Pawnee Montane Skipper Monitoring Study for the Upper South Platte Watershed Protection and Restoration Project August 2017

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CNHP's mission is to preserve the natural diversity of life by contributing the essential scientific foundation that leads to lasting conservation of Colorado's biological wealth.

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Cover photograph: A Pawnee montane skipper (*Hesperia leonardus montana*) resting on foliage, Cheesman Reservoir, Jefferson County, Colorado (*photo by John Sovell*)

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 evaluating project effects over the short- and long-term, the USFS and Denver Water sponsored a pilot *Hesperia* skipper monitoring program for the federally threatened Pawnee montane skipper (PMS) (*Hesperia leonardus montana*), 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 of this species, is to document and interpret year-to-year variability in skipper densities in the monitored areas and their response to drought.

The monitoring study was designed to compare the number of adult *Hesperia* skippers within four treatment areas 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 PMS and Western branded skipper (*H. comma/H. colorado*[1]). 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.

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.

During the current year, the growing season (March through August) experienced warmer than average temperatures. This was the 16th year in a row of above-average growing season temperatures for the area (**Figure 2**). Growing season precipitation was 0.30 inches below the 25-year mean, and represents the eight driest growing season over the period of monitoring

[1] The western North American populations of *Hesperia comma*, including those in Colorado, are considered by some authors [*e.g.,* Opler 1999] to be a separate species: the Western branded skipper, *Hesperia colorado*. Because this designation is not universally accepted, and to maintain consistency with previous reports, the name *Hesperia comma* has been retained here.

(**Figure 2**). Annual precipitation was 9.9 inches or about 1.8 inches below the 25-year mean.

The skipper monitoring data in this study now cover nearly 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 and the Pawnee montane skipper sample taken individually (**Figure 3**). 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 2017.

Populations of *Hesperia* skippers on transects of the Trumbull treatment area remained low for the third consecutive year. There were 0.9 PMS per acre recorded at the 15 transects monitored. This number was over 50 percent less than the 2.0 per acre recorded within the South Platte River Valley during sampling efforts conducted in 1985 and 1986. This was also 70 percent less than the maximum density of 2.9 PMS per acre recorded during the monitoring period (**Figure 7).** What may have caused this decline in the densities of PMS is unknown. Weather, in this case precipitation, can have strong impacts on insect populations through impacts on the quality of both plants used as nectar sources and as hosts for butterfly larvae. A severe drought in 2002, combined with the Hayman Fire reduced the number of PMS in the study area to 0.3 per acre. Low growing season rainfall has consistently resulted in low flowering densities of the butterflies preferred nectar source, dotted gayfeather, on the monitored transects (**Figure 9**). The densities of PMS are positively correlated with densities of flowering dotted gayfeather and this correlation is statistically significant on the <u>2000</u> and <u>2002 Treatment Areas</u> (**Table 10**). The current low densities in PMS are probably the indirect result of the direct negative effect that below normal precipitation of the last two growing seasons has had on the densities of flowering dotted gayfeather and also possibly on the quality of blue grama, the larval host plant.

As indicated above, PMS, like most host specific butterflies, are particularly dependent on their primary nectar plant as well as their larval host plant, blue grama. Consequently, the objective of vegetation management for PMS conservation is to provide habitat conditions that maintain, expand, or add to the mosaic of dotted gayfeather and blue grama found in the study area. The following management considerations for the PMS draws upon the discussion found in Sovell (2014). Forest restoration prescriptions to improve habitat for the PMS should mimic those found on the <u>Control Area</u> and <u>2000 Treatment Area</u> 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 PMS and forest hydrologic function (Lowe 2005).

The densities of the pooled skipper sample, PMS and the western branded skipper (*Hesperia comma*) combined, on transects of the Trumbull treatment area also remained low for the third consecutive year. The limited densities estimated for the pooled skipper sample can probably also be attributed to below normal amounts of precipitation as discussed for the PMS. The management actions recommended for maintaining viability of the PMS population are also relevant for sustaining the overall *Hesperia* community present on the monitoring area.

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1.0 INTRODUCTION

In 2000, the U.S. Forest Service (USFS), in cooperation with the 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. In conjunction with the National Environmental Policy Act review process for this project, the USFS prepared a Biological Assessment to evaluate the potential effects on listed species that could be affected by the proposed forest restoration program. Among the species evaluated was the Pawnee montane skipper (PMS) (*Hesperia leonardus montana*) because suitable habitat for this species was included within the proposed forest thinning and prescribed burning areas. The USFS 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 Endangered Species Act including the PMS. The USFWS prepared a Biological Opinion (BO), which has been updated three times, to evaluate the effects of the proposed actions on listed species (USFWS 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.

Thinning operations conducted under the USPWPRP are, in part, occurring within areas mapped as suitable habitat for the PMS. In general, the proposed thinning should create a more suitable canopy cover for the skipper. Treatment areas consist of ponderosa pine forest, with more than 40 percent cover. Treatment areas will be thinned to approximately 30 percent cover (25 percent cover in ponderosa pine and 5 percent cover in Douglas-fir), which is considered to be the optimum canopy cover for the skipper. An analysis on PMS population in thinned areas of the Trumbull project indicate that basal area should average less than 60 feet^2 per acre, except in openings where few or no trees are present and with an average canopy cover less than 35 percent across a treatment area (Sovell 2014). Thinning was completed at three separate sites within the study area in 2000, 2002, and 2004. Each site received a different thinning prescription, which created a forest canopy structure that varies between sites. Reducing the forest canopy cover is expected to result in an increase in blue grama (*Bouteloua gracilis*) and dotted gayfeather (*Liatris punctata*), the butterfly's nectar and host plant, respectively. The monitoring conducted in association with this project is to examine whether forest thinning is in fact affecting the PMS, blue grama, and dotted gayfeather populations as hypothesized.

To assist in evaluating project effects over the short- and long-term, the USFS and Denver Water sponsored a pilot skipper monitoring program for both the PMS and Western branded skipper (*Hesperia comma*) during the flight season in August 2000, to evaluate the relative use by skippers of treated and untreated areas with continued monitoring for three years following treatment as called for in the Biological Opinion (USFWS 2001, 2003, 2009) (ENSR International 2003a, 2003b, Drummond 2004, 2005, 2007, 2008, 2009). The objectives, methods, and results of this program are described below. This report describes the results from adult skipper monitoring conducted between August 21 and 23, 2017, and provides comparisons with sampling completed annually since 2000.

2.0 STUDY OBJECTIVES

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 butterfly use at the three sites, where the ponderosa pine forest has been thinned to reduce fire danger and that is expected to improve PMS 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 and dotted gayfeather and to compare the annual variation in the abundance of PMS, blue grama, and dotted gayfeather populations to changes in annual growing season precipitation and temperature.

3.0 STUDY AREA

The study area is defined as suitable skipper habitat within four sections (Township 9 South, Range 70 West, Sections 10, 11, 15, 16, and 22) east and west of the South Platte River near the community of Trumbull (Douglas County and Jefferson County), Colorado. Together, these four sections include more than 1500 acres of suitable skipper habitat, based on the skipper habitat map included in the Environmental Research and Technology 1986 skipper survey report. **Figure 1** illustrates the estimated suitable habitat in the defined study area based on the skipper habitat map generated from the 1986 field studies. The dominant vegetation is mature ponderosa pine forest, with Douglas-fir as a co-dominant on north-facing slopes. Elevation ranges from approximately 6,300 feet at the South Platte River to 6,800 feet at the top of the transects. Since 1902, the average high July temperature was 78°F, the average low January temperature was 11°F, and the average annual precipitation was 16 inches[1] (Western Regional Climate Center, 2017).

Approximately 150 acres of this study area, on land owned by Denver Water, were thinned during 2000 (= <u>2000 Treatment Area</u>). An additional 674 acres, on National Forest land, were thinned between August and November 2002 (= <u>2002 Treatment Area</u>), with piling of slash by bulldozers continuing in the area through the summer of 2003. Two of the study transects in the <u>2002 Treatment Area</u> were thinned just prior to the sampling period of 2002 (late August). By the sampling period of 2003 (also late August), the entire 2002 Treatment Area had been thinned, although the burning of piled slash had not yet been completed. By the start of the 2005 field season, most slash piles had been burned and some additional thinning and log removal had occurred in section 15 (near the west ends of Transects 209 and 210). The final treatment area added to the study was thinned in 2004 (= <u>2004 Treatment Area</u>). Most of the work was conducted by the USFS using a rotary ax built by Hydro-Ax, with a smaller portion to the west thinned by the Colorado State Forest Service using a Bullhog horizontal wood grinder built by Fecon.

Barry C. Johnston (USFS) compared vegetative cover and plant species composition in the Trumbull study area between 2000 and 2003, before and after the thinning operations in the <u>2002 Treatment Area</u> (Johnston 2005). Thinning operations reduced tree basal area from about 65 ft^2/acre to about 44 ft^2/acre (32% decrease). The cover of lower tree layers was reduced by about one-third and most trees less than 10 inches dbh were removed. Shrub cover doubled in the thinned area and the cover of graminoids and forbs increased slightly during a period of extreme drought in 2002, and Johnston (2005) speculated that herbaceous ground cover would increase dramatically in future years. The characteristics of the individual treatment areas are as follows:

- **<u>Control Area</u>**. There are three control transects, each 400 m in length, established west of Trumbull on hillsides just west of the South Platte River. These transects have been sampled annually since 2000. The criteria for establishing the control included: proximity to the treated

[1] Weather data for the study area was collected from the Cheesman weather station, Douglas Co., CO: NWS, NCDC Station #052528. Lat =1050 17' Long = 390 13' Elev. = 6,880 ft.

areas, similarity in slope and management history, and location outside the area proposed for future thinning as part of the watershed program. Control Area transects are unique in that they are on east-facing slopes, whereas the experimental transects, all located east of the river, are mostly on west-facing slopes. The forest density over the majority of the Control Area approaches the objective for a 25 to 30 percent tree canopy specified as a forest habitat quality objective for the PMS (USFWS 2001). The Control South (CS) and Control Middle (CM) transects are located on east- to south-facing slopes with a widely-spaced woodland overstory representing high skipper habitat suitability; approximately 2/3 of the length of the Control North (CN) transect is located on a north- facing slope occupied by a young dense stand of ponderosa pine and Douglas-fir trees representing low skipper habitat suitability. In 2002, the Hayman fire burned parts of the upper (western-most) halves (last 200 meters) of the CM and CN control transects, with low severity intensity fire. The dominant aspects for the three Control Area transects are as follows:

  - CS – southwest
  - CM – east
  - CN - northeast

- **<u>2000 Treatment Area</u>**. This area, which was thinned in 2000, is represented by three transects [Transects 208 and 211 are each 200 meters long and were combined for analysis (referred to as 208/211); Transects 209 and 210 are each 400 meters long]. These transects have been sampled annually since 2000. The area is east of Trumbull and east of the South Platte River on low gradient hillsides just above the floodplain of the river. The locations of transects were dictated by the thinned areas, but are generally placed in an east-west orientation approximately 400 meters apart, and approximately 50 meters from the boundary of the adjacent untreated forest. The one exception to east-west orientation is Transect 210, which is fixed along a line running SW-to-NE (see **Figure A1** in Appendix A). Transects 208 and 211 occur on west-facing slopes, 209 occurs on a gentle northwest-facing slope, and 210 traverses varied terrain from west-facing at its southern end, extending through southwest- facing slopes, with its north end on a NE-facing slope of low quality skipper habitat. The forest canopy cover in the treated area was thinned to approximately 25 to 30 percent, and some 3- to 5-acre openings were created in the north harvest blocks. Because of differences in topography and in stand treatment prescriptions, the amount of understory disturbance is different between the area represented by Transects 208/211 and Transects 209 and 210. Very little surface disturbance was caused by tree harvest on Transects 208/211, which have relatively gentle slopes and were harvested during winter on frozen ground. Both blue grama and gayfeather are now relatively common within this area. Metal-track equipment was used for tree harvest on the steeper slopes of Transects 209 and 210, and more extensive surface disturbance occurred along skid roads and in drainages. Between 2004 and 2008, the Colorado State Forest Service conducted some pile and broadcast burning to reduce surface fuels in the eastern portion of the study area, which contains Transects 201-206 (see **Figure A1**). The dominant aspects for the three <u>2000 Treatment Area</u> transects are as follows:

  - 208/2011 – west

- 209 – northwest
- 210 - west

- **2002 Treatment Area**. Six transects, each 400 meters long, were established in an east- west orientation and were spaced approximately 400 meters apart. These transects have been sampled annually since 2000. In 2000 and 2001, the 2002 Treatment Area was sampled, but it had not yet been thinned. This area is located east of the 2000 Treatment Area on steeper slopes that are further from the river (about 500 m) and of higher elevation than the 2000 Treatment Area. Approximately 12 acres of this treatment area consist of pine woodland that was thinned in November 2001, with a rotary ax in the vicinity of Transect 201 along an ephemeral drainage. The rotary ax treatment thinned smaller trees over a distance of 50 to 80 meters in the middle portion of Transect 201. The remainder of the unit was thinned using a hot saw mounted on a tracked vehicle in 2002-2003, affecting parts of the remaining transects in this Treatment Area. Subsequent treatments of this area to reduce ground fuels include: slash piled with a bulldozer (winter 2003); slash piles burned in situ (winter 2003 and winter 2004; August, September, and October 2004; January and April 2005; May, June, July, and October 2007); broadcast burns (April and May 2005; May and June 2007); hand-felling of trees for public firewood near transects 201 and 202 (fall 2003); public gathering of firewood (downed wood) on 423 acres encompassing Transects 201 and 202 (January 19 through May 30, 2004). Transects 201, 202, 205, and 206 are located in relatively dense ponderosa pine stands, or on north-facing slopes. Skipper habitat understory characteristics of these transects are of lower quality (blue grama and gayfeather occurrences are infrequent). The two middle transects (203 and 204) are on relatively gentle west-facing slopes in a more open woodland, and consistently showed much higher blue grama and gayfeather frequency of occurrence. The dominant aspects for the six 2002 Treatment Area transects are as follows:
    - 201 – northwest
    - 202 – west
    - 203 – south
    - 204 – southwest
    - 205 – north
    - 206 - north
- **2004 Treatment Area**. Three transects were established between Jenny Gulch and Hatch Gulch and have been sampled annually since 2005 (see **Figure A2** in Appendix A). The transects are oriented east-west and are 400 m long. In their distance from the river (about 500 m) and their higher elevation, they are more similar to those of the 2002 Treatment Area than to transects in the 2000 Treatment Area and the Control Area. The three transects are on predominantly west-facing slopes; 241 is on a slope facing slightly south of west; 242 and 243 are on slopes facing slightly north of west. The area was thinned in 2004 using two methods. Most of the area was thinned by the USFS using a rotary ax. Transects 241 and 242 are entirely within this rotary ax-treated area. Along the western edge of the rotary ax-thinned area is a strip of forest roughly 300 m wide that was treated by the Colorado State Forest Service (CSFS) in 2004 using a Bullhog horizontal wood grinder. The western end

(about 150 meters) of Transect 243 lies within this Bullhog-treated area; the remaining 250 meters are in the rotary ax-thinned area. Subsequent treatment of this area include: slash piles burned in situ (January 2005); logging (trees cut and removed) and piling of slash (October through December 2006; March through early June 2007). These later logging operations resulted in considerable ground cover and soil disturbance throughout the Jenny Gulch unit. The dominant aspects for the three 2004 Treatment Area transects are as follows:

- 241 – northwest
- 242 – northwest
- 243 - west

Although topographically similar, the 2002 Treatment Area and the 2004 Treatment Area differ markedly in the way they were thinned. The 2002 Treatment Area was thinned in a manner consistent with thinning on the 2000 Treatment Area: selective thinning throughout to create a mixed age stand over the entire area. By contrast, the 2004 Treatment Area was thinned by tiling, creating a checkerboard pattern of forested and non-forested patches. Non-forest patches, up to 10 acres in size, were created by removing all trees in the patch; forested patches were not thinned. In terms of skipper habitat, neither patch type is suitable: unthinned patches are too dense (inadequate sunlight reaches the ground to stimulate *Liatris* growth) and cleared patches provide no shade or cover (skippers require both to provide shelter and to avoid desiccation and predation).

