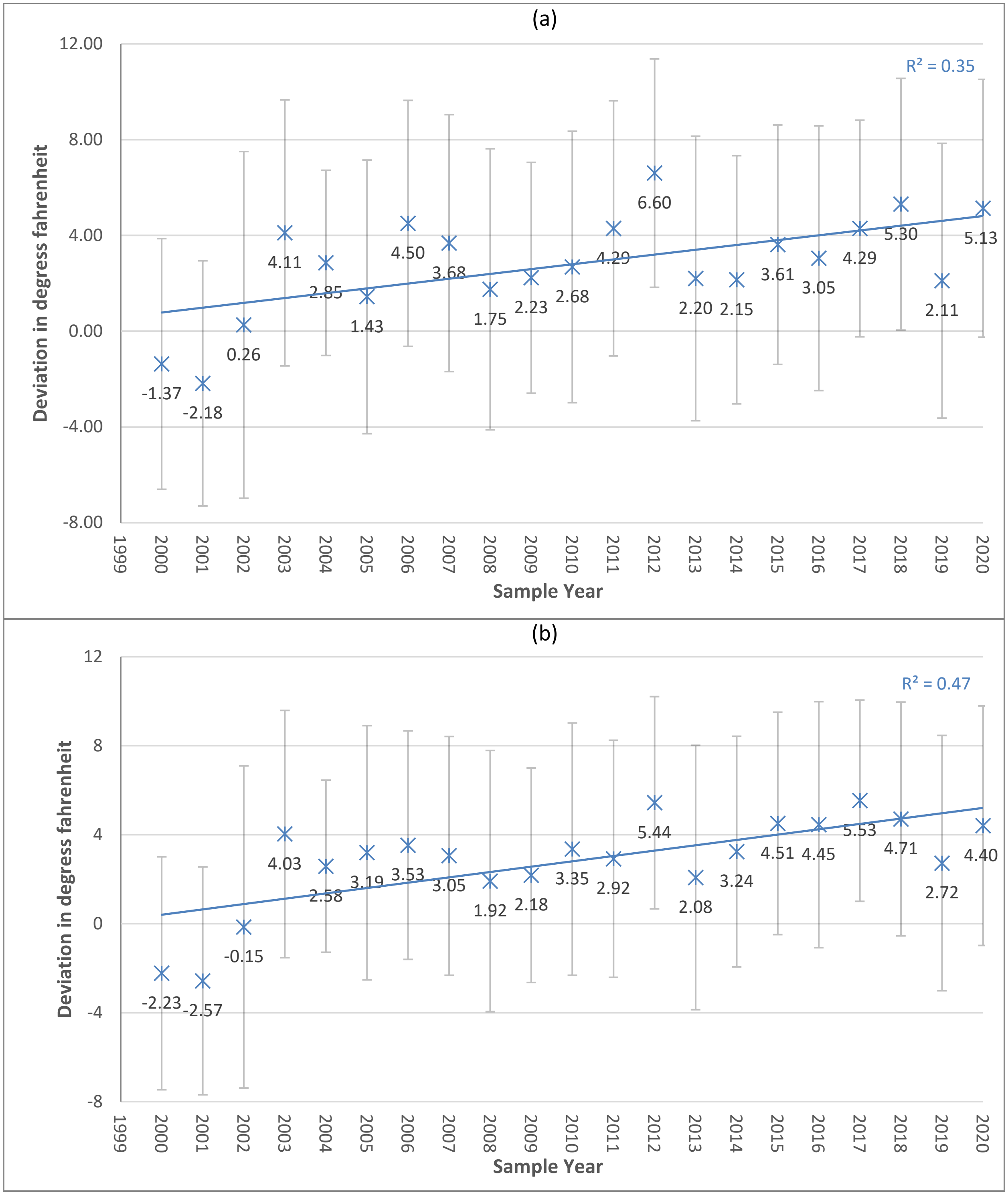

Figure 3. Deviations from mean values of (a) growing season temperature (degrees F + 1 SE) and (b) annual temperature (degrees F + 1 SE) with the 25-year mean shown on each graph as 0.00. The linear trend lines over the entire study period for both growing season and annual temperature are displayed.

Skipper (*Hesperia*) Counts

Among Years

Skipper densities have significantly increased in both the pooled *Hesperia* sample (r^2=0.51, p=0.0003) and the HLM sample (r^2=0.41, p=0.003) since the beginning of monitoring in 2000 (**Figure 4**).

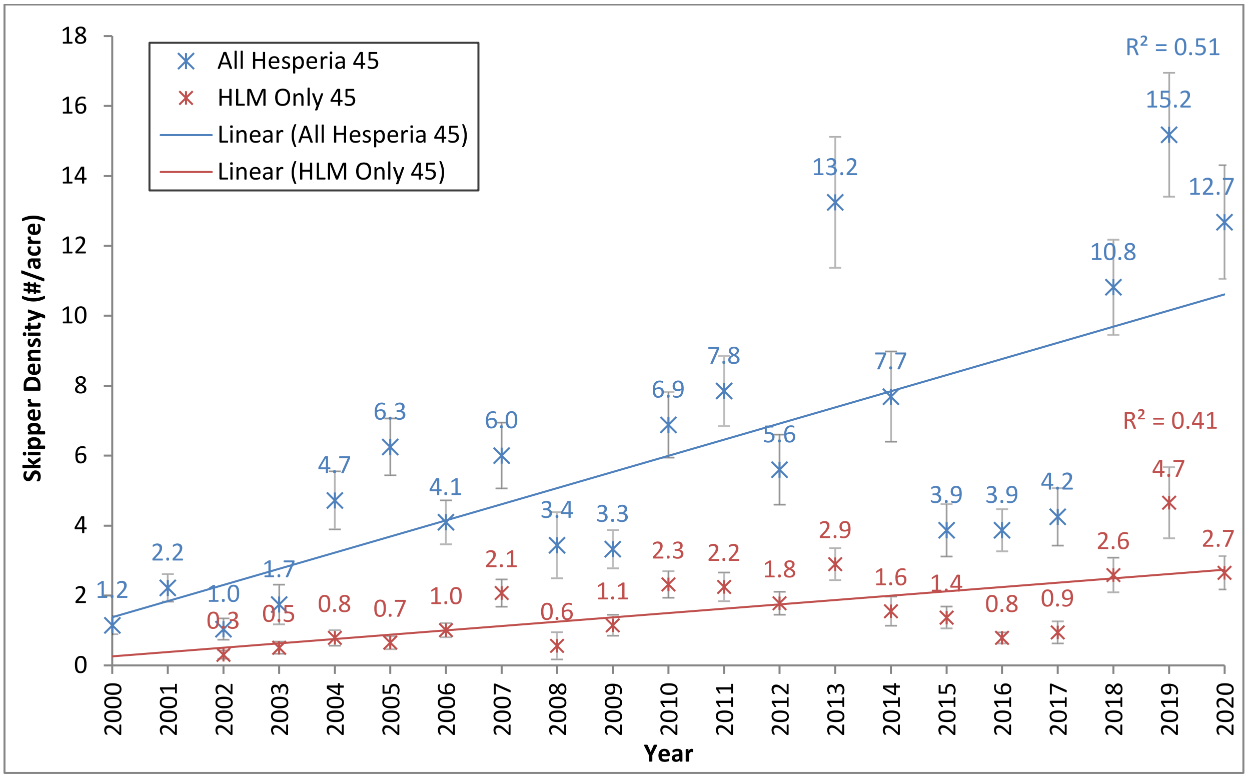

Figure 4. Comparisons of skipper (*Hesperia* and HLM) densities across time, averaged for all forest treatments.

Table 1 provides a summary of skipper densities for both the pooled *Hesperia* sample and the HLM sample averaged over all treatments for the monitoring period 2010 through 2020. This year's skipper densities when all transects are included were towards the higher end of the recorded values, over 12.7 per acre for the pooled *Hesperia* sample and 2.7 per acre for the HLM sample (**Figure 4 and Table 1**). These values of density were some of the highest recorded during the period of monitoring (**Figure 4 and Table 1).** The trend in the magnitude of variability in density has been similar between the pooled *Hesperia* sample and the HLM sample while both discontinued the most recent increase in density initiated in 2016 (**Figure 4**). When all 15 transects are analyzed this year's densities are statistically similar to the years 2001, 2013, 2014, 2018, and 2019 for the pooled skipper sample while this year's HLM sample differ from any of the years analyzed (**Table 1**).

Table 1. Comparisons of skipper (*Hesperia* and HLM) densities (number/acre) across time, averaged for all forest treatments[1].

	Pooled *Hesperia* Sample (*Hesperia colorado* and *Hesperia leonardus montana)*				**Pawnee Montane Skipper Sample (*Hesperia leonardus montana*)**			
	***Hesperia* Skippers**				**Pawnee Montane skipper**			
	Number of Transects[2] = 36 (2004 Treatment Area Excluded		**Number of Transects[3] = 45** (2004 Treatment Area Included)		**Number of Transects[2] = 36** (2004 Treatment Area Excluded)		**Number of Transects[3] = 45** (2004 Treatment Area Included)	
Year	**Mean skippers/ acre[4]**	**Homogeneous Groups[5] P = 0.05**	**Mean skippers/ acre[4]**	**Homogeneous Group[5] P = 0.05**	**Mean skippers/ acre[4]**	**Homogeneous Groups[5] P = 0.05**	**Mean skippers /acre[4]**	**Homogeneous Group[5] P = 0.05**
2010	7.42	AB	6.88	AB	2.50	A	2.32	A
2011	8.83	ABC	7.85	ABC	2.67	A	2.25	A
2012	6.46	AB	5.60	AB	2.08	A	1.78	A
2013	15.04	CD	13.24	CD	3.49	AB	2.90	AB
2014	9.27	ABC	7.69	ABC	1.94	A	1.55	A
2015	4.10	A	3.87	A	1.38	A	1.37	A
2016	4.27	A	3.87	A	0.94	A	0.79	A
2017	5.00	A	4.25	A	1.15	A	0.94	A
2018	12.08	BCD	10.81	BCD	2.87	AB	2.59	AB
2019	17.26	D	15.18	D	5.37	B	4.65	B
2020	12.34	BCD	12.68	CD	2.92	AB	2.65	AB

[1] Control Area, 2000 Forest Treatment, 2002 Forest Treatment, and 2004 Forest Treatment in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado. Upper South Platte Watershed Restoration Project.

[2] *n* = 36: 12 transects sampled 3 times per year, which excludes data from the 2004 Treatment Area for every year.

[3] *n* = 45: 15 transects sampled 3 times per year, which includes data from the 2004 Treatment Area for every year.

[4] The means are reported in two ways. In the second and the sixth columns, the mean skippers/acre for every year is calculated **without** the 2004 Treatment Area data (this was done so that the means can be compared based on the same number of transects across all years with a consistent *n*=36). In the fourth and eighth columns, the mean skippers/acre is calculated **with** the 2004 Treatment Area data (*n*=45).

[5] Compare the treatment areas for each year by reading the columns vertically. Tukey's Mean Comparison Test — means (number of skippers per acre) with the same letter are not statistically different at the probability level indicated (e.g., See (**A**) and (**B**): for the Pawnee montane skipper with the 2004 Treatment Area excluded the years 2010 through 2018 and 2020 do not different from each other, but 2019 does differ from the years 2010-2017 except for the year 2013).