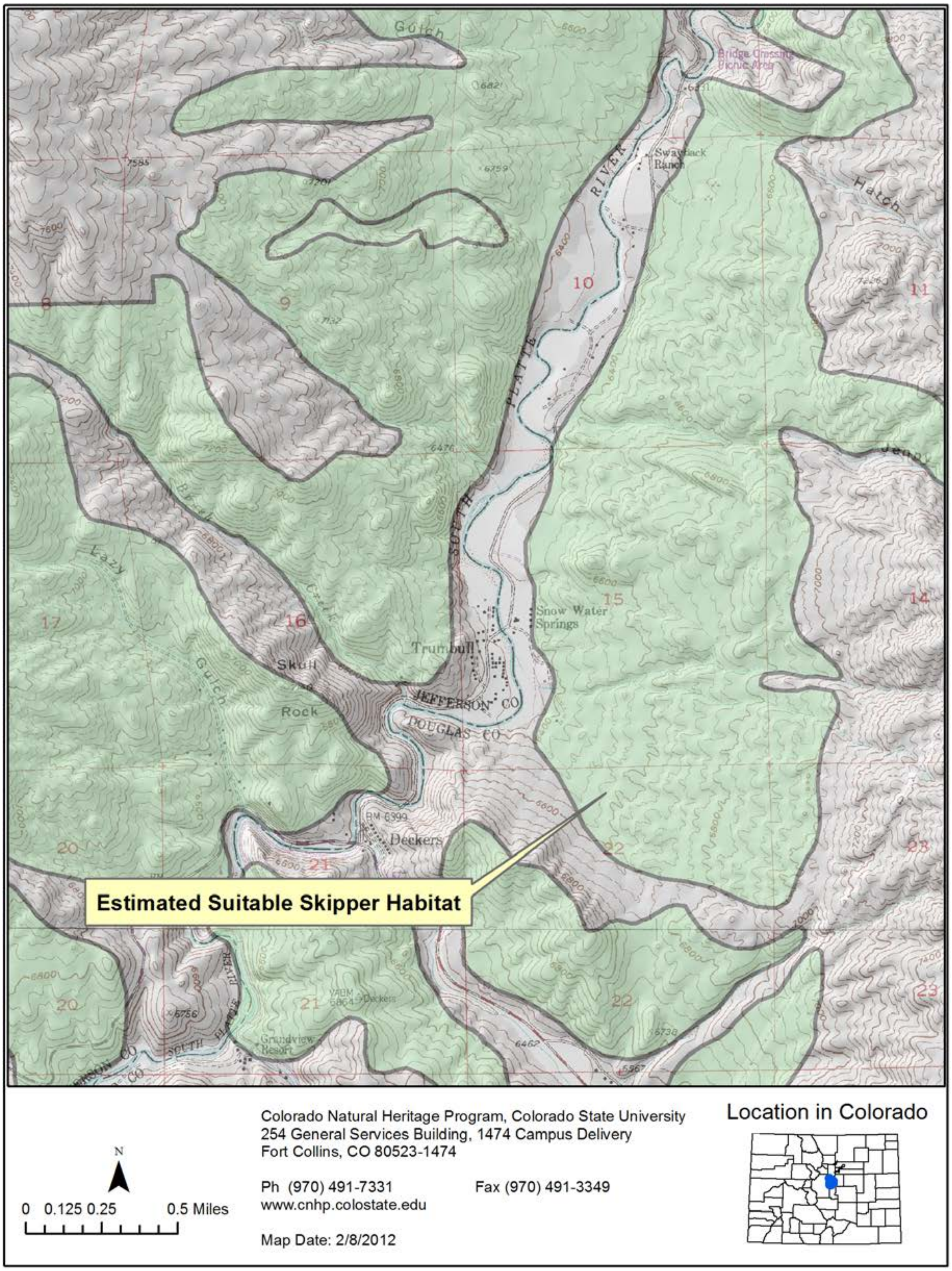


Figure 1. Estimated suitable Pawnee montane skipper habitat in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado.

4.0 STUDY DESIGN AND SAMPLING METHODS

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.

5.0 TRANSECT SAMPLES

5.1 Study Area Conditions

Precipitation measured at the Cheeseman Reservoir weather station was below normal for the calendar year. In the first quarter of the year (January-March) the mean precipitation was 0.32 inches below the 25 year mean, quarter two was 0.57 inches below the mean, quarter three was 0.22 inches above the mean, and quarter four was 0.5 inches below the mean. The below normal rainfall during spring and early summer resulted in diminished amounts of flowering gayfeather plants on most all of the four treatment areas (**Table 5**, **Figure 8**). Annual precipitation for the year was 13 inches or about 2.9 inches below the 25-year mean. The 25 year mean for both precipitation and temperature is based on data from 1985-2009 from the Cheesman Weather Station for the months of March-August (= growing season) (Western Regional Climate Center 2018).

Figure 3 shows the variation in growing season precipitation (GSP: March-August) over the monitoring period at the Cheesman weather station, showing that GSP has been below normal for the majority of years sampled (13 of the 18 sample years). The past year continued a pattern from 2016 of below normal precipitation. During the current year, the growing season precipitation was 9.9 inches, which was 1.8 inches below the 25-year mean, and represents the ninth driest year for GSP during the monitoring period (**Figure 2**). May received 35% more precipitation than normal, June 95% less, July 47% more, and August 22% less. March received 0.8 inches of rain, 0.6 inches below the 25 year average while moisture in April (1.3 inches) was 0.4 inches below normal, adding to the precipitation deficit experienced from May through August.

During the current year, temperatures were consistently above the 25-year monthly means (Western Regional Climate Center 2018). Late winter and spring air temperatures (January–May 2016) ranged from 0.03^{0}F above average in May to 11.5^{0}F above average in February, whereas summer temperatures (June–August) were 11.5^{0}F above average. Fall temperatures (September-November), averaged 6.1^{0}F above average. The current year's growing season, the important period for skipper host plant and nectar resources, experienced warmer than average temperatures (the mean was 56.4^{0}F or 4.3^{0}F above the 25-year mean). This was the 16th year in a row of above-average growing season temperatures (GST) for the area (**Figure 2**). Late winter and spring air temperatures (January–May 2017) were 28.2^{0}F above average. Mean annual temperature (MAT) was 49.5^{0}F, which was 4.8^{0}F above the 25-year mean.

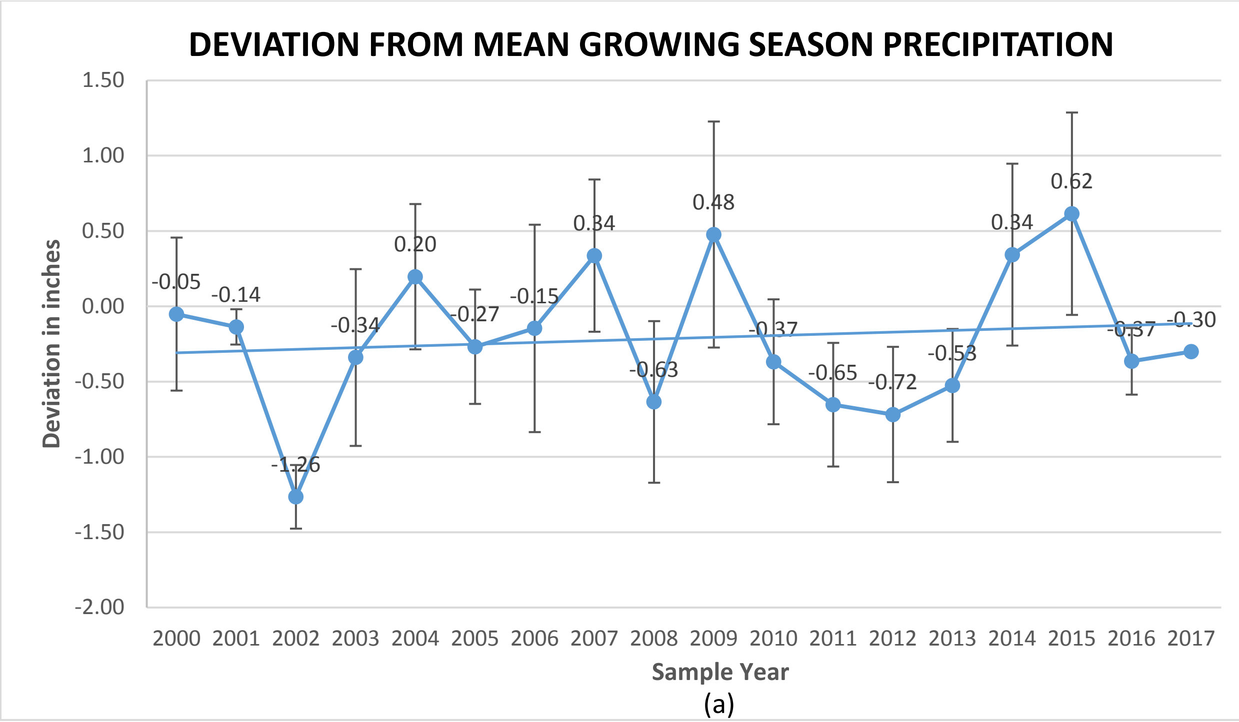
Field reconnaissance of the Trumbull area prior to initiation of fieldwork was conducted by personnel from the USFS and based on *Liatris* condition and skipper abundance at that time, the annual "skipper season" (period of peak *Liatris* flowering and skipper activity) seemed to coincide with an average year's schedule, as determined by previous studies (ERT 1986, 1988, 1989; ENSR 2003a, b; Drummond 2005). Adult skippers tend to appear in early to mid-August with the Western branded skipper (*H. comma*) being more abundant, while the PMS is absent or represented by only a few individuals in observations. By the third week of August the

PMS increases in number making up at least 50% or more of the observations. By the first week of September the PMS is more abundant, comprising the vast majority of observations, although the total number of skippers observed is starting to decline as the end of the flight season approaches.

Sampling for this year was conducted over a five day period starting at approximately 10 am each day with start temperatures ranging from 70^0 to 77^0F on all five days. Temperatures rose steadily each morning reaching highs by 1-3pm:

- August 21, 84 degrees
- August 22, 90 degrees
- August 23, 90 degree
- August 25, 77 degrees

Rain on the study site resulted in cancelation of the survey on transect 241 August 23. The transect was then surveyed the morning of August 24.



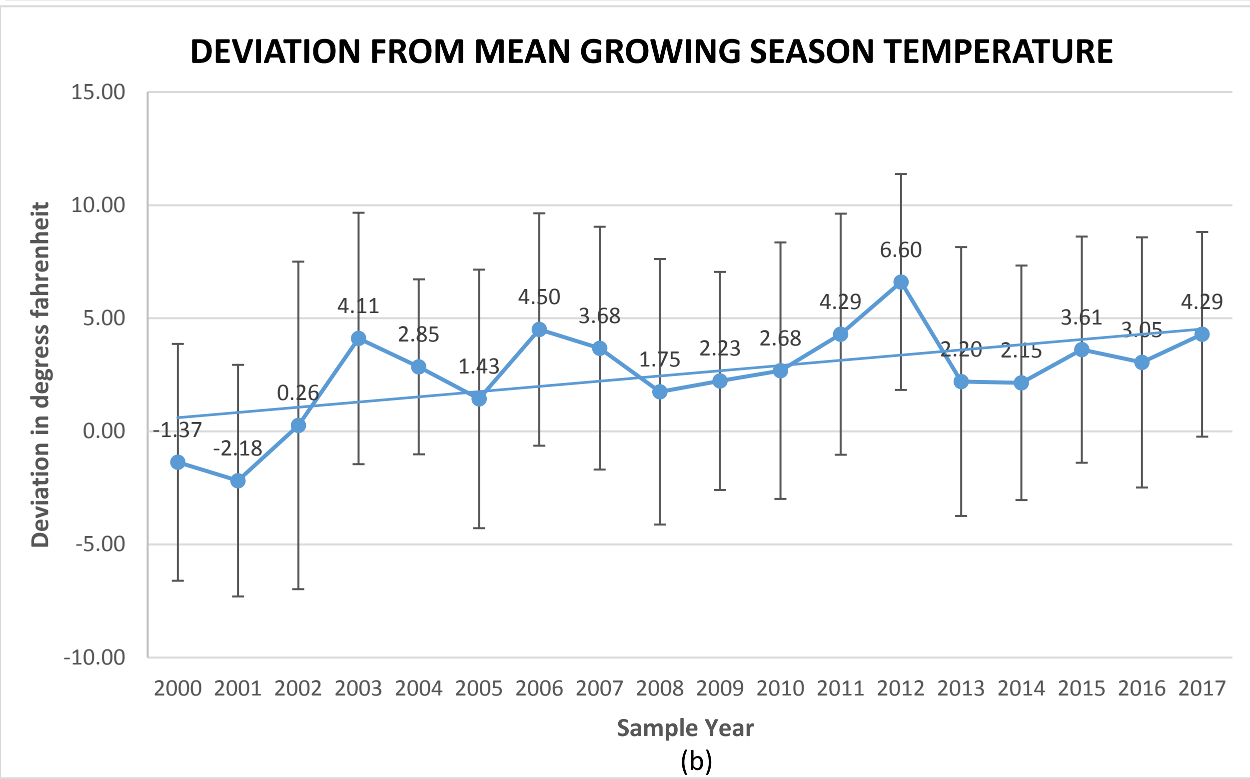


Figure 2. Deviations from mean values of (a) growing season precipitation (inches + 1 SE) and (b) growing season temperatures (^{0}F + 1 SE) with the 25-year mean deviation shown on each graph as 0.00. The linear trend line over the 18 year study period for both precipitation and temperature are displayed.