The past three years and the year 2013 had high ratios of Western branded skippers to Pawnee montane skippers, particularly the years 2013 and this year, suggesting that sampling for these years was conducted before the HLM peak flight period (**Table 2**).

Table 2 Comparisons of Skipper (*Hesperia Colorado* and *Hesperia leonardus montana*) Densities by Year.

Year	Mean Western branded skippers[4]	Mean Pawnee montane skippers[4]	Difference	Homogeneous Group[5] P = 0.05
2010	4.51	2.29	2.22	AB
2011	5.53	2.22	3.31	AB
2012	3.78	1.76	2.02	AB
2013	10.22	2.87	7.36	C
2014	6.07	1.53	4.53	ABC
2015	2.47	1.36	1.11	A
2016	3.04	0.78	2.27	AB
2017	3.27	0.93	2.33	AB
2018	8.13	2.56	5.58	BC
2019	10.40	4.60	5.80	BC
2020	9.91	2.62	7.29	C

Among Forest Treatments

Table 3 provides a summary of skipper densities for both the pooled *Hesperia* sample and the HLM sample for all forest treatments over the monitoring period 2010 through 2020. The current year's skipper density (all *Hesperia*) was statistically similar across all four forest treatments ($p<0.05$) (**Figure 5 and Table 3**). The density of the HLM this year was also statistically similar among all four forest treatments ($p<0.05$) (**Table 3**). For most all years analyzed, skipper density (all *Hesperia*) was greatest at the Control Area, and it was significantly greater than at the 2002 and 2004 Treatment Areas in 2013, 2018, and 2019 ($p<0.05$). For all years analyzed, HLM density was greatest at the Control Area, and this difference was statistically significant in 2018, and 2019 ($p<0.05$). The Control Area consistently contained the highest density of HLM, despite the variable conditions affecting different parts of the study area during this period, including drought and thinning operations (**Figure 5**). The 2000 Treatment Area had the second highest HLM densities over this time period except for in 2015, 2017, and 2018 (**Figure 5**).

Table 3. Comparisons of the pooled *Hesperia* densities and the Pawnee montane skipper densities within each year, among treatment areas[1].

	Pooled *Hesperia* Sample (*Hesperia colorado* and *Hesperia leonardus montana*)				Pawnee Montane Skipper Sample (*Hesperia leonardus montana*)			
	Mean Number of Skippers per Acre P = 0.05[2]				Mean Number of Skippers per Acre P = 0.05[2]			
Year	**Control (N=9)[3]**	**2000 Treatment (n=9)**	**2002 Treatment (N=18)**	**2004 Treatment[4] (N=9)**	**Control (N=9)[3]**	**2000 Treatment (n=9)**	**2002 Treatment (N=18)**	**2004 Treatment[4] (N=9)**
2010	7.31 A	7.99 A	7.2 A	4.72 A	4.047 A	2.586 A	1.686 A	1.574 A
2011	11.35 A	9.22 A	7.36 A	3.94 A	4.159 A	3.148 A	1.686 A	0.562 A
2012	12.7 A	7.08 A	3.04 A	2.14 A	4.497 A	2.137 A	0.843 A	0.561 A

2013	25.74 A	15.29 AB	9.56 B	6.07 B	5.397 A	3.484 A	2.529 A	0.562 A
2014	16.75 A	8.66 AB	5.85 AB	1.35 B	3.709 A	1.574 A	1.236 A	0.000 A
2015	8.54 A	4.5 A	1.69 A	2.92 A	3.48 A	1.24 A	0.39 A	1.34 A
2016	5.85 A	5.85 A	2.7 A	2.25 A	1.46 A	1.12 A	0.62 A	0.110 A
2017	7.87 A	3.94 A	4.1 A	1.24 A	3.15 A	0.22 A	0.62 A	0.110 A
2018	21.13 A	8.21 AB	9.50 B	5.73 B	6.183 A	1.461 B	1.911 B	1.460 B
2019	25.18 A	18.66 AB	12.59 B	6.86 B	12.029 A	4.048 B	2.698 B	1.797 B
2020	8.77 A	17.65 A	11.47 A	14.05 A	4.39 A	2.81 A	2.25 A	1.57 A

[1] Control Area, 2000 Forest Treatment, 2002 Forest Treatment, and 2004 Forest Treatment in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado. Upper South Platte Watershed Restoration Project.

[2] Compare the treatment areas within each year by reading the rows horizontally. Tukey's Mean Comparison Test: means (number of skippers per acre) with the same letter are not statistically different at the given probability level. [*e.g.*: for Year 2010, skipper densities are not significantly different between treatments at P=0.05 level (**A**). For 2018 and 2019, Pawnee montane skipper densities at the control area (**A**) were greater than at the other three treatment areas (**B**)].

[3] Sample size (*n*) refers to the number of transects in each treatment area multiplied by 3 samples each per year.

[4] 2004 Treatment Area was first sampled in 2005.

HLM densities have significantly increased at the Control Area (r^2=0.53, p=0.0004) and the 2002 Treatment Area (r^2=0.28, p=0.02) since the beginning of monitoring in 2000, but not at the 2000 Treatment Area (r^2=0.05, p=0.4)(**Figure 5**). The increase in density of HLM at the 2004 Treatment Area has been marginally significant (r^2=0.22, p=0.06) since the beginning of monitoring in 2000

The densities of all *Hesperia* have significantly increased at the Control Area (r^2=0.48, p=0.0005), the 2000 Treatment Area (r^2=26, p=0.02), and the2002 Treatment Area (r^2=0.48, p=0.0005) since the beginning of monitoring in 2000, but not at the 2004 Treatment Area (r^2=0.17, p=0.11) (**Figure 5**).

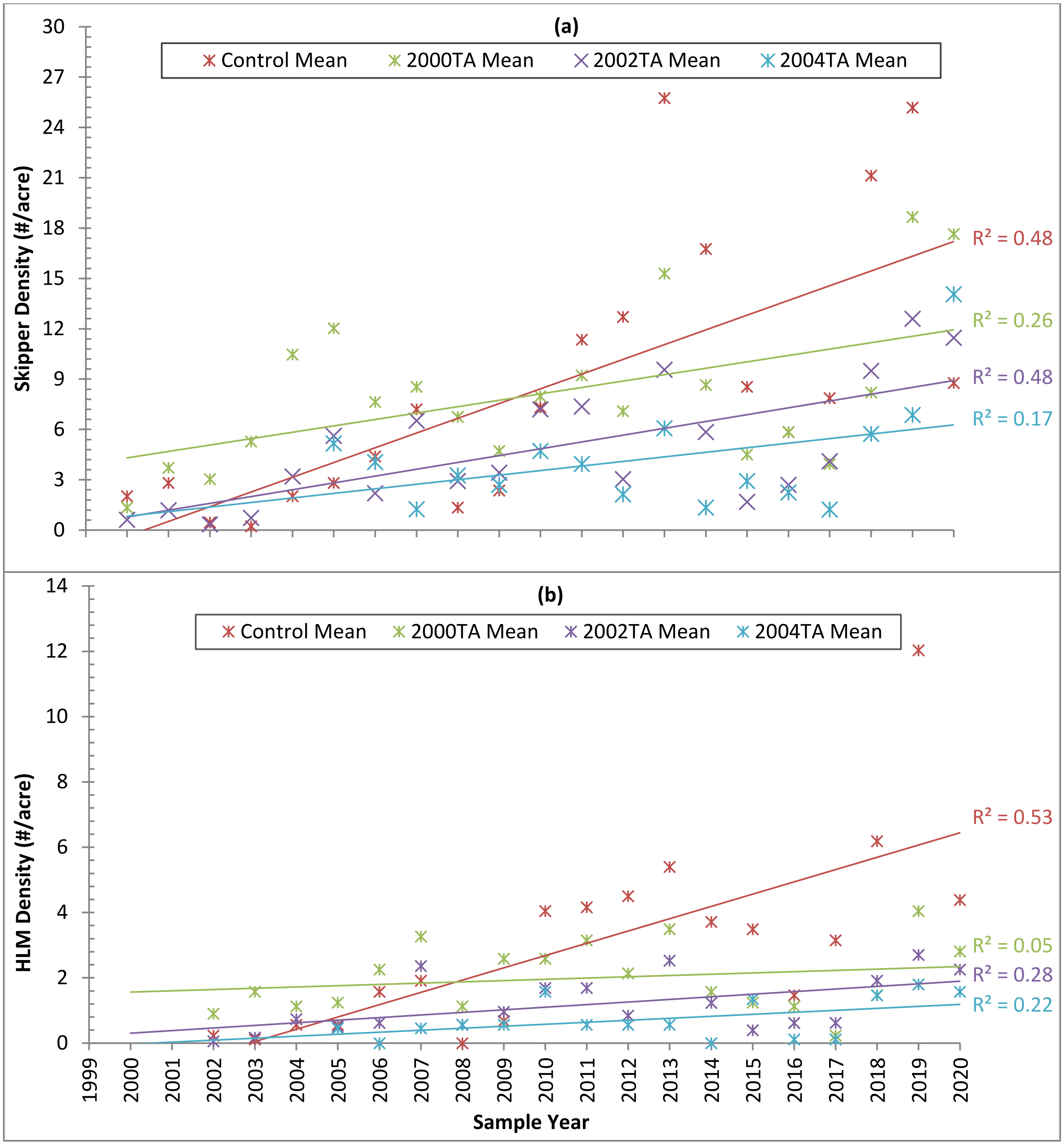

Figure 5. Skipper [*Hesperia* (a) and HLM (b)] densities (number/acre) separated by forest treatment (linear trend lines and associated R^2 values are shown for each forest treatment).

Dotted Gayfeather (*Liatris*) Counts

Among Years

Table 4 provides a summary of flowering dotted gayfeather stem density averaged over all forest treatments. The table includes outcome of the analyses excluding the <u>2004 Treatment Area</u> (12 transects in total) and an analysis that uses all of the treatment areas (15 transects in total). This year's flowering dotted gayfeather stem densities decreased dramatically from the previous year, to

61.4 per acre with the 2004 Treatment Area excluded and to 61.1 per acre for all forest treatments combined (**Table 4**). These values of density are lower than for all other years monitored except for the extreme drought year of 2002**.** The GSP this year was dramatically less than that of the previous year and dotted gayfeather densities were negatively impacted by this large decrease in precipitation. There has been little statistical difference among years in flowering stem densities over the past decade of monitoring (**Table 4**). This year's dotted gayfeather density was similar to the values recorded in 2017 and 2018 in that all three were significantly less than densities for 2010, when there were around 400 flowering stems per acre.

Table 4. Comparisons of Dotted Gayfeather (*Liatris punctata*) Stem Densities Over Time Averaged Across all Forest Treatments[1].

	Number of Transects[2] = 12 (2004 Treatment Area Excluded)		**Number of Transects[3] = 15** (2004 Treatment Area Included)	
Year	**Mean # flowering gayfeather stems/acre**	**Homogeneous Groups[4] P=0.05**	**Mean # flowering gayfeather stems/acre**	**Homogeneous Groups[4] P=0.05**
2010	403.5	B	373.0	B
2011	199.6	AB	211.9	AB
2012	151.8	AB	153.4	AB
2013	253.6	AB	243.6	AB
2014	245.5	AB	236.6	AB
2015	229.5	AB	217.5	AB
2016	220.1	AB	231.3	AB
2017	123.8	A	132.7	A
2018	85.7	A	74.5	A
2019	260.4	AB	248.7	AB
2020	61.4	A	61.1	A

[1] Control Area, 2000 Treatment Area, 2002 Treatment Area, and 2004 Treatment Area in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado. Upper South Platte Watershed Restoration Project.