5.2 Transect Sample Schedule

Skipper counts were conducted on August 21, 22, 23, and 24, during a time of low moisture and high daytime temperatures.

Skipper counts were conducted from approximately 10:00 am to 1:30 pm each day. Each day started out sunny with 20% or less of cloud cover, but clouds increased throughout the day, reaching 50% or greater of cloud cover on each day by the time surveys were completed.

Annual counts were conducted by John Sovell of the Colorado Natural Heritage Program; Mikele Painter, Ariel Demarest, and Yann Lapotre of the USFS; and volunteers Cheryl Ames (Volunteer), Heather Bell (USFWS) Taylor Cassidy (USGS), Jean-Pierre Dagon (Volunteer), Carlos Fernandez (Volunteer), Taylor Hackemack (USFWS), Susan Hall (CH2M), Sara Leibel (USFS), Jack Mudd (Volunteer), Cabel Patterson (USFWS), John Nelson (NPS),Thomas Rains (Volunteer),Tammy Sanders (Volunteer), Bonnie Saville (CPW), Stephanie Shively (USFS), Matt Schweich (Volunteer), Tiffany Trunnell (Volunteer), Lela Updegrave (USFS), Lin Wareham-Morris (Volunteer) and Steve Williams (JCOS)

August 21: Sovell, Lapotre, and Patterson (CM, CN, CS, 241, 242); Painter, Cassidy, and Hall (203, 204, 205, 209, 210); Demarest, Leibel, and Saville (201, 202, 203, 208/211, 243).

August 22: Sovell, Dagon, Lapotre, and Shively (201, 202, 203, 208/211, 243); Painter, Nelson, Sanders, and Williams (CM, CN, CS, 241, 242); Demarest, Cassidy Patterson, and Updegrave (203, 204, 205, 209, 210).

August 23: Sovell, Hackemack, and Rains (203, 204, 205, 209, 210); Painter, Cassidy, Fernandez, and Patterson (201, 202, 203, 208/11, 243); Demarest, Bell, Trunell, and Williams (CM, CN, CS, 241, 242).

August 24: Demarest, Ames, Mudd, and Wareham-Morris (204, 241).

Only on the first day of sampling (August 21), observers recorded the presence or absence of blue grama along each transect and counted the number of flowering dotted gayfeather stems within the belt transect area. Digital photos were not taken during this year of surveying. Prior to 2016, these photos were taken at every 50-meter interval along the centerline of all 15 transects to document vegetation condition. Only on day two (August 22), observers recorded the number of dotted gayfeather plants (whether flowering or not) within the belt transect area on all 15 transects. During those counts, on August 23, cloudy conditions on the study site resulted in the suspension of sampling effort, but sampling was completed on August 24.

6.0 RESULTS

6.1 Skipper (*Hesperia*) Counts Among Years

The general trend has been for increasing skipper numbers since initiation of monitoring in 2000 (**Table 1, Figure 3**). **Table 1** provides a summary of skipper densities (pooled *Hesperia* sample of both species) over all treatments for the monitoring period to date. This year's skipper densities remained low, and like in 2015 and 2016, were indistinguishable from the years 2000 through 2004, a period when drought severely decreased skipper populations within the study area (**Table 1, Figure 3**). The low counts for skippers held true for both the pooled skipper sample and for the sample of PMS, although the densities of both study groups increased slightly compared to the previous year (**Figure 3**). The general trend in skipper densities has been for increasing populations through 2013. This year, however, has seen the third straight year of low densities for both the pooled skipper sample and the sample of PMS (**Figure 3**). The GSP in 2017 was similar to precipitation in 2016, consequently having little effect on the density of HMS in the study area (**Figures 2 and 3**). There seems to be less volatility in swings in PMS density than in the pooled skipper sample, but PMS densities appear to be continuing their low values, which started in 2014 (**Figure 3)**.

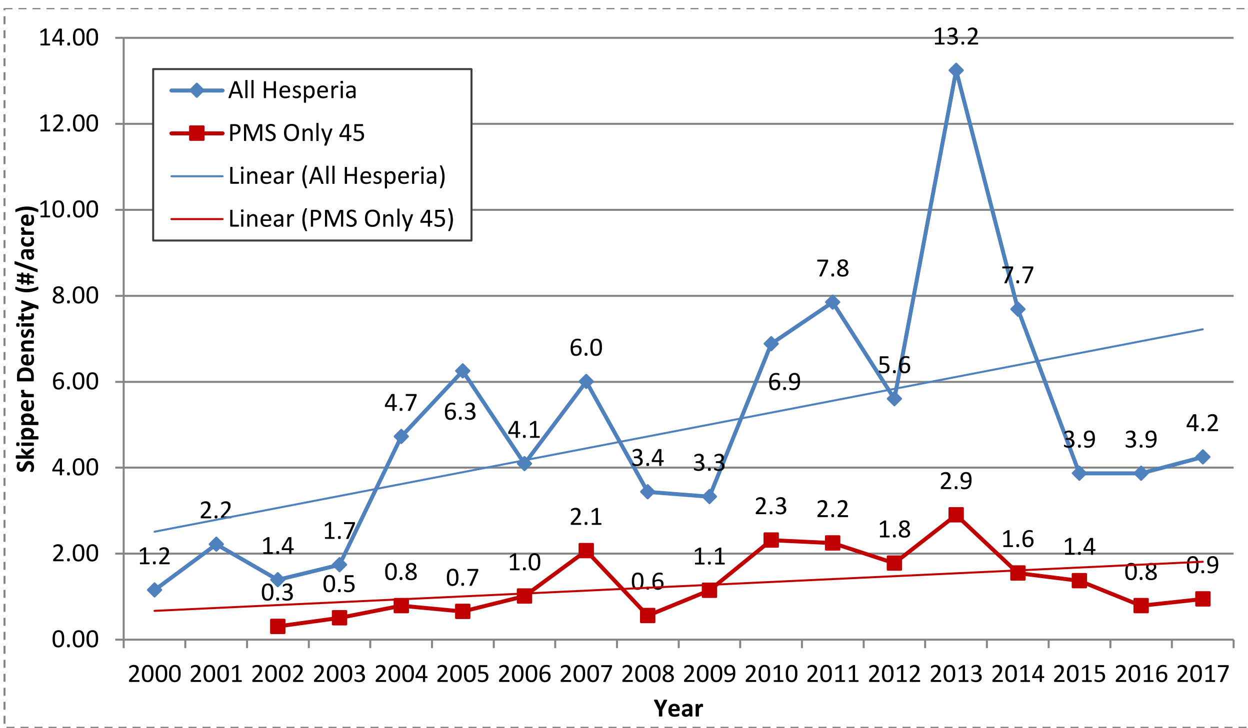


Figure 3. Skipper densities and PMS densities (along with their linear trend line) summed across all the treatment areas (see **Table 4**).

Table 1. Comparisons of Skipper (*Hesperia*) Densities (number/acre) Over Time Averaged Across all Forest Treatments[1].

	Number of Transects[2] = 36 (2004 Treatment Area Excluded)			Number of Transects[3] = 45 (2004 Treatment Area Included)		
Year	**Mean # skippers/acre**	**Homogeneous Groups[4] P = 0.05**	***p=0.10***	**Mean # skippers/acre**	**Homogeneous Group[4] P = 0.05**	***p=0.10***
2000	1.15	A	a	1.15	A	a
2001	2.22	AB	ab	2.22	AB	ab
2002	1.04	A	a	1.04	A	a
2003	1.74	A	a	1.74	A	a
2004	4.72	ABCD	abcd	4.72	ABCD	abcd
2005[5]	6.52	BCDE	bcde	6.25	BCDE	bcde
2006	4.10	ABCD	abc	4.09	ABCD	abc
2007	7.20	CDE	cde	6.00	CDE	cde
2008	3.44	ABC	abc	3.44	ABC	abc
2009	3.48	ABC	abc	3.33	ABC	abc
2010	7.42	CDE	cde	6.88	CDE	cde
2011	8.83	DE	de	7.85	DE	de
2012	6.46	CDE	cde	5.60	CDE	cde
2013	15.04	F	f	13.24	F	f
2014	9.27	E	e	7.69	E	e
2015	4.10	ABCD	abc	3.87	ABCD	abc
2016	4.27	ABCD	abc	3.87	ABCD	abc
2017	5,00	ABCD	abcd	4.25	ABCD	abc

1 Control Area, Year 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 Twelve 400m transects, each sampled 3 times per year.

3 Fifteen 400m transects, each sampled 3 times, for years 2005-2017; twelve 400m transects, each sampled 3 times, for years 2000-2004.

4 Tukey's Mean Comparison Test — means (number of skippers per acre) with the same letter are not different at the probability level indicated; [*e.g.*: in the data column when n=36 (2004 Treatment Area excluded), the means for 2006, 2007 and 2010 are not significantly different from each other at P=0.05 (**CD, c**) or at $p = 0.10$, but 2007 and 2010 (**CDE, c*de***) are significantly different from years 2000-2003 at both significance levels.

5 The means for 2005-2017 are reported in two ways. In the second and third columns, the data for the 2004 Treatment Area are excluded (this was done so that the means of all 11 years can be compared based on the same number of transects [*n*=36]). In the fourth and fifth columns, the 2004 Treatment Area data (3 transects, each sampled 3 times per year) are included in the 11-year comparison. See text for discussion.

6.1.1 Pooled Skipper Counts and The Effect of Treatment

Skipper densities at the Control Area were the highest of the four treatment areas sampled. However, these densities were not significantly greater than those observed on the other three treatment areas (*p≤0.05* or *p≤0.1*) (**Figure 4 and Table 2**). From 2001 through 2010, the greatest density of skippers was counted at the 2000 Treatment Area, although this difference was not statistically significant in any year (**Table 2**). The trend of higher skipper densities on the Control Area and 2000 Treatment Area relative to the other two treatments is persistent.

Starting in 2011, there was a shift in the treatment area with the highest density of skippers from the 2000 Treatment Area to the Control Area (**Figure 4**). These two sampling areas have consistently contained the highest density of skippers, despite the variable conditions affecting different parts of the study area during this period, including drought, fire, and other thinning operations.. In 10 of 18 sample years, the 2000 Treatment Area had the highest density of skippers and the second highest density in six of the other eight years monitored (**Figure 4**). The Control Area had the highest density in seven of the sample years monitored and the second highest density in five of the 18 years monitored (**Figure 4**). The sample means by treatment exhibit a multimodal distribution across the 18 years of sampling with skipper numbers usually increasing during wetter periods and decreasing during drier periods (**Figure 4**). This was true for all of the treatments except the Control Area, which from 2011 through 2012, experienced increases in skipper numbers during a period of abnormally low precipitation. In 2014, however, skipper numbers began a decline on all treatment areas that persisted into 2016, during a period of both high and low growing season precipitation. In 2016, precipitation showed the sixth lowest GSP in the 16 years of monitoring. In 2017, there was a slight recovery in skipper densities at the Control and 2002 Treatment Areas with slight decreases observed at the 2000 and 2004 Treatment Areas.

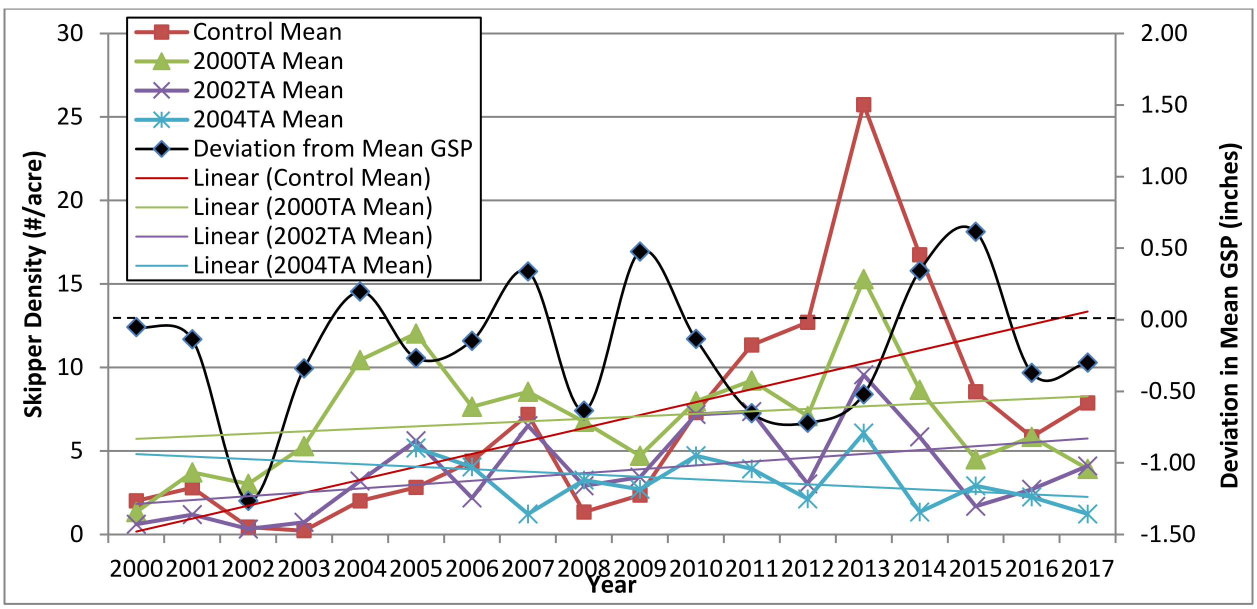


Figure 4. Pooled skipper densities by treatment area for each year on the *Hesperia* skipper monitoring transects. Deviation form mean growing season precipitation in inches is included for comparison (linear trend lines are shown for the 2000 Treatment Area and the 2004 Treatment Area).

Table 2. Comparisons of Pooled Skipper (Hesperia) Densities within Year, Among the 4 Treatment Areas.

	Mean # skippers/acre[1] P = 0.05 [p=0.10]																	
AREA[2]	**Year 2000**	**Year 2001**	**Year 2002**	**Year 2003**	**Year 2004**	**Year 2005**	**Year 2006**	**Year 2007**	**Year 2008**	**Year 2009**	**Year 2010**	**Year 2011**	**Year 2012**	**Year 2013**	**Year 2014**	**Year 2015**	**Year 2016**	**Year 2017**
Control (n=9)[3]	2.02 A[5] [a]	2.80 A [a]	0.44 A [a]	0.22 A [a]	2.02 A [a]	2.81 A [a]	4.38 A [a]	7.2 A [a]	1.35 A [a]	2.36 A [a]	7.31 A [a]	11.35 A [a]	12.70 A [a]	25.74 A [a]	16.75 A [a]	8.54 A [a]	5.85 A [a]	7.87 A [a]
2000 Treatment (n=9)	1.35 A [a]	3.71 A [a]	3.03 A [a]	5.28 A [a]	10.4 5 A [a]	12.03 A [a]	7.64 A [a]	8.54 A [a]	6.75 A [a]	4.72 A [a]	7.99 A [a]	9.22 A [a]	7.08 AB [ab]	15.29 B [b]	8.66 AB [ab]	4.50 A [a]	5.85 A [a]	3.94 A [a]
2002 Treatment (n=18)	0.62 A [a]	1.18 A [a]	0.34 A [a]	0.73 A [a]	3.20 A [a]	5.62 A [a]	2.19 A [a]	6.52 A [a]	2.92 A [a]	3.43 A [a]	7.20 A [a]	7.36 A [a]	3.04 B [b]	9.56 B [b]	5.85 B [b]	1.69 A [a]	2.70 A [a]	4.1 A [a]
2004 Treatment[4] (n=9)	*	*	*	*	*	5.171 A [a]	4.05 A [a]	1.24 A [a]	3.26 A [a]	2.70 A [a]	4.72 A [a]	3.94 A [a]	2.14 B [b]	6.07 B [b]	1.35 B [b]	2.92 A [a]	2.25 A [a]	1.24 A [a]

[1] Compare the treatment areas for each year by reading the columns vertically.

[2] Control Area, Year 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.

[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.

[5] Tukey's Mean Comparison Test: means (number of skippers per acre) with the same letter are not different at the given probability level. [*e.g.*: for Year 2000, skipper count means are not significantly different between treatments at either the P=0.05 level (**A**) or the P=0.1 level [**a**]. For 2013

6.1.2 Pawnee Montane Skipper Counts

PMS densities (summed over all treatments) are presented in **Table 3**, showing a noticeable decrease in the number of skippers per acre from 2013 through 2017. In 2000 and 2001, *Hesperia* skippers were not identified to species, leaving an absence of data for PMS in those years. The PMS densities showed considerable year-to-year variability in density over the four treatment areas (**Figure 5**). The general trend has been for increasing numbers of PMS on the Control and the 2002 Treatment Areas and a lower or decreasing trend on the 2000 Treatment and 2004 Treatment Areas as shown by the trend lines for all treatment areas (**Figure 5**). PMS densities on all 15 transects have fluctuated between 0.3 (2002) and 2.9 (2013) skippers/acre.

Like the pooled skipper sample, the 2000 Treatment Area and the Control Area have consistently contained the highest densities of PMS (**Table 4, Figure 5**). In eight of 16 sample years, the 2000 Treatment Area had the highest density of PMS and the second highest density in six of the other eight years monitored (**Figure 5**). The Control Area had the highest density in eight of the sample years and the second highest density in three of the remaining eight years of monitoring (**Figure 5**). Although the Control Area and the 2000 Treatment Area supported greater numbers of PMS throughout most all of the sample years, the only statistically significant differences noted were among the Control Area and comparisons with both the 2004 Treatment Area (2012 – 2014) and the 2002 Treatment Area (2012) (**Table 4**). Densities of PMS at the 2004 Treatment Area have been consistently low, about 0.5 individuals/acre or less each year except for 2006 and 2014, when no PMS were seen and 2010 and 2015, when 1.6 and 1.3 skippers/acre where recorded, respectively.

After the drought of 2002, PMS densities increased in seven of the 16 intervals between years, with a slight decline occurring in 2005 and large declines in 2008, 2012, and 2014 through 2016 (**Figure 6**), mostly years when precipitation was abnormally low (**Figure 6**). The years 2014 and 2015 are the exception to this trend, when precipitation was above the mean, yet PMS densities declined by 53 percent over that two year period. Current densities of PMS are 0.9 individuals/acre. At peak abundance in 2013, PMS reached 2.9 adults/acre (**Table 4**), an increase of 867 percent over densities recorded in 2002 (0.3 adults/acre). From 2010 through 2015, the density of PMS fluctuated above and below 2.0 skippers/acre (range 1.4 - 2.9), with some indication that in the absence of severe drought and catastrophic wildfire, densities may be stabilizing. The general trend in PMS densities has been for increasing density over the entire monitoring period (**Figure 6)**. However, abnormally low precipitation in 2016 and 2017 resulted in a decrease of PMS on the study area with densities declining by 57 percent to 0.8 PMS/acre in 2016 and remaining low at 0.9 PMS/acre in 2017.

Table 3. Comparisons of Pawnee Montane Skipper Densities Over Time Averaged Across All Forest Treatments[1].

	Number of Transects[2] = 36 (2004 Treatment Area Excluded)		Number of Transects[3] = 45 (2004 Treatment Area Included)	
Year	**Mean # skippers/acre**	**Homogeneous Groups[4]** P = 0.05 ***p=0.10***	**Mean # skippers/acre**	**Homogeneous Groups[4]** P = 0.05 ***[p=0.10]***
2002	0.31	A a	0.31	A a
2003	0.51	AB ab	0.51	AB ab
2004	0.79	ABC abc	0.79	ABCD abcd
2005[5]	0.70	AB ab	0.65	AB ab
2006	1.26	ABCD abcd	1.01	ABCD abcde
2007	2.47	CDE cde	2.07	BCDE cdef
2008	0.56	AB ab	0.56	A ab
2009	1.29	ABCD abcd	1.15	ABCD abcde
2010	2.50	CDE cde	2.32	DE ef
2011	2.67	DE de	2.25	CDE def
2012	2.08	BCDE bcde	1.78	ABCDE bcdef
2013	3.48	E e	2.90	E f
2014	1.94	ABCDE abcde	1.55	ABCDE abcdef
2015	1.38	ABCD abcd	1.37	ABCD abcde
2016	0.94	ABCD abcd	0.79	ABC abc
2017	0.34	ABCD abcd	0.94	ABCD abcde

[1] Control Area, Year 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] Twelve 400m transects, each sampled 3 times per year.

[3] Fifteen 400m transects, each sampled 3 times per year, for years 2005-20018.; twelve 400m transects, each sampled 3 times per year, for years 2002-2004.

[4] Tukey's Mean Comparison Test — means (number of skippers per acre) with the same letter are not different at the probability level indicated; [*e.g.*: in the data column when *n*=36 (2004 Treatment Area excluded), the mean for 2011 at both p = 0.05 (DE) is significantly different then the years 2002-2005, and 2008. And at p = 0.1, the same is true.

[5] The means for 2005-2017 are reported in two ways. In the second and third columns, the data for the 2004 Treatment Area are excluded (this was done so that the means of all 16 years are based on the same number of transects [*n*=36]). In the fourth and fifth columns, the 2004 Treatment Area data (3 transects, each sampled 3 times per year) are included in the 16-year comparison. See text for discussion.

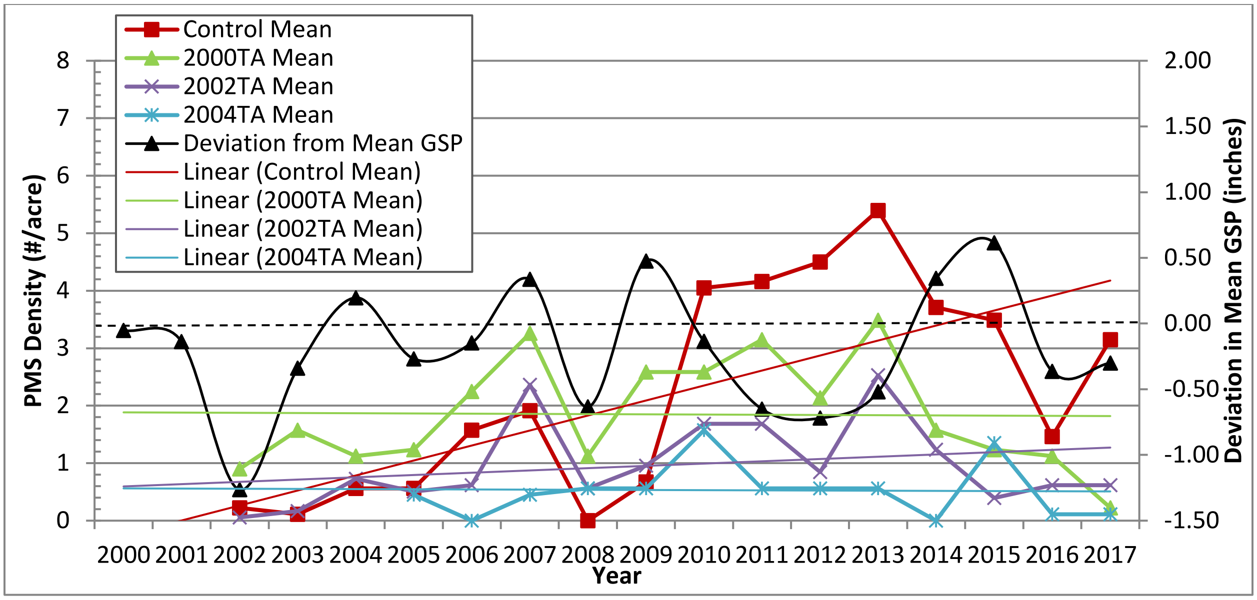


Figure 5. Pawnee montane skipper densities by treatment area for each year on the *Hesperia* skipper monitoring transects (linear trend lines are shown). Deviation form mean growing season precipitation in inches is included for comparison (linear trend lines are shown for the 2000 Treatment Area and the 2004 Treatment Area).

Table 4. Comparisons of Pawnee Montane Skipper (*Hesperia leonardus montana*) Densities within Year, Among the 4 Treatment Areas.

	Mean # skippers/acre[1] P = 0.05 [p=0.10]															
AREA[2]	**Year 2002**	**Year 2003**	**Year 2004**	**Year 2005**	**Year 2006**	**Year 2007**	**Year 2008**	**Year 2009**	**Year 2010**	**Year 2011**	**Year 2012**	**Year 2013**	**Year 2014**	**Year 2015**	**Year 2016**	**Year 2017**
Control (n=9)[3]	0.225 A [a]	0.112 A [a]	0.562 A [a]	0.562 A [a]	1.574 A [a]	1.911 A [a]	0.000 A [a]	0.675 A [a]	4.047 A [a]	4.159 A [a]	4.497 A [a]	5.397 A [a]	3.709 A [a]	3.48 A [a]	1.46 A [a]	3.15 A [a]
2000 Treatment (n=9)	0.899 A [a]	1.574 A [a]	1.124 A [a]	1.237 A [a]	2.248 A [a]	3.260 A [a]	1.124 A [a]	2.586 A [a]	2.586 A [a]	3.148 A [ab]	2.137 AB [ab]	3.484 AB [ab]	1.574 AB [ab]	1.24 A [ab]	1.12 A [a]	0.22 A [a]
2002 Treatment (n=18)	0.056 A [a]	0.169 A [a]	0.731 A [a]	0.506 A [a]	0.618 A [a]	2.361 A [a]	0.562 A [a]	0.956 A [a]	1.686 A [a]	1.686 A [ab]	0.843 B [b]	2.529 AB [ab]	1.236 AB [ab]	0.39 A [b]	0.62 A [a]	0.62 A [a]
2004 Treatment[4] (n=9)	*	*	*	0.450 A [a]	0.000 A [a]	0.450 A [a]	0.562 A [a]	0.562 A [a]	1.574 A [a]	0.562 A [b]	0.561 B [b]	0.562 B [b]	0.000 B [b]	1.34 A [ab]	0.11 A [a]	0.11 A [a]

[1] Compare the treatment areas for each year by reading the columns vertically.

[2] Control Area, Year 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.

[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.

[5] 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 skipper count means on all four treatment areas are not significantly different from each other at P=0.05 (A), but at *p=0.10* (b) the skipper count mean for the2004 Treatment Area [b] is significantly lower than the mean on the Control Area [a].