[2] Twelve transects, each sampled 1 time per year.

[3] Fifteen transects, each sampled 1 time per year.

[4] Tukey's Mean Comparison Test — means (number of *Liatris* stems per acre) with the same letter are not different at the probability level indicated; [*e.g.*: in the data column when *n*=12 (2004 Treatment Area excluded), the mean for 2010 (**B**) differs from the means for 2017, 2018, and 2020 (**A**) at P=0.05**.**

Among Forest Treatments

Table 5 provides a summary of flowering dotted gayfeather stem densities among the forest treatments over the last decade of monitoring. Stem density this year were greatest in the 2000 Treatment Area, although this difference was not significant (**Table 5**). The trend has been for flowering dotted gayfeather density to be greatest in the 2000 Treatment Area except for in the years 2016 through 2018. However, the difference was significant only in the year 2010.

Table 5. Comparisons of Dotted Gayfeather (*Liatris punctata*) Densities by Year among Treatment Areas[1].

	Mean # flowering dotted gayfeather stems/acre[2] P =0.05[3]			
Year	**Control(N=9)[4]**	**2000 Treatment (n=9)**	**2002 Treatment (N=18)**	**2004 Treatment (N=9)**
2010	130.8 A	837.4 B	321.6 A	253.6 A
2011	60.7 A	473.1 A	132.2 A	261.3 A
2012	62.1 A	280.2 A	132.5 A	159.5 A
2013	156.5 A	477.5 A	190.2 A	203.7 A
2014	147.0 A	441.1 A	197.0 A	201.0 A
2015	111.6 A	471.5 A	167.4 A	169.3 A
2016	130.2 A	194.6 A	277.7 A	276.1 A
2017	61.5 A	50.2 A	154.8 A	266.1 A
2018	56.3 A	44.2 A	77.2 A	117.7 A
2019	99.5 A	552.1 A	195.1 A	202.0 A
2020	67.4 A	91.8 A	41.1 A	60.0 A

[1] Control Area, 2000 Forest Treatment, 2002 Forest Treatment, and 2004 Forest Treatment in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado. Upper South Platte Watershed Restoration Project.

[2] Compare the treatment areas for each year by reading the columns horizontally.

[3] Tukey's Mean Comparison Test: means (number of skippers per acre) with the same letter are not different at the given probability level. For example, the 2011 dotted gayfeather count means on all four treatment areas are not significantly different from each other at P=0.05 (**A**).

[4] Sample size (*n*) refers to the number of transects in each treatment area sampled three times per year.

There has been no general trend over time in the density of flowering dotted gayfeather stems on any of the forest treatments, rather density has fluctuated greatly (**Figure 6**). The main, discernable pattern is that dotted gayfeather densities is positively correlated with GSP (r^2=0.43, p=0.002) and has increased dramatically in some of the wetter years, especially on the 2000 Treatment Area, with a peak of 1,377 flowering stems/acre in 2007 and 1,358 flowering stems/acre in 2009 (**Figure 6**).

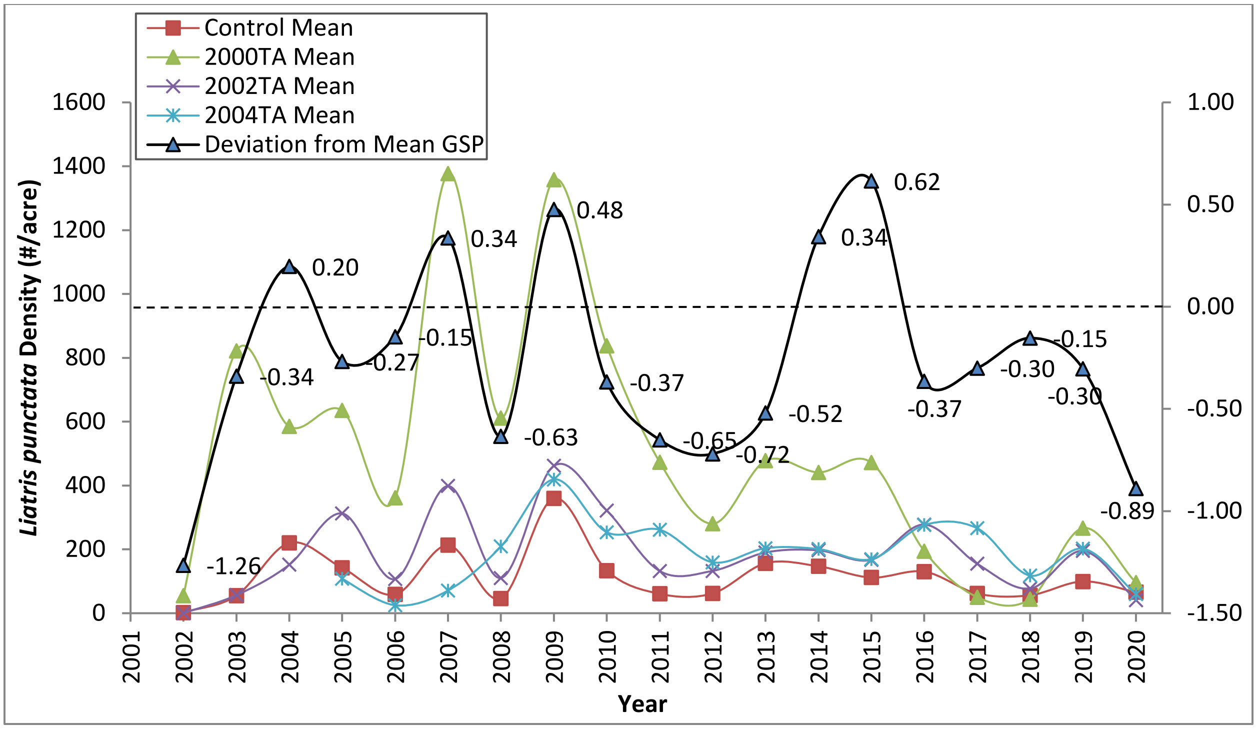

Figure 6. Dotted gayfeather flowering stem densities for all treatment areas and for all years monitored (see Table 4). The deviation from mean growing season precipitation in inches is included for comparison.

For each year of this monitoring study since 2009 separate tallies were made of all *Liatris* plants on transect, whether blooming or not. In 2009, the number of plants in flower was not differentiated from the number of total plants present and data on flowering plants is unavailable for that year. For the years with data on the total plants, there has been a significant decline in the percent of plants in flower during the period when sampling was completed for only the 2004 Treatment Area (r^2=0.39, p=0.05) (**Figure 7**). For the years with data on the total plants, there has been no trend for any of the forest treatments in the total number of plants present (**Figure 7**). In the current year, the proportion of plants in bloom was the lowest on record (60 percent), suggesting that skipper counts were conducted before peak flowering and/or that the drought had compromised plant flowering.

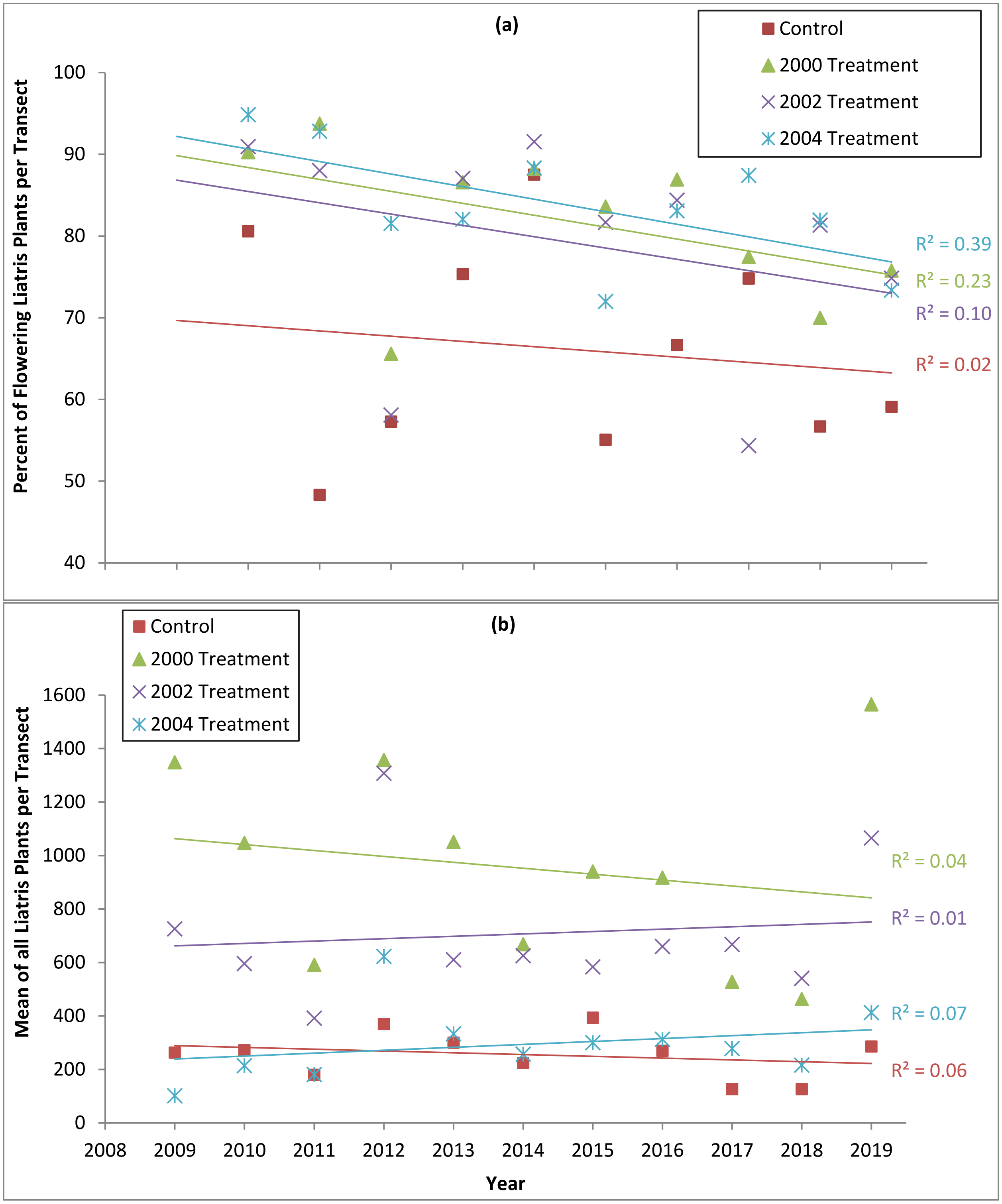

Figure 7. Percent of flowering plants for all treatments (a) with the mean of the total number of dotted gayfeather plants (b) (linear trend lines and associated R^2 values are shown for each forest treatment).