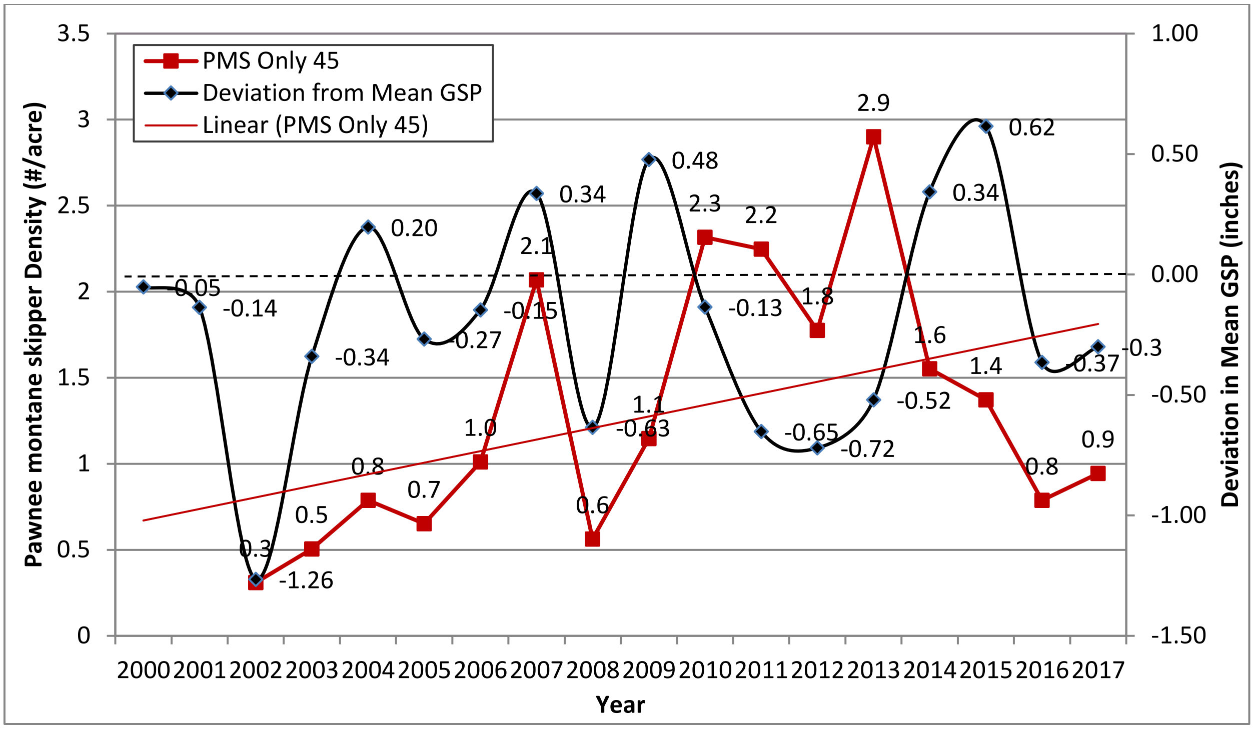


Figure 6. Comparison of Pawnee montane skipper mean densities for all treatments combined and for all years monitored. The deviation from mean growing season precipitation in inches, is included for comparison (the linear trend line is shown for the Pawnee montane skipper sample pooled across treatment area).

As in previous years, an attempt was made to record all skippers seen "off-transect" by field crews moving to or between transects during the three-day sampling period. Although these data were collected with less rigor and consistency than transect data, they are included here as an additional indicator of relative skipper abundance. A total of 29 skippers were observed "off-transect". This is more than the 56 observed off-transect in 2016. The number observed off-transect in 2015 was 12, 40 in 2014, 66 in 2013, 15 in 2012, 73 in 2011, 71 in 2010, and in 2009, 61 were observed off transect (Sovell 2014). The general trend in off-transect skipper counts has been for declining numbers, although there is a lot of variation in the data (**Figure 7**). This year, the counts of skippers off-transect declined. The trend in the number of PMS observed off-transect has been for declining numbers over the entire monitoring period, but again the data is variable.

The 29 off-transect skippers recorded this year were distributed as follows: 8 in the Control Area, 6 in the 2000 Treatment Area, 13 in the 2002 Treatment Area, and 4 in the 2004 Treatment Area. Of these, 8 individuals (28%) were identified as PMS: 5 in the Control Area, 5 in the 2000 Treatment Area, 2 in the 2002 Treatment Area, and 1 in the 2004 Treatment Area. Of the remaining 16 skippers observed off-transect, 7 were *Hesperia comma* and 9 were unknowns. Of these 16 individuals 3 were observed in the Control Area, 3 in the 2000 Treatment Area, 7 in the 2002 Treatment Area, and 3 in the 2004 Treatment Area. In general, there were fewer skippers of both species recorded from all the treatment units in 2017 compared to 2016: Control Area (8 versus 17), 2000 Treatment Area (6 in both years), 2002 Treatment area (9 versus 21), and 2004 Treatment Area (4 versus 12).

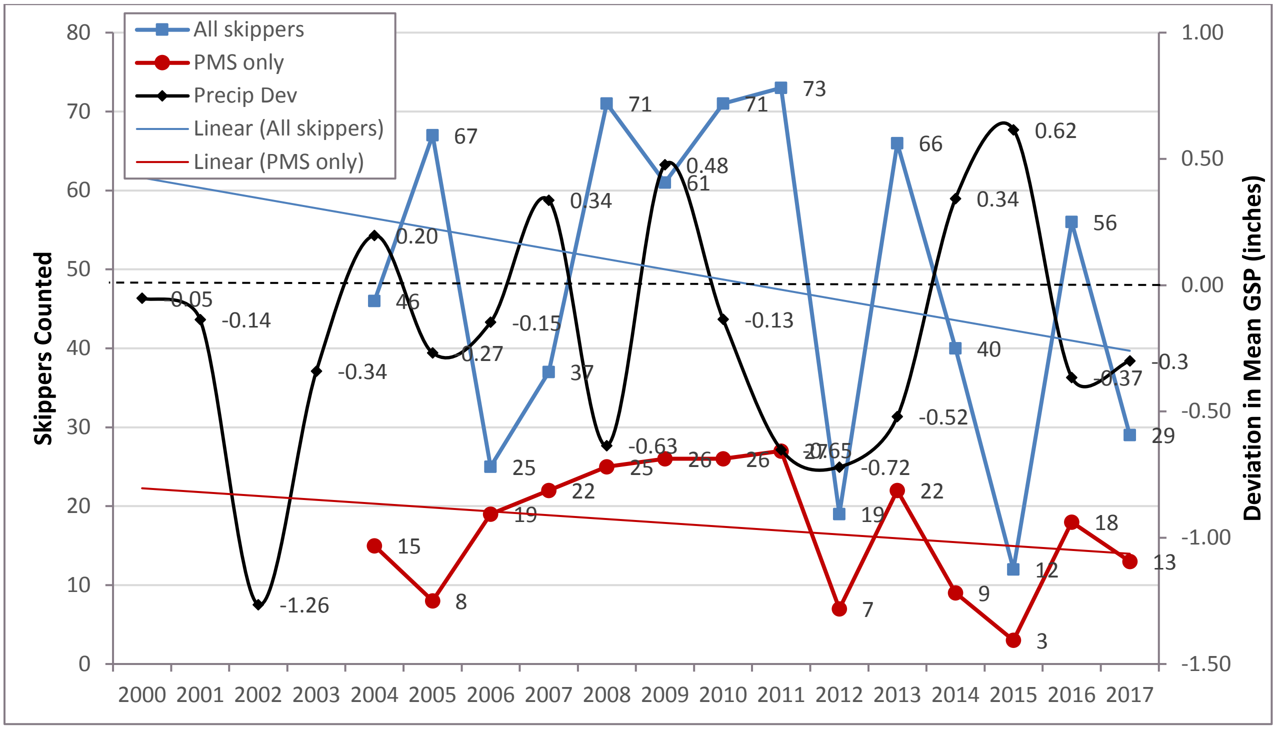


Figure 7. Counts of all skippers and Pawnee montane skippers observed off-transect. The deviation from mean growing season precipitation in inches, is included for comparison.

6.2 Dotted Gayfeather (*Liatris punctata*) Counts

Annual dotted gayfeather densities were low. At a mean count of 133 stems/acre, densities are below the all-time high average of 612 stems/acre counted and the second lowest density recorded during the monitoring period **(Table 5**). In general, dotted gayfeather has not shown any trend, rather it has fluctuated greatly (**Figure 8**). The main, discernable pattern is that dotted gayfeather densities have increased dramatically in wet 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 (**Table 6** and **Figure 8**). However, below normal growing season precipitation in this year was correlated with a 74 percent decline in flowering dotted gayfeather on the 2000 Treatment Area. In 2017, dotted gayfeather densities fell on the 2000 Treatment Area and remained low at all treatment areas tracking the below average GSP (**Figure 8**). Although dotted gayfeather density has been consistently highest, except for the last two years, in the 2000 Treatment Area, that difference has not been statistically significant except for in the years 2007 and 2009 (**Table 6**). Since 2002, a year of severe drought, the daily counts of dotted gayfeather increased, at the 2009 peak, by about 4000%. Since 2009, counts have declined and in 2017 the number of stems in bloom ranged from 1 to 548, much less than the 360 to 1358 blooming stems observed across the four forest treatment areas in 2009. In general, over the period of monitoring dotted gayfeather has been trending down at the 2000 Treatment Area while the trend is slightly up at the other three treatment areas (Figure 9).

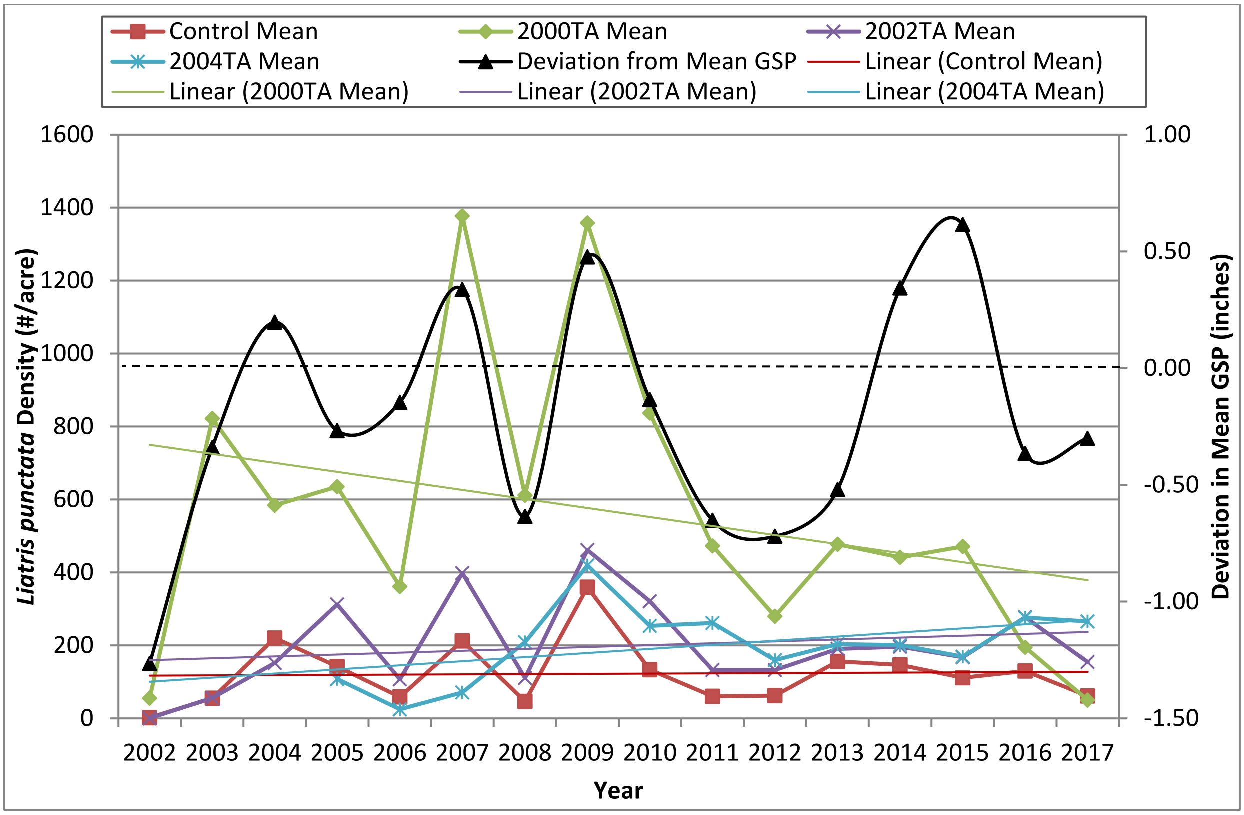


Figure 8. Dotted gayfeather flowering stem densities for all treatment areas and for all years monitored (see Table 6). The deviation from mean growing season precipitation in inches is included for comparison.

Table 5. Comparisons of Dotted Gayfeather (*Liatris punctata*) 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 *[p=0.10]***	**Mean # flowering gayfeather stems/acre**	**Homogeneous Groups[4] P=0.05 *[p=0.10]***
2002	14.5	A a	14.5	A a
2003	247.5	ABC abc	247.5	ABC abc
2004	277.3	ABC abc	277.3	ABC abc
2005[5]	350.6	ABC abc	302.0	ABC abc
2006	158.6	AB ab	131.8	AB a
2007	596.9	BC bc	491.6	BC cb
2008	219.7	ABC abc	217.5	ABC ab
2009	660.4	C c	611.9	C c
2010	402.8	ABC abc	373.0	ABC abc
2011	199.6	AB ab	211.9	AB ab
2012	151.8	AB ab	153.4	AB a
2013	253.6	ABC abc	243.6	ABC abc
2014	245.5	ABC abc	236.6	ABC abc
2015	229.5	ABC abc	217.5	ABC ab
2016	220.0	ABC abc	231.3	ABC ab
2018	99.4	A a	132.7	A a

1 Control Area, Year 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 Twelve 400m transects, each sampled 1 time.

3 Fifteen 400m transects, each sampled 1 time, for years 2005-2011; twelve 400m transects, each sampled 1 time, for years 2002-2004.

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 means for 2002-2006, 2008, and 2010-2018 are not significantly different from each other at P=0.05 **(A)** or at *p = 0.10* ***(a*)**, but the mean for 2002 **(A, *a*)** is significantly different from 2007 **(BC, *bc*)** and 2009 **(*C,c*** at both significance levels.

5 The means for 2005-2016 are reported in two ways. In the second and third columns, the data for the 2004 Treatment Area are excluded (this was done so that the means of all 14 years are based on the same number of transects [n=12]). In the fourth and fifth columns, the 2004 Treatment Area data (3 transects) are included in the 10-year comparisons. See text for discussion.

Table 6. Comparisons of Dotted Gayfeather (*Liatris punctata*) Densities by Year among Treatment Areas.

	Mean # flowering gayfeather stems/acre[1] P =0.05 [p=0.10[5]]															
AREA[2]	**Year 2002**	**Year 2003**	**Year 2004**	**Year 2005**	**Year 2006**	**Year 2007**	**Year 2008**	**Year 2009**	**Year 2010**	**Year 2011**	**Year 2012**	**Year 2013**	**Year 2014**	**Year 2015**	**Year 2016**	**Year 2017**
Control (n=9)[3]	2.0 A *[a]*	55.0 AB *[a]*	220.2 A *[a]*	142.0 A *[a]*	58.7 A *[a]*	212.8 A *[a]*	46.2 A *[a]*	359.5 A *[a]*	130.8 A *[a]*	60.7 A *[a]*	62.1 A [a]	156.5 A [a]	147.0 A [a]	111.6 A [a]	130.2 A [a]	61.5 A a
2000 Treatment (n=9)	55.0 A *[a]*	821.9 A *[b]*	584.8 A *[a]*	635.0 A *[a]*	361.5 A *[a]*	1377.3 B *[b]*	611.4 A *[a]*	1357.7 B *[b]*	837.4 A *[a]*	473.1 A *[a]*	280.2 A [a]	477.5 A [a]	441.1 A [a]	471.5 A [a]	194.6 A [a]	50.2 A a
2002 Treatment (n=18)	0.51 A *[a]*	56.5 B *[a]*	151.9 A *[a]*	312.5 A *[a]*	106.9 A *[a]*	398.3 A *[a]*	110.4 A *[a]*	461.5 A *[a]*	321.6 A *[a]*	132.2 A *[a]*	132.5 A [a]	190.2 A [a]	197.0 A [a]	167.4 A [a]	277.7 A [a]	154.8 A a
2004 Treatment[4] (n=9)	*	*	*	107.9 A *[a]*	25.0 A *[a]*	71.2 A *[a]*	209.1 A *[a]*	419.2 A *[a]*	253.6 A *[a]*	261.3 A *[a]*	159.5 A [a]	203.7 A [a]	201.0 A [a]	169.3 A [a]	276.1 A [a]	266.1 A a

[1] Compare the treatment areas for each year by reading the columns vertically.

[2] Control Area, Year 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.

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

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

[5] Tukey's Mean Comparison Test: means (number of *Liatris* flowering stems per acre) followed by the same letter are not significantly different at either probability level, P = 0.05 or *p=0.10* [*e.g.*: for Year 2009, the dotted gayfeather stem count means for the Control Area (**A,a**), 2002 Treatment Area (**A,a**),and 2004 Treatment Area (**A,a**) are not significantly different from each other, but all three are significantly different from the mean for the 2000 Treatment (**B,b) at both probability levels**].

The density of both the pooled skipper sample and PMS sample has generally tracked the dotted gayfeather flowering stem density (**Figure 9**). However, this was not true in 2014 and 2015, when dotted gayfeather and skipper counts declined during a period of increasing precipitation. Additionally, skipper densities did not track declining dotted gayfeather densities and below normal GSP in 2017 (**Figure 9**).

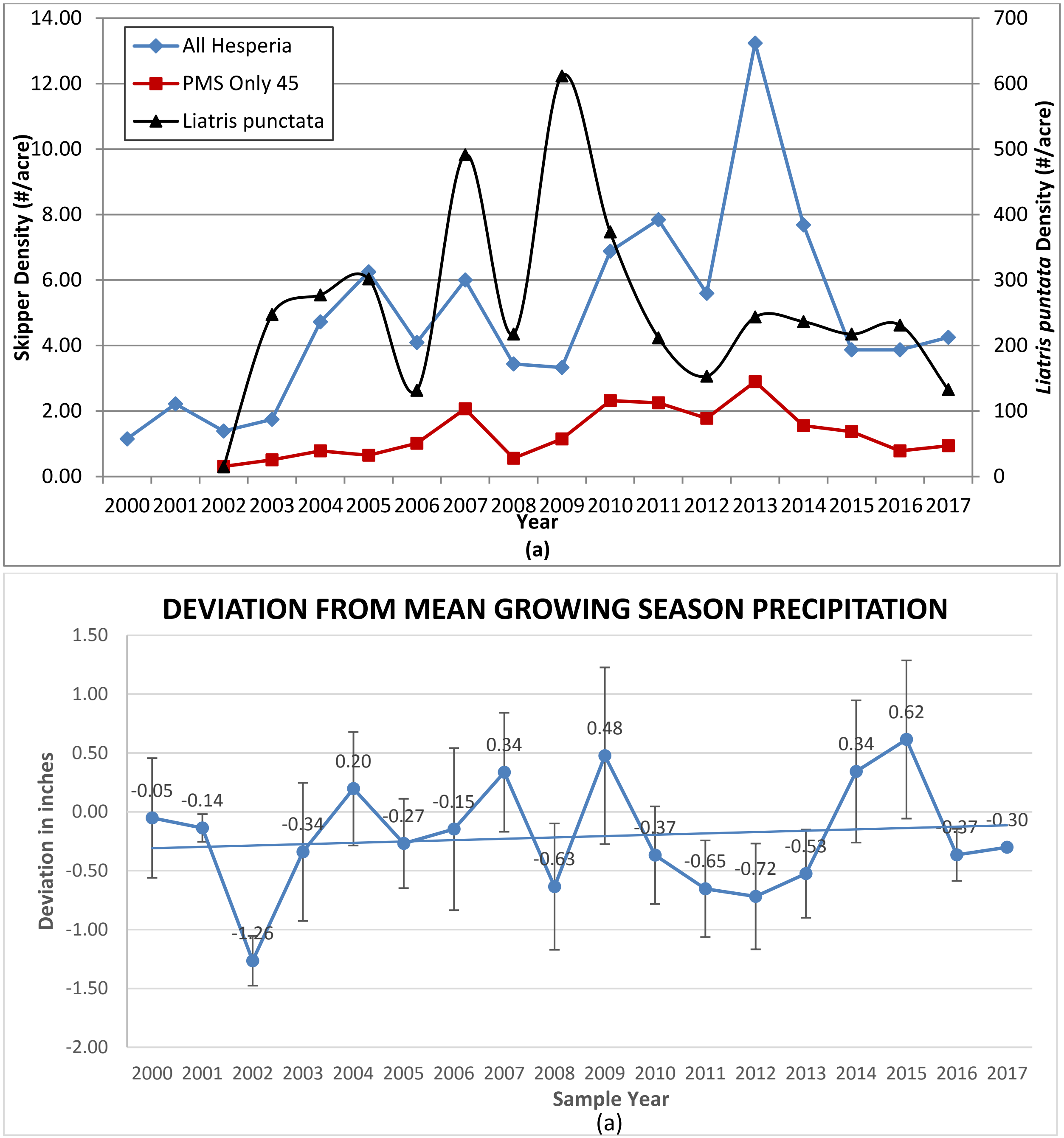


Figure 9. Comparison of (a) skipper densities with the flowering stem density of dotted gayfeather and (b) growing season precipitation (inches + 1 SE) for all treatments and for all years monitored.

For each year of this monitoring study, the number of flowering stems of dotted gayfeather have been counted on each transect. Originally, this was done without regard for the number of total plants present or the actual number of plants in flower. From 2009 to 2017 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 not available for that year. During each survey period for which plant data exists, 2009 to 2017, there were a high proportion of plants in bloom (**Figure 10**). This suggests that skipper counts were conducted at, or near, the peak of dotted gayfeather flowering.

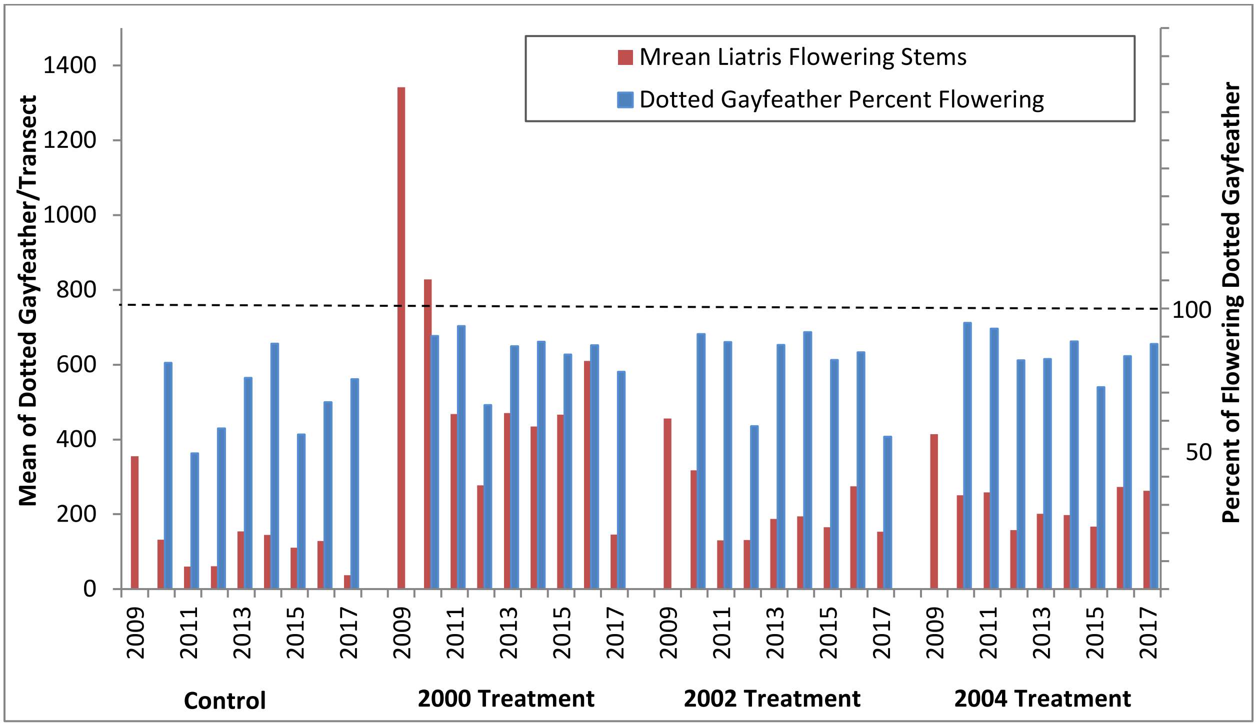


Figure 10. Count of flowering stems of dotted gayfeather (left bar in each couplet) with the percent of dotted gayfeather plants that were flowering from 2010 – 2016 for all treatments.

6.3 The Search for Predictive Correlations

This section of the report analyzes data fron the entire monitoring period to determine if there are correlations among skipper densities, dotted gayfeather densities, precipitation, and temperature. A visual comparison of growing season precipitation and dotted gayfeather flowering stem densities is given in **Figure 8**; a similar visual comparison between dotted gayfeather flowering stem densities and skipper densities is given in **Figure 9**. The results of correlation analysis (Pearson's product moment coefficient: ***r***) for these same comparisons are presented in **Tables 7-10**.

6.3.1 Correlations with Precipitation

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 (**Table 7**). Precipitation was measured in two ways: annual precipitation (AP) and growing season precipitation (GSP), the latter described as the precipitation occurring in the six-month period of March-August. The density of dotted gayfeather flowering stems was strongly correlated with GSP, with 38% of the variation in dotted gayfeather density attributable to variation in GSP ($p=0.03$) for the four treatment areas combined. When treatment areas were analyzed separately, r^2 (coefficient of determination) values were 0.49 (Control Area), 0.54 (2000 Treatment Area), and 0.56 (2002 Treatment Area), and all correlations were significant at $p\leq0.02$. Dotted gayfeather showed a weak, nonsignificant positive correlation with GSP on the 2004 Treatment Area ($p=0.5$; $r^2= 0.004$). Correlation with annual precipitation (AP) was not as strong, accounting for only 22% of dotted gayfeather variation over all treatments combined ($p=0.03$). Correlations were significant for the Control Area ($p=0.004$; $r^2=0.4$), 2000 Treatment Area ($p=0.06$; $r^2=0.17$), and 2002 Treatment Area ($p=0.05$, $r^2=0.17$). When looking at data from the 2004 Treatment Area individually, there is a weak, insignificant negative correlation between AP and dotted gayfeather density ($p=0.7$; $r^2=0.003$). Why increases in AP would cause declines in flowering dotted gayfeather at this treatment is unknown. Again, the combined dotted gayfeather sample (Control, 2000, 2002, and 2004 Treatment Areas combined) showed positive correlations with rainfall, both GSP and AP, and on three of the treatment areas these positive correlations were significant (**Table 7**).

The relationship between PMS densities and GSP showed both positive and negative correlations, but the correlations were much weaker than for dotted gayfeather and were insignificant for all treatments (**Table 7**). Only 1% of the variation in PMS density is attributable to variation in GSP ($p=0.35$) for the four treatment areas combined. The r^2 (coefficient of determination) values were 0.00002 ($p=0.49$, Control Area); 0.008 ($p=0.49$, 2000 Treatment Area); 0.004 ($p=0.41$, 2002 Treatment Area); and 0.006 ($p=0.39$, 2004 Treatment Area). Correlation with AP was also both positive and negative. Again, accounting for only 1% of PMS variation over all treatments combined ($p=0.35$).

Correlation of GSP to the pooled skipper sample was also weak, showing both positive and negative correlations, and accounting for only 0.2% of the variation in pooled skipper densities ($p=0.45$) for the four treatment areas combined. The pooled skipper sample showed a marginally significant negative correlation with GSP on the 2004 Treatment Area (*p=0.1,* r^2*=15*) (**Table 7**). Correlation with AP was also both positive and negative, but weak, accounting for only 1% of the pooled skipper variation over all treatments combined (*p=0.34*). None of the treatment areas, when analyzed separately, showed a significant correlation with AP (**Table 7**).

6.3.2 Correlations with Temperature

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. However, there is some evidence that PMS were positively affected by temperature. When treatment areas were analyzed separately, GST had a positive and significant correlation with PMS on the Control Area (*p=0.05,* r^2=0.17) (**Table 8**). There is also some evidence that high annual temperatures (AT) may be beneficial to skippers at the Control Area as PMS densities at this treatment showed positive, marginally significant correlation with AT (*p=0.08,* r^2*=14*) (**Table 8**).

6.3.3 Correlations between Dotted Gayfeather and Skippers

Data collection for both gayfeather flowering stems and skipper numbers allowed for a one-to-one analysis of density estimates between these two factors on all treatment areas and for the treatment areas combined. The 2017 analysis, showed a significant positive correlation between gayfeather flowering stem density and the density of the pooled skipper sample for the 2002 Treatment Area, where 20% of the variance in skipper numbers was explained by the flowering stems of dotted gayfeather (*p=0.05,* r^2=0.21) (**Table 9**). When PMS density was analyzed separately by treatment, significant correlations were detected on the 2000 Treatment Area (*p=0.01,* r^2=0.3) and 2002 Treatment Area (*p=0.04,* r^2=0.21), with 30% and 21% of the variance in skipper numbers explained by the variation in dotted gayfeather densities on the treatments , respectively (**Table 10**). Over time, these correlations have weakened considerably. In 2009, significant positive correlations between dotted gayfeather flowering stem density and the density of the pooled skipper sample for the treatment areas combined and for the 2002 Treatment Area were detected that explained 60% and 84% of the variance in skipper numbers, respectively (Drummond 2009). When PMS density was analyzed separately, significant correlations were detected on all treatment areas except for the Control Area and for all treatment areas combined that explained between 77% and 60% of the variance in skipper numbers (Drummond 2009).