The Effect of Weather on Skippers and Dotted Gayfeather

We used a multiple regression analysis to look for correlations and potential causal relationships that weather variables and dotted gayfeather had on *Hesperia* population density. We also analyzed the relationship between weather and dotted gayfeather density. There was a great deal of variation in which environmental variables significantly affected skipper population size among forest treatments, however, there were three consistent patterns. First, the 2004 Treatment Area differed from the other three forest treatments in the environmental variables that significantly influenced skipper density. Secondly, growing season temperature consistently had a positive and significant influence on both HLM and *Hesperia* skipper densities and third, annual temperature consistently had a negative and significant influence on both HLM and *Hesperia* skipper densities (**Table 6**).

We also used multiple regression to analyze the effect that precipitation and temperature had on dotted gayfeather flowering stem density. Again, there was variation in the environmental variables that affected dotted gayfeather flowering stem density among the forest treatments, however, there were two consistent patterns. First, growing season precipitation consistently had a positive and significant influence on dotted gayfeather flowering stem density. Second, annual precipitation and temperature were both consistent in negatively and significantly influencing dotted gayfeather flowering stem density at most, but not all, of the forest treatments (**Table 6**).

Table 6. Summary of multivariate linear regression by treatment for influence of precipitation, temperature, and dotted gayfeather flowering stem densities (number/acre) on Pawnee montane skipper and *Hesperia* skippers. Also, the summary of multivariate linear regression by treatment for influence of precipitation and temperature on dotted gayfeather flowering stem densities (yellow highlight indicates significance at p ≤ 0.05 and green at p ≤ 0.1). Bold text highlights negative correlations.

	Regression Variables		**Forest Treatment**			
	Dependent Variable	Environmental[1] Variable[1]	Control Area	2000 Treatment Area	2002 Treatment Area	2004 Treatment Area
Amount of precipitation or temperature at the Cheesman Station, Colorado or and *Liatris* stems (#/acre)	Pawnee Montane Skipper Density	GSP	**t = - 0.91 p = 0.4**	t = 0.02 p = 1.0	t = 1.20 p = 0.2	**t = - 0.24 p = 0.8**
		GST	t = 2.98 p = 0.003	t = 2.31 p = 0.02	t = 3.41 p = 0.0007	**t = - 0.32 p = 0.7**
		AP	**t =-0.55 p = 0.6**	**t = - 1.04 p = 0.3**	**t = - 2.86 p = 0.005**	**t = -0.99 p = 0.3**
		AT	**t = - 2.84 p = 0.005**	**t = - 5.02 p < 0.00001**	**t = - 5.12 p < 0.00001**	**t = -0.32 p = 0.7**
		Liatris (#/ac)	**t = - 0.04 p = 1.0**	**t = - 1.63 p = 0.1**	t = 2.63 p = 0.009	**t = - 1.44 p = 0.2**
	Hesperia Skipper Density	GSP	**t = - 0.34 p = 0.7**	**t = - 1.20 p = 0.2**	t = 0.26 p = 0.8	t = 2.07 p = 0.04
		GST	t = 3.06 p = 0.003	t = 2.26 p = 0.03	t = 2.99 p = 0.003	t = 1.30 p = 0.2
		AP	**t = - 0.48 p = 0.6**	t = 0.47 p = 0.6	**t = - 1.30 p = 0.2**	**t = - 2.40 p = 0.02**
		AT	**t = -2.82 p = 0.005**	**t = - 2.72 p = 0.03**	**t = - 3.44 p = 0.0006**	**t = - 1.60 p = 0.1**
		Liatris (#/ac)	t = 1.08 p = 0.3	t = 1.77 p = 0.08	t = 3.96 p = 0.00009	**t = - 0.01 p = 1.0**
	Dotted Gayfeather Flowering Stem Density	GSP	t = 2.75 p = 0.01	t = 5.05 p < 0.00001	t = 3.70 p = 0.0003	t = 1.72 p = 0.09
		GST	**t = -1.16 p = 0.3**	**t = - 0.59 p = 0.6**	**t = - 1.11 p = 0.3**	**t = - 2.02 p = 0.05**
		AP	**t = - 0.88 p = 0.4**	**t = -3.22 p = 0.002**	**t = -2.24 p = 0.03**	**t = - 1.73 p = 0.09**
		AT	**t = - 1.64 p = 0.1**	**t = - 5.77 p < 0.00001**	**t = - 2.49 p = 0.01**	t = 0.19 p = 0.9

[1] GSP = growing season precipitation (March – August), GST = growing season temperature, AP = annual precipitation, AT = annual temperature, and *Liatris* (#/ac) = dotted gayfeather flowering stem density (#/acre).

DISCUSSION

The differences and similarities among the previous sample years can be found in Appendix B. A summary for the current year's observations follows.

The potential exists that this year's monitoring effort was undertaken prior to the peak flight period of the HLM. There was a higher ratio of Western branded skippers to HLM relative to the other years monitored, suggesting that the emergence of skipper butterflies was delayed on the study site this year. Alternatively, the potential exists that drought conditions in the study area had a larger negative effect on the HLM as opposed to the Western branded skipper.

Within a given year, the differences in the density of skippers (both HLM and *Hesperia*) among the forest treatments has been highly variable during the period of monitoring. Generally, the observed differences have been insignificant, and this is true of the current year. The most reliable trend across all years monitored is the significantly increasing trend in density of both HLM and all *Hesperia* skippers across the study site. Also notable, is how skipper density at the Control Area in 2018 and 2019 were two to three times greater than that at most all of the other forest treatments. Otherwise, the only other statistically significant differences occurred when density of *Hesperia* skippers at the Control Area was greater than at the 2002 and 2004 Treatment Areas in 2013 and greater than at the 2004 Treatment Area in 2014. The density of flowering dotted gayfeather has consistently been lower at the Control Area than at the other forest treatments, which is counter intuitive to the high skipper densities observed at this forest treatment area.

Monitoring has also revealed that patterns in the relationships among temperature, skippers and dotted gayfeather are complex. The high estimates of skipper density from 2018 through 2020 coincided with elevated growing season temperatures. Growing season temperatures in 2018 and 2020 were higher than in any other year except for 2012 and GST this year was five degrees warmer than the 25-year mean. This result corresponds to the positive relationships between temperature and butterfly density that are reported in the scientific literature (Stewart et al 2020, Kuussaari et al. 2016, Radchuk et al. 2013, Ashton et al. 2009). Unlike GST, annual temperature has a negative relationship with the density of HLM, all *Hesperia,* and dotted gayfeather. However, dotted gayfeather has a somewhat positive relationship with skippers. Since annual temperature has a negative relationship with both skippers and dotted gayfeather, and GST also has a negative relationship with dotted gayfeather while dottedd gayfeather is positively related to skippers, there is likely a point at which the negative effects of increasing annual temperatures will override whatever positive relationship that GST has on skippers.

Annual precipitation in the years when these high butterfly densities occurred (2018 through 2020), and in the years leading up to those high-density years, was low. Below normal annual precipitation, particularly lessened levels of snowpack, has been suggested as a driver of increases in some butterfly populations (Swengel and Swengel 2015), but declines in snowpack are also implicated in the declines of other butterfly populations (Boggs and Inouye 2012). Analysis of our data using linear multiple regression indicate that annual precipitation has a very weak, negative effect on the size of skipper populations in our study area. Since relationships between precipitation and skippers is somewhat weak and inconsistent, temperature seems to be the more dominant weather factor affecting HLM and all *Hesperia* densities.

Densities of dotted gayfeather have been consistently lower at the Control Area in recent years, yet the Control Area has consistently had the greatest densities of skippers during this period and for even longer, but this year the pooled *Hesperia* sample were lowest at this treatment. The environmental characteristics of the Control Area including forest canopy cover, tree basal area, the availability of blue grama grass, and particularly solar radiation influenced by the terrain's aspect (east facing) (Ashton et al. 2009) are likely all interacting to create niche spaces that are particularly suitable for *Hesperia* skippers (Sovell 2014, Illan et al 2010, Yamamoto et al. 2007). However, the high temperatures and reduced precipitation experienced across the study area this year, combined with east facing aspect may have created a dry and hot microclimate that was unsuitable to the larva of the butterflies. Extreme climatic events including heatwaves in both winter and summer are known to cause mortality of both eggs and larval butterflies (Abarca et al. 2019, Klockmann, et al. 2017, Long et al. 2017).

There has been consistently lower densities of skippers recorded at the 2004 Treatment Area throughout the period of monitoring and this year the density of HLM decreased from last year to this year in the 2004 unit just like at all the other treatment areas. Throughout 16 years of monitoring the 2004 Treatment Area, that unit had the lowest density of HLM in 14 of those years. The large, treeless, clear cut areas created by the forest thinning undertaken in 2004 Treatment Area is unsuitable for skipper butterflies, much like the treeless landscape of the moderate-to-high severity burn areas of the Hayman Fire (Sovell 2019).

The density of skippers and dotted gayfeather has varied extensively among the years of monitoring, and since the beginning of the last decade there have only been a few years with densities of HLM or *Hesperia* skippers that are significantly greater than a majority of the other years monitored. These years of greater density included 2013, 2018, 2019, and 2020 for the pooled *Hesperia* sample and only the year 2019 for the HLM sample. The years with higher densities of skippers tend to also have the highest densities of dotted gayfeather, although the correlation is not very strong (see **Table 6**). Interestingly, dotted gayfeather flowering stem density in both 2018 and 2020 was less at all forest treatments than in most of the other years monitored, yet skipper densities were high in both years. This goes against the general wisdom that nectar plant abundance is a critical determinant of butterfly abundance (Turlure et al. 2019, Kloeppel et al. 2015). However growing season temperatures in 2018 and 2020 were the second and third highest recorded during the period of monitoring and as previously mentioned temperatures during the growing season are positively correlated with high densities of skippers.

MANAGEMENT IMPLICATIONS

Additional surveys in subsequent years will be required to continue evaluating the long-term effects of forest thinning treatments on skipper populations. It is expected that densities of both dotted gayfeather and HLM will generally continue to track changes in precipitation and temperature, although the trends are not in lockstep and the relationships are likely complicated by other factors. The HLM is clearly adapted to the fire-dependent habitat type that the suggested forest treatment prescription is attempting to mimic (open lower montane forests; see Johnston 2005, Sovell 2014). The spectacular drought and fires of 2002 caused a significant decline in HLM numbers. The rate of recovery of the HLM populations in the face of both severe habitat degradation (nearly 50 percent of the known skipper habitat has burned in high-severity wildfire since 1996) and reoccurring drought has been strongest in low severity burn areas and in moderate burn areas that are in close proximity to unburned areas (Sovell 2009). Thus, forest fuel reduction programs that mimic the ecological effects of low severity forest burns and that increase the number of blooming dotted gayfeather stems (such as those in the 2000 Treatment Area) may contribute appreciably to this species' recovery. Also, the 2000 Treatment Area has most frequently supported higher numbers of HLM and western branded skippers than all other treatments except for the Control Area, and only since 2010 have densities in the Control Area surpassed those of the 2000 Treatment Area. This suggests that forest thinning prescriptions mimicking the vegetation characteristics of both the 2000 Treatment Area and Control Area will benefit HLM population viability.

In the South Platte River Valley, human activities have modified the key ecological process of fire. Decades of fire suppression has resulted in dense stands of ponderosa pine forests that are prone to catastrophic wildfire and have shaded out the herbaceous understory including the HLM larval food plant, blue grama, and primary adult nectar source, dotted gayfeather. Over the last two to three decades, ponderosa pine forest within the distribution of the HLM has experienced stand-replacing wildfire that has removed wide expanses of forest. Burned areas, where ponderosa pine no longer exist, have not been recolonized by Pawnee montane skippers and appear unsuitable for the butterfly (Sovell 2019). The lack of forest cover as a detriment to *Hesperia* skipper abundance is further supported by the low density of skippers within the very open forest of the 2004 Treatment Area. It will take decades, or even centuries, for these burned areas to return to forest and until then, these areas will probably remain unsuitable for Pawnee montane skippers. There are still wide expanses of forested habitat within the range of the Pawnee montane skipper, but many of these areas have become very dense forest as a result of fire suppression and are less suitable for the butterfly. Management to return these overgrown forests to a more open structure would mitigate the threat of wildfire while improving the habitat for HLM.

The HLM, like many host plant specific and nectar plant specific butterflies (Turlure et al 2019, Swartz et al. 2015), is closely associated with its host plants, blue grama, and its primary nectar source, dotted gayfeather. Adult skippers will nectar at plants other than dotted gayfeather including hairy false goldenaster (*Heterotheca villosa*), particularly when dotted gayfeather is sparse or absent, but adults are attracted to dotted gayfeather. The objective of vegetation management for HLM conservation is to provide niche space that is suitable for the butterfly. Forest management that creates and maintains a mosaic of forest and open pockets with increased solar radiation where blue grama, dotted gayfeather, and the butterfly can flourish is recommended. The following management considerations for the HLM draws upon the discussion found in Sovell (2014). Forest restoration prescriptions to improve habitat for the HLM should mimic those found on the Control Area and 2000 Treatment Area for overstory structure including DBH, crown width, canopy cover, tree height, and basal area (see Table 6 in Sovell 2014). Forest restoration treatments should attempt to recreate historic forest conditions by promoting a variety of tree size classes in a clumpy spatial arrangement (see Figure 4 in Sovell 2014). Thinning should be focused on diameter classes that are overly abundant (Lowe 2005), like the small- to mid-sized classes present on the northwest ends of transects CS and CM and almost all of CN. Variability of the forest structure should be promoted by creating a mosaic of forested patches and openings of approximately 0.1 acre in average size. Treatment should focus on reducing the continuity of surface and ladder fuels, while simultaneously seeking a broader ecosystem response including creating more forest clearings and inducing the growth of blue grama and dotted gayfeather in the understory cover, thus benefiting both the HLM and forest hydrologic function (Lowe 2005).

Local environments that produce conditions where blue grama, dotted gayfeather, and ponderosa pine coexist and persist are where HLM are most abundant and also where their populations will persist. Areas of suitable habitat for this butterfly occur in a patchy mosaic within ponderosa pine forests of the South Platte River Valley. Populations of Pawnee montane skippers probably track the mosaic of ponderosa pine, blue grama and dotted gayfeather found across the landscape. Populations probably become locally extinct during years where conditions no longer support healthy populations of ponderosa pine, blue grama and dotted gayfeather. Areas are probably recolonized when conditions improve (Thomas 1994). For the Pawnee montane skipper too much loss of suitable habitat throughout their limited range could result in extinction. Sufficiently large areas containing a mosaic of suitable and unsuitable habitat must be maintained, improved and/or created through timber and fire management that supports viable metapopulations of HLM across the entire range of the subspecies. Focusing HLM management on the idea of an environmental mosaic makes enlarging and improving the quality of existing suitable niche space as important as the creation of new niche spaces. Consequently, population declines in large patches may be as worrying as local extinctions in small patches, and the expansion of populations in existing patches is as valuable as colonization of newly created small patches.

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APPENDIX A: STUDY DESIGN AND SAMPLING METHODS

Scott Ellis of ENSR Corporation, who designed and managed the adult skipper and habitat monitoring studies in the 1980s (ERT 1986, 1988, 1989) also designed and initiated the sampling for this monitoring program using the same sampling methods (see ENSR 2003a). He was assisted in the field sampling by Boyce Drummond of Natural Perspectives and personnel from the USFS and USFWS in 2002 and 2003 and by John Sovell of the Colorado Natural Heritage Program (CNHP) in 2003. Boyce Drummond (Natural Perspectives) conducted the sampling for this monitoring program in 2004, 2005, 2006, 2007, 2008, 2009, and 2010 using the sampling methods referenced above for adult skipper butterflies and with broadened scope that now includes habitat assessment and vegetation analyses of the larval and adult food plants of the Pawnee montane skipper (HLM) (*Hesperia leonardus montana*). John Sovell (CNHP) conducted the sampling in 2012 through 2016 using the broadened sampling methods implemented by Boyce Drummond. Field work has been performed by USFS and USFWS staff, Scott Ellis, Boyce Drummond, volunteers from Cheyenne Mountain Zoo (CMZ), Colorado College (CC), and Colorado Department of Transportation (CDOT).

The purpose of this study is to count, and then compare, the number of adult *Hesperia* skippers within the <u>2000</u>, <u>2002</u>, and <u>2004 Treatment Areas</u> to a <u>Control Area</u>**.** The <u>Control Area</u> approximates optimal skipper habitat than the rest of the Lower Montane Forest that comprises the mapped suitable skipper habitat and that corresponds to optimal skipper habitat characteristics outlined in the Biological Opinion (U. S. Fish and Wildlife Service 2001, 2003, 2009). This area was not treated and will not receive future thinning treatment.

The overall design consideration was to ensure proximity of the four sampling areas to reduce potential differences in climate and land use history. The locations of the sampling areas are illustrated in **Figures A1** and **A2**.

The 400-meter-long transects within the treatment areas are located a standard distance apart. In general, transects are located parallel to each other at a distance of about 400 meters in the largest sampling area (<u>2002 Treatment</u>), and at less distance apart (200-300 meters) in the smaller sampling areas (<u>Control</u> and <u>2000 Treatment</u>). There are two exceptions (see **Figure A1**). First, Transect 210 is angled relative to the others to fit within the available thinned area. Second, Transects 241, 242, and 243 (<u>2004 Treatment</u>) are not evenly spaced because Transect 242 is offset from its planned midway point between 241 to the south and 243 to the north to avoid unsuitable terrain (**Figure A2**). The distance between 241 and 242 is about 250 m; the distance between 242 and 243 is just over 500 m.

The transects are oriented parallel to the drainage pattern (generally east-west). The landscape of the four treatment areas consists of a network of small lateral drainages and a heterogeneous mixture of slopes and aspects within a small area. Because of this landscape heterogeneity, the east-west transect orientation encompasses the range of slopes and aspects of the sampling area. A complete list of the sixteen transects, with their elevation ranges, aspects, slopes (% grade), and utm coordinates at the transects starting point, is presented in **Table A1.**

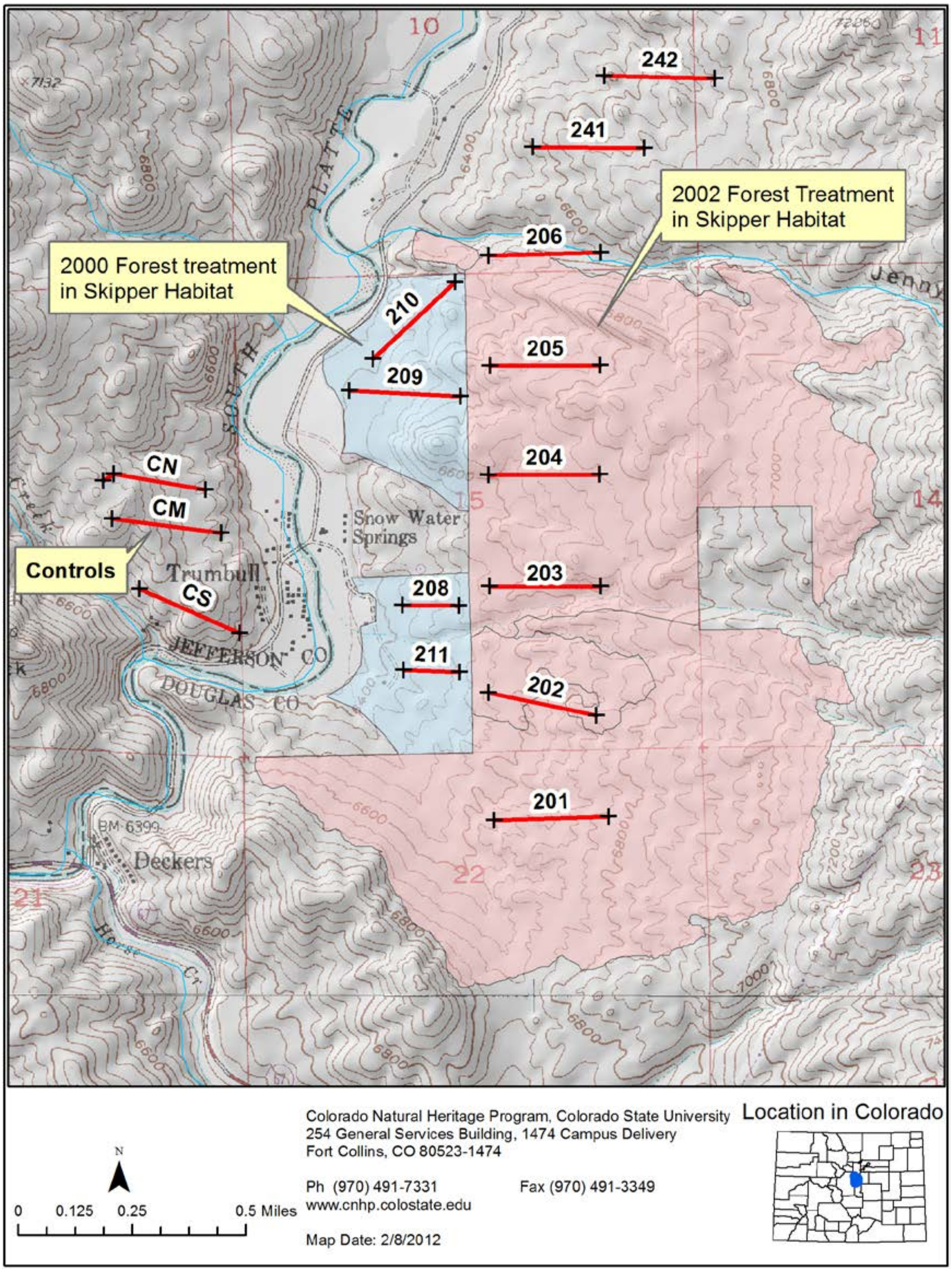

Figure A1. Pawnee montane skipper Monitoring Transects within Control, 2000 Forest Treatment and 2002 Treatment Areas in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado.