Table 7. Correlation Matrix Comparing Densities of Dotted Gayfeather and *Hesperia* skippers to Precipitation Over Time (2002-2017).

***Pearson Correlation*[3]** *One-tailed test*[4] *For dotted gayfeather, pooled skipper, and Pawnee montane skipper comparisons.* N = 17, DF = 14 P = 0.05, CV = 0.549 P = 0.10, CV = 0.443		**Amount of precipitation in inches Cheesman Station, Colorado[2]**					
		AP Annual Precipitation (January-December)			**GSP Growing Season Precipitation (March-August)**		
		Dotted Gayfeather	Pooled *Hesperia* sample	Pawnee montane skipper	Dotted Gayfeather	Pooled *Hesperia* sample	Pawnee montane skipper
Flowering stems or skippers per acre	All Treatment Areas[1]	r = 0.47 r^2 = 0.22 p = 0.03	r = 0.11 NS p = 0.34	r = -0.11 NS p = 0.35	r = -0.62 r^2 = 0.38 p = 0.005	r = 0.04 NS p = 0.45	r = 0.1 NS p = 0.35
	Control Area	r = 0.63 r^2 = 0.40 p = 0.004	r = -0.13 NS p = 0.31	r = -0.03 NS p = 0.46	r = 0.70 r^2 = 0.49 p = 0.001	r = -0.02 NS p = 0.47	r = -0.004 NS p = 0.49
	2000 Treatment Area	r = 0.41 r^2= 0.17 p = 0.06	r = 0.05 NS p = 0.54	r = 0.14 NS p = 0.30	r = 0.54 r^2= 0.29 p = 0.02	r = 0.03 NS p = 0.46	r = 0.09 NS p = 0.37
	2002 Treatment Area	r = 0.41 r^2= 0.17 p = 0.05	r = 0.03 NS p = 0.43	r = 0.13 NS p = 0.31	r = 0.56 r^2= 0.31 p = 0.01	r = 0.06 NS p = 0.41	r = 0.06 NS p = 0.41
	2004 Treatment Area	r = -0.16 NS p = 0.7	r = -0.2 NA p = 0.26	r = -0.05 NS p = 0.43	r = 0.02 NS p = 0.48	r = -0.39 r^2= 0.15 p = 0.1	r = 0.08 NS p = 0.39

1 All Treatment Areas includes Control Area, Year 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. Years evaluated are 2002 to 2017 (N=16).

2 Cheesman, Douglas Co., CO: NWS, NCDC Station #052528. Lat =105^0 17' Long = 39^0 13' Elev. = 6880 ft.

3 Pearson's product moment coefficient: *r* values greater than the critical value (CV) indicate that a statistically significant correlation exists for sample size N (=years) with degrees of freedom DF with a confidence level of 95% (*p = 0.05*) or 90% (*p=0.10*). Highlighted cells indicate significant correlations. For example, for the 2002 Treatment Area, the Pearson correlation between Growing Season Precipitation (GSP) and density of dotted gayfeather sample is *r* = 0.56, indicating that a significant positive correlation (*p=0.01*) exists between GSP and the density of dotted gayfeather present for the years 2002-2017; the strength of the correlation means that 31% of the variability in skipper densities can be predicted by GSP.

4 A one-tailed test was used because the direction of the correlation (positive) was predicted in advance.

Table 8. Correlation Matrix Comparing Densities of Dotted Gayfeather and *Hesperia* skippers to Temperature Over Time (2002-2016).

***Pearson Correlation*[3]** *One-tailed test*[4] *For dotted gayfeather, pooled skipper, and Pawnee montane skipper comparisons.* N = 16, DF = 14 P = 0.05, CV = 0.549 P = 0.10, CV = 0.443		**Amount of temperature in degrees Fahrenheit Cheesman Station, Colorado[2]**					
		AT Annual Temperature (January-December)			**GST Growing Season Temperature (March-August)**		
		Dotted Gayfeather	Pooled *Hesperia* sample	Pawnee montane skipper	Dotted Gayfeather	Pooled *Hesperia* sample	Pawnee montane skipper
Flowering stems or skippers per acre	All Treatment Areas[1]	r = -0.05 NS p = 0.42	r = 0.01 NS p = 0.48	r = 0.1 NS p = 0.35	r = -0.09 NS p = 0.37	r = 0.03 NS p = 0.45	r = 0.27 r^2 = 10 p = 0.15
	Control Area	r = - 0.1 NS p = 0.35	r = 0.17 NS p = 0.27	r = 0.37 r^2 = 14 p = 0.08	r = -0.17 NS p = 0.26	r = -0.19 NS p = 0.24	r = 0.41 r^2 = 0.17 p = 0.05
	2000 Treatment Area	r = -0.17 NS p = 0.26	r = -0.14 NS p = 0.30	r = -0.17 NS p = 0.26	r = -0.07 NS p = 0.39	r = -0.1 NS p = 0.36	r = 0.19 NS p = 0.24
	2002 Treatment Area	r = 0.08 NS p = 0.38	r = -0.04 NS p = 0.44	r = -0.09 NS p = 0.37	r = -0.11 NS p = 0.34	r = - 0.05 NS p = 0.43	r = - 0.08 NS p = 0.39
	2004 Treatment Area	r = -0.12 NS p = 0.35	r = -0.48 r^2 = 0.23 p = 0.05	r = -0.07 NS p = 0.45	r = -0.24 NS p = 0.22	r = -0.35 NS p = 0.12	r = - 0.07 NS p = 0.41

1 All Treatment Areas" includes Control Area, Year 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. Years evaluated are 2002 to 2017 (N=16).

2 Cheesman, Douglas Co., CO: NWS, NCDC Station #052528. Lat =105^0 17' Long = 39^0 13' Elev. = 6880 ft.

3 Pearson's product moment coefficient: *r* values greater than the critical value (CV) indicate that a statistically significant correlation exists for sample size N (=years) with degrees of freedom DF with a confidence level of 95% (*p = 0.05*) or 90% (*p=0.10*). Highlighted cells indicate significant correlations. For example, for the Control Area, the Pearson correlation between Growing Season Temperature (GST) and density of Pawnee montane skipper sample is *r* = 0.41, indicating that a significant positive correlation (*p=0.05*) exists between GST and the density of all Pawnee montane skippers present for the years 2002-2017; the strength of the correlation means that 17% of the variability in skipper densities can be predicted by GST.

4 A one-tailed test was used because the direction of the correlation (positive) was predicted in advance.

Table 9. Correlation Matrix Comparing Densities of *Hesperia* skippers (pooled sample) to Densities of Dotted Gayfeather Over Time (2002-2016).

Pearson Correlation[2] *One-tailed test*[3] N = 16, DF = 14 p = 0.05, CV = 0.549 p = 0.10, CV = 0.443		**Pooled skipper sample Individuals per acre**				
		All Treatment Areas[1]	Control Area	2000 Treatment Area	2002 Treatment Area	2004 Treatment Area
Dotted gayfeather (*Liatris punctata*) flowering stems per acre	All Treatment Areas[1]	$r = 0.15$ NS $p = 0.29$				
	Control Area		$r = 0.04$ NS $p = 0.44$			
	2000 Treatment Area			$r = -0.14$ NS $p = 0.30$		
	2002 Treatment Area				$r = 0.45$ $r^2 = 0.2$ $p = 0.05$	
	2004 Treatment Area					$r = -0.11$ NS $p = 0.37$

1 All Treatment Areas” includes all four treatments: 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. Years evaluated are 2002 to 2017 (N=16).

2 Pearson's product moment coefficient: *r* values greater than the critical value (CV) indicate that a statistically significant correlation exists for sample size N (years) with degrees of freedom DF with a confidence level of 95% ($p = 0.05$) or 90% ($p=0.10$). The coefficient of determination (r^2) expresses the strength of the relationship by stating the portion of the variability in one variable that can be predicted using the relationship with the second variable. Highlighted cells indicate significant correlations. For example, for the 2002 Treatment Area, a significant positive correlation ($p=0.05$) exists between the density of flowering stems of gayfeather and the density of all *Hesperia* skippers present for the years 2002-2017; the strength of the correlation means that 20% of the variability in skipper densities can be predicted by knowing the density of flowering stems of *Liatris punctata*.

3 A one-tailed test was used because the direction of the correlation (positive) was predicted in advance.

Table 10. Correlation Matrix Comparing Densities of Pawnee montane skipper to Densities of Dotted Gayfeather Over Time (2002-2016).

Pearson Correlation[2] *One-tailed test*[3] N = 16, DF = 14 p = 0.05, CV = 0.549 p = 0.10, CV = 0.443		**Pawnee montane skipper sample Individuals per acre**				
		All Treatment Areas[1]	Control Area	2000 Treatment Area	2002 Treatment Area	2004 Treatment Area
Dotted gayfeather (*Liatris punctata*) flowering stems per acre	All Treatment Areas[1]	r = 0.28 NS p = 0.15				
	Control Area		r = 0.04 NS p = 0.44			
	2000 Treatment Area			$r = 0.54$ $r^2=0.3$ $p = 0.01$		
	2002 Treatment Area				$r = 0.46$ $r^2=0.21$ $p = 0.04$	
	2004 Treatment Area					r = 0.16 NS p = 0.31

1 All Treatment Areas" includes all four treatments: 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. Years evaluated are 2002 to 2017 (N=16).

2 Pearson's product moment coefficient: *r* values greater than the critical value (CV) indicate that a statistically significant correlation exists for sample size N (years) with degrees of freedom DF with a confidence level of 95% ($p = 0.05$) or 90% ($p=0.10$). The coefficient of determination (r^2) expresses the strength of the relationship by stating the portion of the variability in one variable that can be predicted using the relationship with the second variable. Highlighted cells indicate significant correlations. For example, for the 2002 Treatment Area, a significant positive correlation ($p=0.05$) exists between the density of flowering stems of gayfeather and the density of Pawnee montane skippers present for the years 2002-2017; the strength of the correlation means that 21% of the variability in skipper densities can be predicted by knowing the density of flowering stems of *Liatris punctata*.

3 A one-tailed test was used because the direction of the correlation (positive) was predicted in advance.

7.0 DISCUSSION

7.1 Observations

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 most striking pattern in skipper numbers noted over the last four sampling seasons (2014 to 2017) is the drop in skipper counts to relatively stable, but low values of density for both the pooled and PMS samples at all of the treatment areas compared to the peak densities reached at all treatments in 2013. Current densities are similar to those observed in the late 2000s, when skipper densities were trending up and appeared to have partially recovered from the severe drought and wildfires of the summer of 2002. At 0.9 PMS per acre, the current densities of PMS are less than 50% of those values calculated in 1986, when approximately 2 PMS per acre were counted within the South Platte River Valley. It will be important to see if densities of PMS return to values of 2 per acre or greater that were observed between 2010 and 2013, and more similar to the density estimated in 1986.

The second important pattern that has remained consistent over the course of monitoring is the significant correlation between both AP and GSP, and dotted gayfeather density. This is true for the dotted gayfeather sample as a whole and for all of the individual treatment areas except for the 2004 Treatment Area. The only time that the 2004 Treatment Area showed a significant positive correlation with precipitation was in 2009, and this was only with GSP. The 2004 Treatment Area received a unique thinning prescription that created a very open landscape, devoid of tree cover and, that on average, is probably hotter and drier than the other treatment areas. These drier conditions might have disrupted the relationship between precipitation, soil moisture content, and dotted gayfeather growth that affects gayfeather abundance on the other treatment areas.

A third important pattern, is that over the course of monitoring the 2000 Treatment Area and Control Area have consistently harbored the highest counts for both the pooled sample and the sample of PMS. Although this broke down somewhat in 2017, when counts at the 2000 Treatment Area were lower than on the 2002 Treatment Area. The 2017 counts notwithstanding, this suggests that these two treatment areas support the best habitat characteristics for *Hesperia* skippers within the study area. This includes a forest structure that creates a heterogeneous tree distribution with small openings, averaging 0.10 acre in size, and an average canopy cover of less than 35% in the overstory with an age class distribution including both smaller and larger trees (Sovell 2014).This type of forest structure appears to support a robust populations of both blue grama and dotted gayfeather, the larval host plant and primary nectar source, respectively, of the PMS.

A fourth consistent pattern is the statistically significant positive correlation between dotted gayfeather densities and PMS densities at the 2000 and 2002 Treatment Areas. This significant correlation has been noted in every annual analysis conducted since 2009. This year, 30% and 21%, respectively, of the variation in PMS density was explained by densities of dotted gayfeather. Although these correlations were significant in 2017, they have weakened considerably since 2009, when over 50% of the variation in PMS density at both treatment areas was explained by the density of dotted gayfeather (Drummond 2009).

Review of the current year's data and preceding year's data reveal the following major points:

- There was a continuation of the low skipper counts first observed since 2014 for both the pooled skipper sample and for the sample of PMS (**Figure 3**). 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 PMS (**Figure 3**).
- The density of both the pooled skipper sample and PMS sample has generally tracked the gayfeather flowering stem density, and 2017 was no different in this respect (**Figure 9**).
- 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, when thinning was completed in the 2000 Treatment Area (**Figures 4 and 5**).
- The sample means by treatment exhibit a multimodal distribution with skipper numbers usually increasing during wetter periods, when flowering dotted gayfeather densities are high, and decreasing during drier periods (**Figures 4 and 5**).
- The general trend has been for increasing numbers of PMS as shown by the trend lines for all treatment areas, but because of the decline in PMS on the 2000 Treatment Area in 2017, there is a slight declining trend on that treatment area (**Figure 5**).
- The 2000 Treatment Area and the Control Area have traditionally contained the highest densities of PMS (**Table 4, Figures 4 and 5**). However, the only statistically significant differences noted were among the Control Area and comparisons with both the 2004 Treatment Area (2012 – 2014) and the 2002 Treatment Area (2012) (**Table 4**).
- 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 (**Table 7**). The density of dotted gayfeather flowering stems was strongly correlated with GSP, with 62% of the variation in dotted gayfeather density attributable to variation in GSP ($p=0.005$) for the four treatment areas combined. Correlation with annual precipitation (AP) was not as strong, accounting for only 47% of dotted gayfeather variation over all treatments combined ($p=0.03$).
- The relationship between PMS densities and GSP showed both positive and negative correlations, but the correlations were much weaker than for dotted gayfeather and were insignificant for all treatments, accounting for only 1% of the variation in PMS densities (**Table 7**). In this system PMS densities are not correlated with GSP; rather GSP appears to positively affect dotted gayfeather density and dotted gayfeather is then positively affecting PMS densities without a correlation between GSP and PMS.