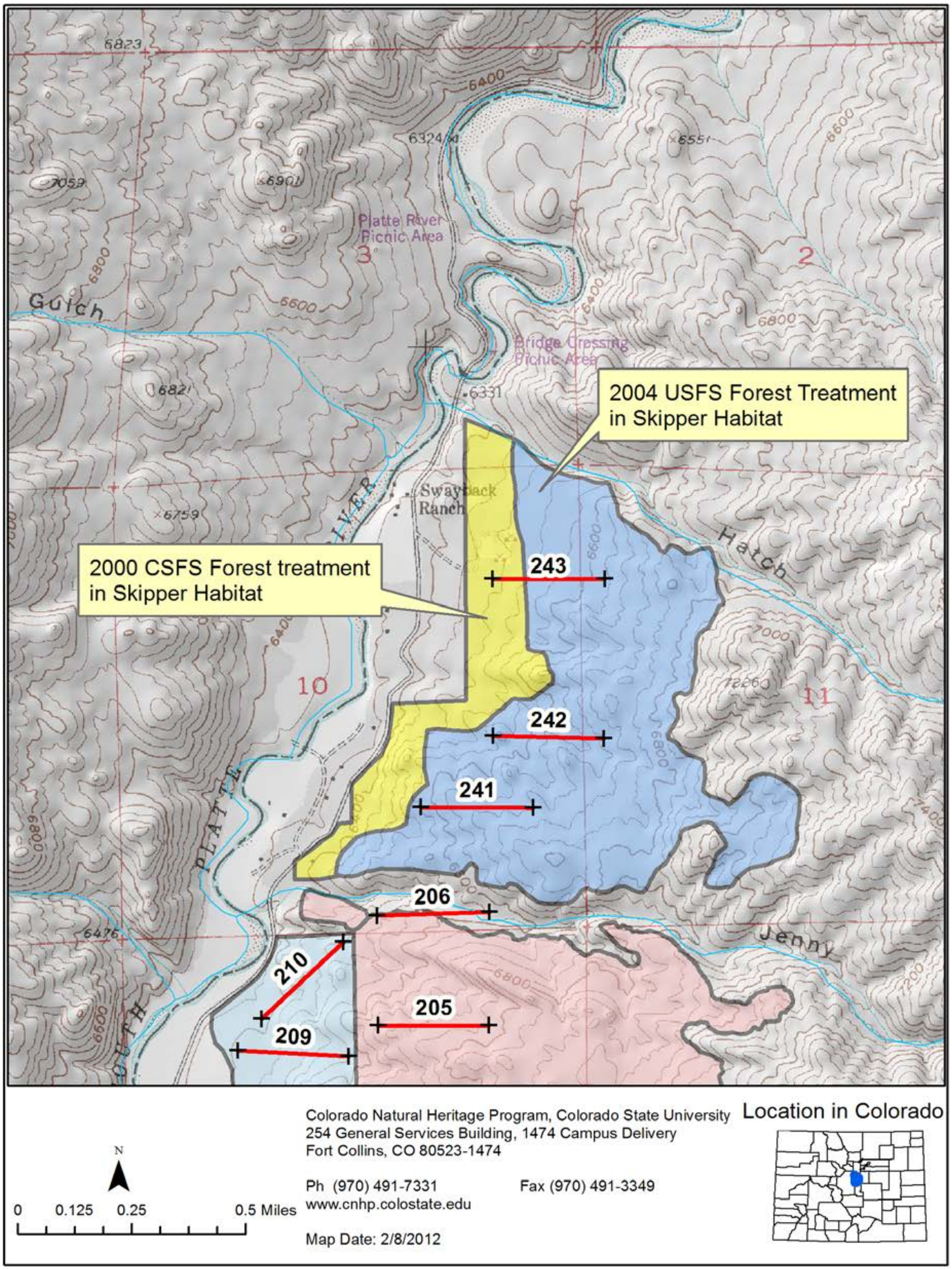

Figure A2. 2004 Treatment Area transects in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado.

Table A1. List of Study Transects and Their Topographic Metrics.

Treatment Area (TA)	Transect Number	Length (meters)	East Elevation (meters)	West Elevation (meters)	Elevation Change (meters)	% Grade	Dominant Slope Aspect	UTM NAD83 (start)	Mean Canopy Cover (± SD)
CONTROL	South	400	6460	6560	100	25	SW	480938E 4345818N	32.3 ± 24.4
CONTROL	Middle	400	6460	6760	300	75	E	480872E 4346173N	72.6 ± 25.0
CONTROL	North	400	6500	6720	220	55	NE	480816E 4346325N	65.6 ± 27.6
2000 TA	208	200	6520	6440	80	40	W	481513E 4345918N	27.3 ± 16.4)
2000 TA	211	200	6580	6520	60	30	NW	481517E 4345688N	47.7 ± 19.0
2000 TA	209	400	6560	6410	150	38	W	481325E 4346675N	42.5 ± 15.7
2000 TA	210	400	6480	6440	40	10	NW	481410E 4346787N	17.3 ± 21.6
2002 TA	201	400	6800	6640	160	40	W	481838E 4345157N	53.0 ± 29.5
2002 TA	202	400	6770	6560	210	53	NW	481817E 4345608N	45.7 ± 22.2
2002 TA	203	400	6680	6570	110	28	S	481822E 4345984N	48.1 ± 29.3
2002 TA	204	400	6760	6600	160	40	SW	481818E 4346377N	32.9 ± 18.8
2002 TA	205	400	6790	6680	110	28	N	481822E 4346764N	24.6 ± 27.6
2002 TA	206	400	6580	6520	60	15	N	481817E 4347152N	54.24 ± 13.5
2004 TA	241	400	6680	6560	120	30	W	481973E 4347536N	27.7 ± 26.9
2004 TA	242	400	6680	6560	120	30	NW	482228E 4347788N	14.9 ± 21.1
2004 TA	243	400	6640	6470	170	43	W	482226E 4348342	43.5 ± 29.1

Sampling Protocol

Skipper Butterflies

Skipper counts followed the same sampling protocol used for the 1986 skipper census surveys (Environmental Research and Technology [ERT] 1986). All skippers in the genus *Hesperia,* including the HLM and the western branded skipper (*H. colorado)* were counted within a belt transect 400 meters long by 10 meters wide (5 meters each side of the centerline), representing a total area of 4000 m^2/transect. Counting was conducted only during sunny and partly sunny conditions. The endpoints of transects were marked with rebar stakes and documented by the USFS with UTM coordinates using global positioning system technology. The transect centerline is flagged annually so that observers can more easily navigate the centerline. Each transect is subdivided into eight 50-meter subplots (staked or flagged at each 50-meter interval) so that skipper and nectar plant dispersion in the habitat can be recorded in segments of 500m^2 area.

The numbers of individual skippers observed in each 50-meter subplot within the overall transect were counted and entered onto a data sheet. When possible, both the species and sex of each skipper individual were determined and recorded, although such determinations were sometimes difficult for flying individuals. However, determinations of species and sex were not made during the first two years of monitoring, 2000 and 2002. Consequently, beginning in 2003, skipper individuals were recorded in three categories: **Hlm** (*Hesperia leonardus montana*), **Hco** (*Hesperia colorado*), or **unk** (unknown species). Within these three categories, each individual was recorded as male, female, or unknown (when sex could not be determined). This resulted in 9 categories of observations (Hlm female, Hlm male, Hlm unknown, Hco female, Hco male, Hco unknown, unknown female, unknown male, and unknown unknown). Behavior of each skipper at the time of observation was recorded in the following categories: perched (**P**), flying (**F**), and nectaring (**N**). The nectar plant species was recorded, and skipper reproductive behavior was recorded when courtship, mating, and oviposition were observed. Skippers observed outside the belt plot during the daily sampling window were recorded separately.

Foodplants

Abundance of the primary adult nectar source (dotted gayfeather, Liatris punctata) was measured by counting the number of flowering stems present in each 50-m subplot of each transect. A stem was counted as a "flowering stem" if at least one flower on the inflorescence on the stem was open. In 2009 and subsequent years, in addition to the traditional count of the total number of flowering stems, the number of gayfeather plants in each 50-m subplot was recorded. A measure of the relative abundance of the larval foodplant (blue grama, *Bouteloua gracilis***[1]) was made by noting its presence or absence at the start of each 50-m subplot [as observed within a rectangle that

**[1] *Note:* Blue grama, currently known as *Chondrosum gracile*, is formerly and better known as *Bouteloua gracilis*, which is used here for continuity with previous reports.

extended from this point 0.5 m to each side and forward along the transect centerline (1.0 x 0.5 m= 0.5 m2)]. These data were recorded on the same data sheets as were the skipper observations.

Data Analysis

For purposes of consistency with the prior years of this study, *Hesperia* observations were treated in two different ways. First, all *Hesperia* observations (*Hesperia colorado*, *Hesperia leonardus montana*, individuals of undetermined species) along each transect were pooled for analysis for years 2000-2016. (Combining all skipper observations in this way was done to increase sample sizes for statistical analysis and to reduce the impact of field identification errors by less skilled members of the survey teams.) Second, as in the past 14 years, comparative analyses of *Hesperia leonardus montana* only were also performed for the years 2002 to 2016.

For the purpose of data analysis, the two transects that are only 200 meters in length (208 and 211 of the 2000 Treatment Area) were combined and treated as one 400-meter transect. Thus, for the years 2000 through 2004 there were 12 transects sampled; for the years 2005 through 2013 there were 15 transects sampled. Consequently, skipper densities are presented in two ways. The first way does not include data collected for the 2004 Treatment Area Transects (241, 242, 243) so that all years contain the same number of transects (12) and the same number of samples (36 = 12 transects sampled over 3 days). The second way does include data collected for the 2004 Treatment Area Transects so that all data collected each year are reported and analyzed (*i.e.*, 15 transects and 45 samples). This same dual analysis is employed for dotted gayfeather flowering stem densities.

An analysis of variance was conducted to determine whether there were significant differences in the skipper counts among treatments (Control Area, 2000 Treatment Area, 2002 Treatment Area, and 2004 Treatment Area) within a year of census data as the main purpose of the study is to compare differences in skipper density among the thinning treatments. Tukey's mean comparison test was performed to determine whether there were significant differences between all pairs of means at the 0.05 and 0.10 probability levels. Similar statistical analyses of blooming gayfeather stems were performed and are reported here as well.

Pearson's product-moment correlation analysis has identified correlations between skipper densities, the density of dotted gayfeather, and weather factors. To further examine these correlations, the relationships were modelled based on multiple linear regression with statistical significance of explanatory factors inferred based on t-statistics and the significance of the full model tested using the F-test. The variables analyzed were growing season precipitation, annual precipitation, growing season temperature, annual temperature, and dotted gayfeather flowering stem density. These variables were used in multiple regression models, both for the HLM individually and for the *Hesperia* community.

APPENDIX B: DIFFERENCES/SIMILARITIES AMONG SAMPLE YEARS

Year 2000. The majority of the skippers were counted on the Control Area transects, and very few skippers were seen on either the 2000 Treatment Area and 2002 Treatment Area transects. The 2000 thinning treatments were completed during this year, and very little understory recovery occurred in the northern thinning treatments (Transects 209, 210), although gayfeather stem counts were highest in the southern thinning treatments (Transects 208/211) (ENSR 2003a).

Year 2001. Most of the skippers were counted on the Control Area transects and the northern thinning treatments (transects 209, 210). There was an insignificant increase in the number of skippers counted on the 2002 Treatment Area and Control Area transects when compared with the year 2000 counts. The number of skippers sharply increased on the northern thinned treatment transects, with a corresponding increase in gayfeather stems in the same area. It appeared that this higher availability of nectar sources in the northern thinning treatment area may have influenced local adult skipper distribution.

Year 2002. The severe drought in 2002 sharply reduced the number of flowering gayfeather stems in all areas, but the least in the thinned 2000 Treatment Area. The most skippers were seen in the downslope thinned areas (2000 Treatment Area), which supported the most nectar sources. Even though nectar sources were seen upslope from the river corridor, skippers were generally not observed in these areas. The net result of these observations is that the adult skipper populations appeared to be concentrated near the most abundant and highest quality nectar sources, which were in the thinned areas. Consequently, the average number of skippers was not significantly different from the prior year, despite the severe drought (ENSR 2003a).

Year 2003. The majority of the skippers were counted in the thinned 2000 Treatment Area. This year showed a continuing decline in the number of skippers in the Control Area, a statistically stable, but fluctuating, number of skippers on the 2002 Treatment Area, and a noticeable, but statistically insignificant, increase in the number of skippers found on the 2000 Treatment Area. The corresponding trends in blooming gayfeather stems were somewhat similar, showing fluctuating but statistically stable numbers in the Control and 2002 Treatment Areas, and an overall increase in the 2000 Treatment Area that became statistically significant in 2003 (ENSR 2003b).

Year 2004. The majority of the skippers were once again counted in the thinned 2000 Treatment Area, which continued to support the greatest density of blooming gayfeather stems. This year, however, the differences among the three areas were less pronounced, as the density of gayfeather stems decreased (by nearly 30%) in the 2000 Treatment Area (perhaps due to competition for resources or to increased shading from forest understory regrowth), whereas there was a fourfold increase of gayfeather in the Control Area (probably a response to increased soil moisture) and a near threefold increase in the 2002 Treatment Area (probably a response to both increased soil moisture and to thinning operations). Not surprisingly, the skippers increased in all three areas, doubling in the 2000 Treatment Area (probably in response to the previous year's huge gayfeather bloom and to continued high densities of this nectar plant), increasing by tenfold in the Control Area (which was the area most adversely affected by the 2002 drought), and by nearly fivefold in the 2002 Treatment Area (probably in response to the beneficial effects of thinning operations two years before) (Drummond 2004).

Year 2005. For the fifth straight year, the 2000 Treatment Area retained its place as the forest treatment type where the majority of skippers were counted, with over twice as many skippers per acre (12.03) as the 2002 Treatment Area (5.62) and the 2004 Treatment Area (5.17), the latter sampled in 2005 for the first time. Skipper densities increased in the Control and the two older treatment areas in 2005: in the Control Area by 39%, in the 2000 Treatment Area by 15%, and in the 2002 Treatment Area by 75%. It appears that skippers are responding to the increase available nectar sources in thinned areas, as the increase in blooming gayfeather stems increased in 2005 by 9% in the 2000 Treatment Area and by 106% in the 2002 Treatment Area. In the Control Area, the density of blooming gayfeather stems actually decreased in 2005 by 35%, yet skipper numbers rose there too. The data would be easier to interpret if skippers' densities always changed proportionally to changes in gayfeather densities, but the fact that they do not suggests that the overall positive effect of gayfeather densities on skipper densities may be confounded by the relative availability of alternative nectar sources and by the presence of other nectar-feeding butterflies and insects. For the Pawnee montane skipper (HLM) (*Hesperia leonardus montana*) in 2005, the baseline number for all but the 2000 Treatment Area was about one skipper for every two acres. This includes the recently thinned 2004 Treatment Area. The 2000 Treatment Area, already boasting twice as many total skippers and flowering gayfeather stems as any other treated area, also had over twice as many HLM as the other forest treatment areas, with about 2.5 skippers for every 2 acres. This is the second straight year that such differences have been recorded, despite skipper increases in all areas (Drummond 2005).

Year 2006. The density of gayfeather flowering stems decreased by 55% between 2005 and 2006, with all four treatment areas affected. This reduction was probably due to decreased soil moisture in spring and early summer, as precipitation during this period was only 45% of normal. Skipper numbers also dropped between 2005 and 2006, by 37% overall. However, skipper densities declined only in the thinned areas. For the second year in a row, skipper numbers increased in the Control Area (this year by 56%), despite a two-year decline in gayfeather flowering stem densities there. This is all the more puzzling because a retrospective analysis performed this year on the seven years of monitoring data revealed a significant correlation between gayfeather flowering stem densities and skipper densities, with from 48 to 98% of the variance in skipper numbers being explained by the abundance of gayfeather flowering stems. As noted last year, the data would be easier to interpret if skipper densities always changed proportionally to changes in gayfeather densities, but the fact that they do not suggests that the overall positive effect of gayfeather densities on skipper densities is probably confounded by other factors, such as the relative availability of alternative nectar sources, the presence of other nectar-feeding butterflies and insects during the skipper flight season, or variability in the quality or quantity of the nectar produced by *Liatris punctata*. One consistency, however, is that for the sixth straight year, the 2000 Treatment Area retained its place as the forest treatment type where the majority of skippers were counted, with nearly twice as many skippers per acre (7.64) as the Control Area (4.38) and the 2004 Treatment Area (4.05), and over three times as many skippers as the 2002 Treatment Area (2.19). For the HLM in 2006, the baseline number was about 1.3 skippers per acre, roughly double the density recorded last year (=1.4 skippers for every *two* acres). The fact that PMSs continued to increase in numbers at a time when the western branded skipper (*H. colorado*) decreased in numbers and when the density of the primary adult food plant (gayfeather flowers) declined, suggests that the HLM and the western branded skipper are responding to different environmental clues or that their behaviors and ecologies (e.g., vagility, home range size, etc.) are significantly unalike to affect their apparent population sizes in different ways (Drummond 2007).

Year 2007. The density of gayfeather flowering stems increased in all four treatment areas between 2006 and 2007, with an overall increase of nearly 300%. This increase was probably due to adequate soil moisture conditions in spring and summer, followed by very heavy precipitation in August. Skipper numbers also increased between 2006 and 2007: the pooled skipper densities increased by 75%, western branded skippers increased by 66%, and HLM increased by 95% over levels recorded in 2006. These increases occurred in three of the four treatment areas, with only the 2004 Treatment Area experiencing a decline (69%) in skipper numbers between 2006 and 2007. The decline in skipper density in the 2004 Treatment Area probably results from the poor recovery of gayfeather plants in the Jenny Gulch forest unit, which experienced considerable ground cover and soil disturbance from logging operations between the 2006 and 2007 flight seasons. For the seventh straight year, the 2000 Treatment Area retained its place as the forest treatment type where the majority of skippers were counted, with slightly more skippers per acre (8.54) than in the Control Area (7.20), and substantially more than in the 2002 Treatment Area (6.52) and the 2004 Treatment Area (1.24). Interestingly, in terms of skipper densities, the positions of the 2002 and 2004 Treatment Areas reversed between 2006 and 2007, with skipper densities higher (by 85%) in the 2002 Treatment Area in 2006 and higher (by 427%) in the 2002 Treatment Area in 2007. This is all the more curious because densities of gayfeather flowering stems did not fluctuate in the same way: in both years the 2002 Treatment Area had much higher stem densities than the 2004 Treatment Area (330% higher in 2006; 460% higher in 2007). Even so, the overall increase in density of gayfeather flowering stems in 2007 was accompanied by a corresponding increase in the density of skippers. As noted above (and previously: Drummond 2005, 2007), such correlations would be easier to interpret if skipper densities always changed proportionally to changes in gayfeather densities, but the fact that they do not suggests that the overall positive effect of gayfeather densities on skipper densities is probably confounded by other factors, such as the relative availability of alternative nectar sources, the presence of other nectar-feeding butterflies and insects during the skipper flight season, or variability in the quality or quantity of the nectar produced by *Liatris punctata*. For the HLM in 2007, the baseline number was about 2.5 skippers per acre, roughly double the density recorded last year (1.3 skippers per acre), which in turn was double that of 2005 (0.7 skippers per acre). The fact that the HLM has steadily increased in numbers during a time when the western branded skipper fluctuated in numbers and when the density of the primary adult food plant (gayfeather flowers) also fluctuated strongly, suggests that the HLM and the western branded skipper are responding to different environmental clues or that their behaviors and ecologies (e.g., vagility, home range size, etc.) are significantly unalike to affect their apparent population sizes in different ways.

<u>Year 2008</u>. The density of gayfeather flowering stems increased in only the <u>2004 Treatment Area</u> in 2008; it decreased dramatically by 2 to 4-fold in the other three treatment areas, although these decreases were not significantly different (**Table 9**). The decreases are probably best explained by the below average rainfall and above average temperatures in June and July (**Figure 4**). The increase in the <u>2004 Treatment Area</u> (four years after thinning) is consistent with the amount of time after thinning before *Liatris* experienced a significant increase in response to increased light and less competition that result from the fuels treatment. Skipper numbers followed a similar pattern, decreasing in all but the 2004 Treatment Area, convincingly illustrating the strong association between gayfeather flower density and skipper densities (Drummond 2007). The decline in skipper density in the <u>2004 Treatment Area</u> probably results from the poor recovery of gayfeather plants in the Jenny Gulch forest unit, which experienced considerable ground cover and soil disturbance from logging operations between the 2006 and 2007 flight seasons. For the eighth straight year, the <u>2000 Treatment Area</u> retained its place as the forest treatment type where the majority of skippers were counted, with two to three times as many skippers as the other treatments. For the HLM in 2008, the baseline number was about 0.5 skippers per acre, roughly one fourth of the density recorded last year (about 2.5 skippers per acre – the highest yet recorded in this monitoring study). The fact that the HLM has steadily increased in numbers during a time when the western branded skipper fluctuated in numbers and when the density of the primary adult food plant (gayfeather flowers) also fluctuated strongly, suggests that the HLM and the western branded skipper are responding to different environmental clues or that their behaviors and ecologies (e.g., vagility, home range size, etc.) are significantly unalike to affect their apparent population sizes in different ways.

<u>Year 2009</u>. The density of gayfeather flowering stems increased dramatically in all four treatment areas in 2009, reaching their highest densities over the ten-year monitoring period in all but the <u>2000 Treatment Area</u>, which nearly matched its high of 2007. Surprisingly, given the strong *Liatris* bloom, overall skipper density (pooled skipper sample) remained virtually the same as 2008 (at 3.33 skippers/acre). Increases were seen only in the <u>Control Area</u> (108%) and the <u>2002 Treatment Area</u> (15%). By contrast, the overall mean density of the HLM increased by 104% over 2008 (from 0.56 to 1.15/acre). This increase occurred in all but the <u>2004 Treatment Area</u>, where the density of HLM remained virtually unchanged from 2008. For the ninth straight year, the <u>2000 Treatment Area</u> retained its place as the forest treatment type where the majority of skippers were counted, with 38% more skippers than the next highest area (<u>2002 Treatment Area</u>). The high skipper count here matches the high *Liatris* flowering stem density found in the <u>2000 Treatment Area</u>, illustrating the strong and significant correlation between *Liatris* flowering stem densities and skipper densities

<u>Year 2010</u>. Responding to a decrease in precipitation of 3.5 inches during the growing season, dotted gayfeather exhibited dramatic declines in density at all treatments. Between 2009 and 2010, dotted gayfeather declined by 239 stems/acre across all 15 sampled transects, a decline of 39%. Despite this decline, *Hesperia* skipper numbers increased by 3.6 skippers/acre, an increase of just over 100% across all 15 sampled transects. Like *Hesperia* skippers, HLM increased as well, by 1.2 skippers/acre across all 15 transects, also an increase of just over 100%. The <u>2000 Treatment Area</u>, at 8 *Hesperia* skippers/acre, had the highest number of skippers recorded at it followed by the <u>Control Area</u> where 7.3 *Hesperia* skippers/acre were recorded. For HLM the <u>Control Area</u> contained the most skippers, 4 HLM/acre contain followed by the 2000 Treatment Area where 2.6 HLM/acre were recorded. It appears as if the skippers may experience a lag in response to changes in dotted gayfeather, and that in 2010 the butterflies were continuing their response to the unprecedented high numbers of dotted gayfeather observed in 2009.

Year 2011. Responding to a decrease in precipitation of 4.3 inches during the growing season, dotted gayfeather density continued the decline initiated in 2010 at all treatments areas except for the 2004 Treatment Area, where density held steady. Surprisingly skipper densities did not respond to this decline in gayfeather and instead numbers of both the pooled skipper sample and HLM increased or held steady on all treatment areas except for the 2004 Treatment Area. The Control Area, as it did in 2010 and for only the second time in 11 years of monitoring, held the most skippers. This occurred despite dotted gayfeather densities being lowest on the Control Area compared to the three treatment areas. The fact that gayfeather densities are greater on the three treatment areas suggests that the forest thinning completed at these treatments has positively impacted flowering gayfeather density. That skipper density is not declining in response to declining gayfeather density, may suggest there is a time lag between declines in precipitation and the indirect effect this has on skipper numbers, as mediated through declines in gayfeather.

Year 2012. The most striking pattern in skipper numbers noted from 2009 through 2012 is the decline in growing season precipitation and its correlation with a dramatic decline in dotted gayfeather flowering stems/acre, which this year was followed by a corresponding decline in the numbers of both the pooled sample of skippers and the sample of HLM. However, these associations are not statistically evident in the correlation analysis. The decrease in both HLM density and the pooled skipper density is occurring during not only a period of decreasing precipitation, but also during a period of increasing temperatures. The decrease in skipper numbers was observed at all treatment areas except the Control Area and was most pronounced at the 2002 Treatment Area. In most of the years monitored, the greatest density of skippers was counted at the 2000 Treatment Area. Perhaps this dominance of the 2000 Treatment Area in skipper densities is due in part to the presence of favorable habitat characteristics that the other treatment areas do not have, such as closer proximity to the river, and a well-established native herbaceous understory that may contribute to its consistently (and often significantly) greater density of gayfeather flowers. The density of dotted gayfeather flowering stems declined by 69% compared to densities recorded in 2009, coming in as the second lowest annual density recorded. Dotted gayfeather was responding to variation in both annual precipitation and growing season precipitation and the decline in dotted gayfeather density corresponds to three years of declines in growing season precipitation.

Year 2013. The decrease in skipper numbers occurring from 2011 through 2012 reversed itself in 2013 for both the pooled skipper sample and HLM sample as precipitation rebounded slightly. This increase in numbers of the pooled skipper sample occurred at all treatment areas and for HLM, at all treatments except the Control Area. Dotted gayfeather continued its response to variation in both annual precipitation and growing season precipitation, and the increase in dotted gayfeather density in 2013 corresponded to a slight increase in growing season precipitation. The correlations of both the pooled skipper sample and HLM densities with dotted gayfeather have weakened over the course of monitoring and were nearly absent in 2013 except for at the 2002 Treatment Area. The density of dotted gayfeather has been consistently, and positively, correlated with precipitation throughout the monitoring effort. Correlation is not indicative of causation, but even so it might suggest that if patterns of below normal annual precipitation continue into the future, we could see subsequent declines in dotted gayfeather densities indirectly leading to further declines in HLM densities. The increase in both HLM density and the pooled skipper density in 2013 occurred during a period of increasing precipitation and decreasing temperatures. Growing season precipitation increased by over one inch in 2013 compared to 2012 and temperature declined by over four degrees Fahrenheit.

Year 2014. In 2014, for the first time, the total counts for dotted gayfeather, the pooled skipper sample, and HLM declined while GSP increased dramatically. This observation, although interesting, is also difficult to explain. In looking at the pattern in GSP from March to August, there is no evident difference in this pattern for 2014 compared to other years that experienced above average deviation in GSP (2004, 2007, and 2009). The decline in counts for both the pooled skipper sample and HLM, followed 2013, a year of extremely high counts. In fact, 2013 exhibited the highest counts ever recorded on monitored transects. Some drop in skipper numbers may have been likely after the unexpectedly high 2013 counts. Even though dotted gayfeather did not exhibit a response to above average deviation in GSP in 2014, gayfeather was still significantly correlated with GSP when all years monitored are analyzed. Both the pooled skipper and HLM samples on the 2002 Treatment Area remain significantly correlated with dotted gayfeather flowering stem density.

Year 2015. The decline observed in the pooled skipper and the HLM counts observed over the last two years (2014 and 2015) is puzzling because GSP was high during both years and up till this point, skipper counts were positively correlated with GSP. This positive relationship was probably mediated through dotted gayfeather, which up to this point had also responded favorably to high values of GSP. But in both 2014 and 2015, the total dotted gayfeather flowering stem counts declined even though values of GSP were high. Actually, values for GSP in 2015 were the highest ever recorded during the 16 years of monitoring. Precipitation was lower at the end of the growing season, particularly during August of both years, compared to other wet years, and this may have affected flowering of dotted gayfeather (Prieto et al. 2008). Cool, wet, spring conditions could also have contributed to the decline in skippers detected during the 2014-2015. Butterflies are particularly sensitive to climate. The direct and indirect effects that weather has on butterfly species is complex. The decline in skipper counts could reflect patterns in weather that can have negative impacts on the survival of both adults and larvae (Gilbert and Singer 1975). HLM counts on the 2004 Treatment Area were relatively high in 2015, only surpassed by HLM counts on the Control Area. This is the first year out of 15 years that the 2004 Treatment Area did not have the lowest densities of HLM.

Year 2016. This year has seen the third straight year of declining or steady, but low, densities for both the pooled skipper sample and the sample of HLM. The density of both the pooled skipper sample and HLM sample has generally tracked the gayfeather flowering stem density, but in 2016 skipper densities decreased or remained stable while densities of dotted gayfeather slightly increased. What is different with the years 2014 through 2016, compared to previous years is that both dotted gayfeather and skipper counts did not track a corresponding increase in precipitation in 2014 and 2015 and dotted gayfeather densities did not track a corresponding decrease in GSP in 2016. Skipper densities at the Control Area and 2000 Treatment Area were equivalent and were the highest of the four treatment areas sampled. Abnormally low precipitation in 2016 is correlated with a collapse of HLM on the study area with densities declining by 57 percent to 0.8 HLM/acre. In

2016, dotted gayfeather densities remained relatively stable, but were still low. The prediction that densities of both dotted gayfeather and skippers are positively correlated with precipitation (one-tailed test) was strongly supported by correlation analysis for dotted gayfeather, but not for the skippers. The prediction that densities of both dotted gayfeather and the pooled skipper sample were positively correlated with temperature (one-tailed test) was not supported by correlation analysis.

Year 2017. There was a continuation of the low skipper counts first observed since 2014 for both the pooled skipper sample and for the sample of HLM. The general trend in skipper densities has been for increasing populations, however, 2017 has recorded the third straight year of low densities for both the pooled skipper sample and the sample of HLM. The density of both the pooled skipper sample and HLM sample has generally tracked the gayfeather flowering stem density, and 2017 was no different in this respect. For the first time in the monitoring period, skipper densities at the 2000 Treatment Area were less than at the 2002 Treatment Area breaking a trend that had been consistent since 2002. The general trend has been for increasing numbers of HLM as shown by the trend lines for all treatment areas, but because of the decline in HLM on the 2000 Treatment Area in 2017, there is a slight declining trend on that treatment area. The prediction that densities of both dotted gayfeather and skippers are positively correlated with precipitation (one-tailed test) was strongly supported by correlation analysis for dotted gayfeather, but not for the skippers. Correlation of both GSP and AP to the pooled skipper sample was weak, showing both positive and negative correlations, and accounting for only 0.16% and 1%, respectively, of the variation in skipper densities. The prediction that densities of both dotted gayfeather and the pooled skipper sample were positively correlated with temperature (one-tailed test) was not supported by correlation analysis. The 2017 analyses showed that densities on the 2002 Treatment Area of both the pooled and HLM samples were positively correlated with dotted gayfeather densities.

Year 2018. Skipper density for both the pooled *Hesperia* and HLM samples increased to some of the highest values ever recorded during the period of monitoring. The general trend of increasing skipper populations was continued this year, and this initiated an increase in the annual populations of skippers compared to the previous year. The general trend continues to be an increase in the number of HLM as shown by the trend lines for all treatment areas. The prediction that densities of both dotted gayfeather and skippers are positively associated with growing season precipitation was mostly supported by multiple regression for both dotted gayfeather and the polled *Hesperia* sample, but not for the HLM. The prediction that densities of both dotted gayfeather and skippers are positively associated with annual temperature was not supported by multiple regression for dotted gayfeather (except for 2004 Treatment) and mostly supported for the pooled *Hesperia* sample, but not the HLM sample.

Year 2019. Skipper density for both the pooled *Hesperia* and HLM samples exploded to the greatest values ever recorded during the period of monitoring and were greatest at the Control Area and the 2000 Treatment Area. The general trend of increasing skipper populations started in 2018 was continued this year. The general trend continues to be an increase in the number of HLM as shown by the trend lines for all treatment areas. The prediction that densities of both dotted gayfeather and skippers are positively associated with growing season precipitation was not supported by multiple regression for either dotted gayfeather or the skipper butterflies. The prediction that densities of both dotted gayfeather and skippers are positively associated with annual temperature was not supported by multiple regression for either dotted gayfeather (except for 2004 Treatment) or skipper butterflies. Densities of both the pooled *Hesperia* and HLM samples were shown by multiple regression to have a significant positive association with growing season temperature and a negative association with annual temperature. Density of dotted gayfeather was had significant negative association with both annual precipitation and annual temperature.

Year 2020. Skipper density for both the pooled *Hesperia* and HLM samples receded from the previous year, which saw the greatest values ever recorded during the period of monitoring. However, the density of both samples was still relatively high. This year unlike previous years when the 2004 Treatment Area had the lowest skipper densities, this treatment harbored the greatest numbers of *Hesperia* skippers among the four forest treatments. There was a high ratio of Western branded skippers to HLM suggesting that this year's sampling may have occurred prior to the peak flight period of the HLM. Like most previous, the densities of both the pooled *Hesperia* and HLM samples did not differ statistically among the four forest treatments. This year's flowering dotted gayfeather stem densities decreased dramatically, relative to the values for the previous year, to 61.1 per acre for all forest treatments combined (**Table 3**). These values of density are lower than for all other years monitored except for the extreme drought year of 2002**.** The GSP this year was dramatically less than that of the previous year, second to omly 2002, and dotted gayfeather densities were negatively impacted by this large decrease in precipitation. Dotted gayfeather flowering stem density this year were greatest in the 2000 Treatment Area, although this difference was not significant (**Table 4**). Similar to previous years dotted gayfeather density was positively correlated with GSP (r^2=0.43, p=0.002) and the proportion of plants in flower was lowest on record (60 percent), suggesting that skipper counts were conducted before peak flowering and/or that the drought had compromised plant fitness anf plant flowering. Similar to previous years, the 2004 Treatment Area differed from the other three forest treatments in the environmental variables that significantly influenced skipper density. Like past years, growing season temperature consistently had a positive and significant influence on both HLM and *Hesperia* skipper densitie, and annual temperature consistently had a negative and significant influence on both HLM and *Hesperia* skipper densities at most all forest treatments.