- Correlation of both GSP and AP to the pooled skipper sample was also weak, showing both positive and negative correlations, and accounting for only 0.16% and 1%, respectively, of the variation in skipper densities. Again, as with PMS, there is no evidence for a direct correlation between the pooled skipper sample and GSP in this system. The pooled skipper sample, however, showed a marginally significant negative correlation with both GSP on the 2004 Treatment Area (*p=0.1, r^2=15*) (**Table 7**).
- 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. However, PMS were positively affected by both AT and GST on the Control Area; *p=0.08, r^2*=0.14 and *p=0.05, r=0.17, respectively* (**Table 8**).
- The 2017 analyses, once again showed that densities on the 2002 Treatment Area of both the pooled and PMS samples were positively correlated with dotted gayfeather densities (pooled: *p=0.05, r^2*=0.20; PMS: *p=0.04, r^2*=0.21) (**Tables 9** and **10**). PMS densities were also positively correlated with dotted gayfeather on the 2000 Treatment Area (*p=0.01, r^2*=0.54). These correlations have weakened considerably since 2009 when values for the coefficient of correlation (r^2) were about 0.6 for these same comparisons (Drummond 2009).

7.2 Summary

Densities of the two sampled skipper populations, the pooled sample and sample of PMS, appear to have returned to levels below that recorded in 1986; after having experienced peak densities in 2013. What may have caused this sudden increase, and then rapid decline, in skipper densities is unknown. Environmental stochasticity, typically represented by weather patterns, is widely accepted as the main factor regulating temporal dynamics of insect populations. Patterns of increased precipitation from 2013 through 2015 did not correspond to high densities of dotted gayfeather at most of the treatments and skipper populations have likely suffered because of that.

Density dependent factors are not considered as important as environmental stochasticity in regulating the temporal dynamics of butterfly populations. However, in the light of several recent studies on butterflies that detected significant density-dependent effects (Schtickzelle and Baguette 2004, Schtickzelle et al. 2005; Baguette and Schtickzelle 2006; Pickens 2007), it would appear that density-dependent regulation may be more widespread in this group than previously thought, while the role of environmental stochasticity has probably been overestimated (Nowicki et al. 2009). Density dependent effects including predation, inter- and intraspecific competition, parasitism, and diseases cannot be discounted when attempting to explain the temporal dynamics observed in skipper populations on the study area. Of course, it is more likely that both density dependent and environmental factors, including patterns of weather, are acting jointly to regulate the temporal dynamics of the skipper populations (Benton et al. 2006).

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 larvae (Gilbert and Singer 1975). Weather can influence butterfly populations through effects on rates of predation, pathogens, weather induced mortality of both larvae and adults, and host plant quality. Climate can affect the rate of butterfly larval mortality, which increases during humid wet conditions due to infections by fungi and unseasonable cold and snow can increase larval and adult butterfly mortality (Ehrlich et al. 1972, Tesar and Scriber 2003 and Barve et al. 2012). Cold wet periods can simultaneously slow development of insects, lengthening their exposure time to predators and increasing their rates of predation by increasing the food requirements of warm-blooded predators (Brower and Calvert 1985 and Chatelain et al. 2013). Environmental stress including cold, heat, and drought can impact host plant quality, indirectly affecting the performance and fertility of herbivorous insects (Awmack and Leather 2002).

The overall trends that appear to be emerging from this long-term study are:

- PMS numbers have been consistently lower on the 2004 Treatment Area than on other study areas. Usually averaging near 0.5 per acre while other areas have consistently averaged over 1 PMS per acre. The low skipper counts on the 2004 Treatment Area is not due to differences in dotted gayfeather, which although averages much lower on the 2004 Treatment Area than on the 2000 Treatment Area, is similar to the averages observed on the Control and 2002 Treatment Area. It appears that the lack of trees and absence of at least some forest canopy structure across large portions of the tile treated 2004 Treatment Area makes it less suitable for *Hesperia* skippers, and particularly PMS during years when climatic conditions are near the 25-year norm.
- The recovery of dotted gayfeather following drought has been most pronounced in the experimentally thinned treatment areas. Since 2002, flowering gayfeather stem density has ranged from 55 to 1,358 stems/acre in the 2000 Treatment Area, from 0.5 to 462 stems/acre in the 2002 Treatment Area, and from 25 to 419 stems/acre in the 2004 Treatment Area. By contrast, the Control Area experienced densities ranging from just 2 to 360 stems/acre. The increase of dotted gayfeather on treated areas seems to be in response to thinning treatment.
- Skipper densities (both the PMS alone and the pooled species sample) are positively correlated with dotted gayfeather flowering stem densities, treatments that increase dotted gayfeather densities will also increase overall skipper densities, including PMS density. Indeed, PMS densities since 2002 have ranged from 0.9 to 3.48/acre in the 2000 Treatment Area, from 0.06 to 2.53/acre in the 2002 Treatment Area, but only from 0 to 1.3 in the 2004 Treatment Area. However, the untreated Control Area has also experienced dramatic increases in PMS density, increasing from 0.23 PMS/acre in 2002 to a peak of 5.4 PMS/acre in 2013. This increase has occurred even though dotted gayfeather densities have been consistently lower on the Control, than on the other three treated areas. The topographic complexity and the mostly eastern aspect of the Control Area compared to the west facing aspects of the treated areas might explain in part why it has consistently recorded high densities of PMS. The Control Area transects are mostly situated on warmer, east facing slopes that should have earlier snowmelt and warmer temperatures than the treated transects that are mostly on cooler, west facing slopes.

Larvae gain mass faster on warmer slopes and faster development shortens generation time, increasing larval survival and ultimately increasing butterfly population size (Murphy et al. 1990, Weiss et al. 1988).

- The 2000 Treatment Area and the Control Area continue to contain the highest densities of PMS. In most of the years sampled, the 2000 Treatment Area had the highest density of PMS and the Control Area consistently had the second highest density, until recently when the Control Area has had the greatest PMS densities (**Figure 5**). These treatments were followed by the 2002 Treatment Area, which never had the highest density of PMS in any year of the study, but which did have the second highest density in some of the sample years. This suggests that thinning prescriptions mimicking the forest cover characteristics of the 2000 Treatment Area and the Control Area should benefit PMS.
- The fact that dotted gayfeather densities have increased on treated areas and are now consistently greater on the three treatment areas compared to the Control Area suggests that forest thinning treatments have positively impacted flowering dotted gayfeather density (**Figure 8)**. Because skipper densities are positively correlated with dotted gayfeather stem densities (**Tables 9 and 10**), the relatively higher numbers of blooming dotted gayfeather stems present in treated areas (**Figure 8**) should make them attractive to skippers. Interestingly, even though dotted gayfeather density was lowest in the Control Area in 9 of the 16 years monitored (**Figure 8**), PMS density in recent years has been highest at control transects (**Figure 5**). This suggests that vegetative characteristics of the Control Area including dotted gayfeather density, upper forest canopy cover, and the percent cover of lower tree layers, coupled with an east facing aspect makes these transects highly suitable for skippers. During the drought of 2002, skipper numbers in the Control Area, parts of which also suffered low severity burn by the Hayman Fire, plummeted to one-sixth of their former values. This pattern also repeated itself during the drought of 2008, but it was not true for the drought of 2011-2012, when skipper densities actually increased on the Control Area. This suggests that skippers likely respond to numerous interacting factors and to changing environmental conditions among the treatments, in a complex and dynamic manner.

7.3 Management Implications

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 that have shaded out the herbaceous understory including the butterfly's 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 PMS 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. 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 these areas as a result of fire suppression have been overgrown 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 PMS.

The PMS, like many host specific butterflies (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 PMS conservation is to provide habitat conditions that maintain or add to the mosaic of blue grama and dotted gayfeather found in the study area. The following management considerations for the PMS draws upon the discussion found in Sovell (2014). Forest restoration prescriptions to improve habitat for the PMS 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 PMS and forest hydrologic function (Lowe 2005).

Local environments that produce conditions where these two plants coexist and persist are where PMS are most abundant and also where their populations will persist. Areas of suitable habitat for this butterfly occur in a patchy mosaic within unburned ponderosa pine forests of the South Platte River Valley. Populations of Pawnee montane skippers probably track the mosaic of blue grama and dotted gayfeather found on the landscape. Populations probably become locally extinct during years where conditions no longer support healthy populations of blue grama and dotted gayfeather. Areas are probably recolonized when conditions improve (Thomas 1994). For the Pawnee montane skipper the 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 management that supports viable metapopulations of PMS across the entire range of the subspecies. Focusing PMS management on this idea of an environmental mosaic makes enlarging and improving the quality of existing patches as important as the creation of new patches. 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.

Additional surveys in subsequent years will be required to evaluate the long-term effects of forest thinning treatments on skipper populations. It is expected that densities of both dotted gayfeather and PMS will generally continue to track changes in precipitation, although the trends are not in lockstep and the relationships are likely complicated by other factors. The PMS 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 2001, 2003, Sovell 2014). The spectacular drought and fires of 2002 caused a significant decline in PMS numbers. The rate of recovery of the PMS populations in the face of both severe habitat degradation (roughly 50 percent of the known skipper habitat has burned 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- to medium-severity forest burns and that increase the number of blooming *Liatris* 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 PMS 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 (**Figures 4 and 5**). This suggests that forest thinning prescriptions mimicking the vegetation characteristics of both the 2000 Treatment Area and Control Area will benefit PMS population viability.

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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 (PMS) (*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 2000, 2002, and 2004 Treatment Areas to a Control Area**.** The Control Area 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 (USFWS 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 (2002 Treatment), and at less distance apart (200-300 meters) in the smaller sampling areas (Control and 2000 Treatment). 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 (2004 Treatment) 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 as a whole. 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.**

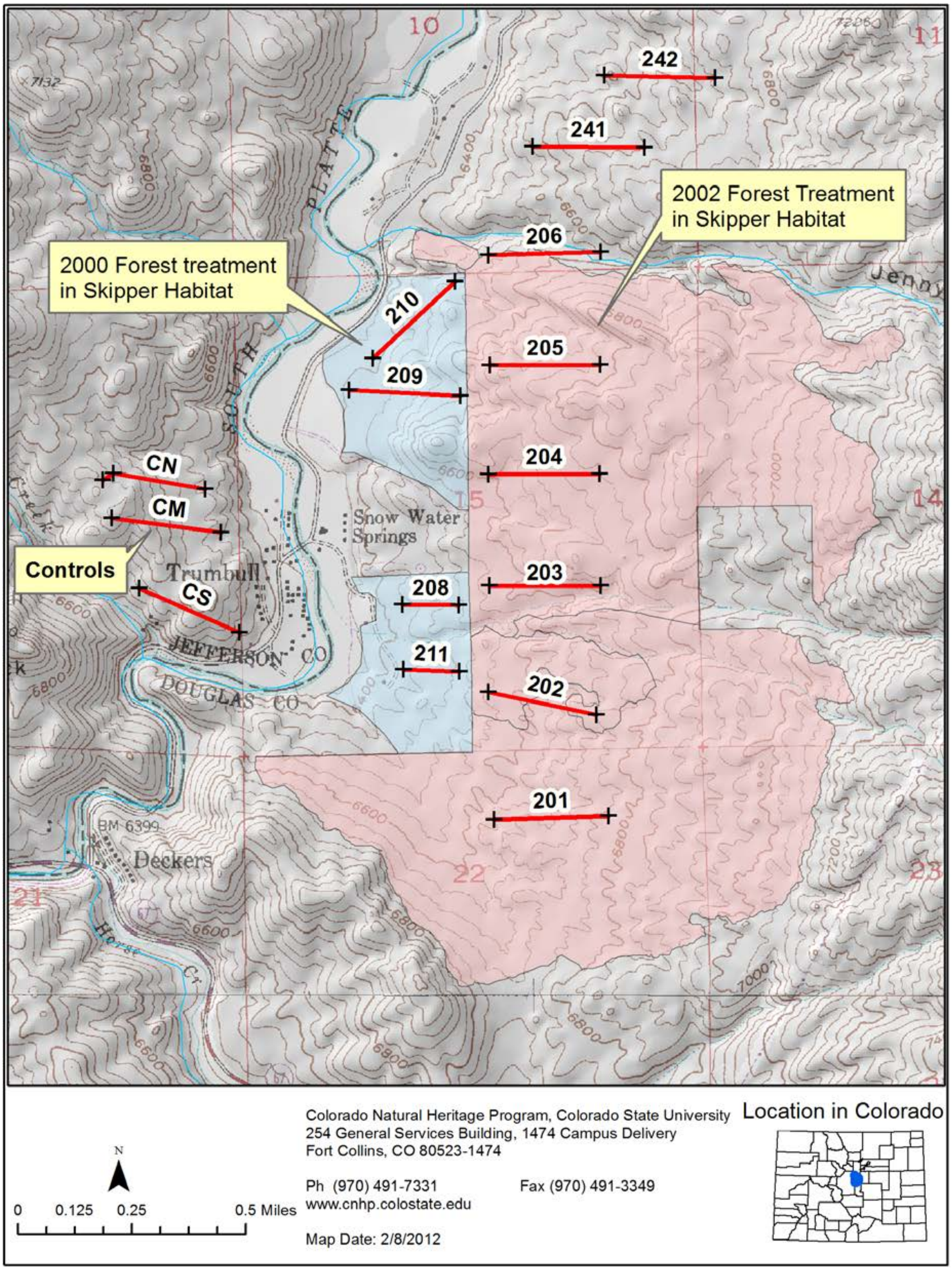

Figure A1. Pawnee montane skipper Monitoring Transects within Control, 2000 Forest Treatment and 2002 Treatment Areas in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado.

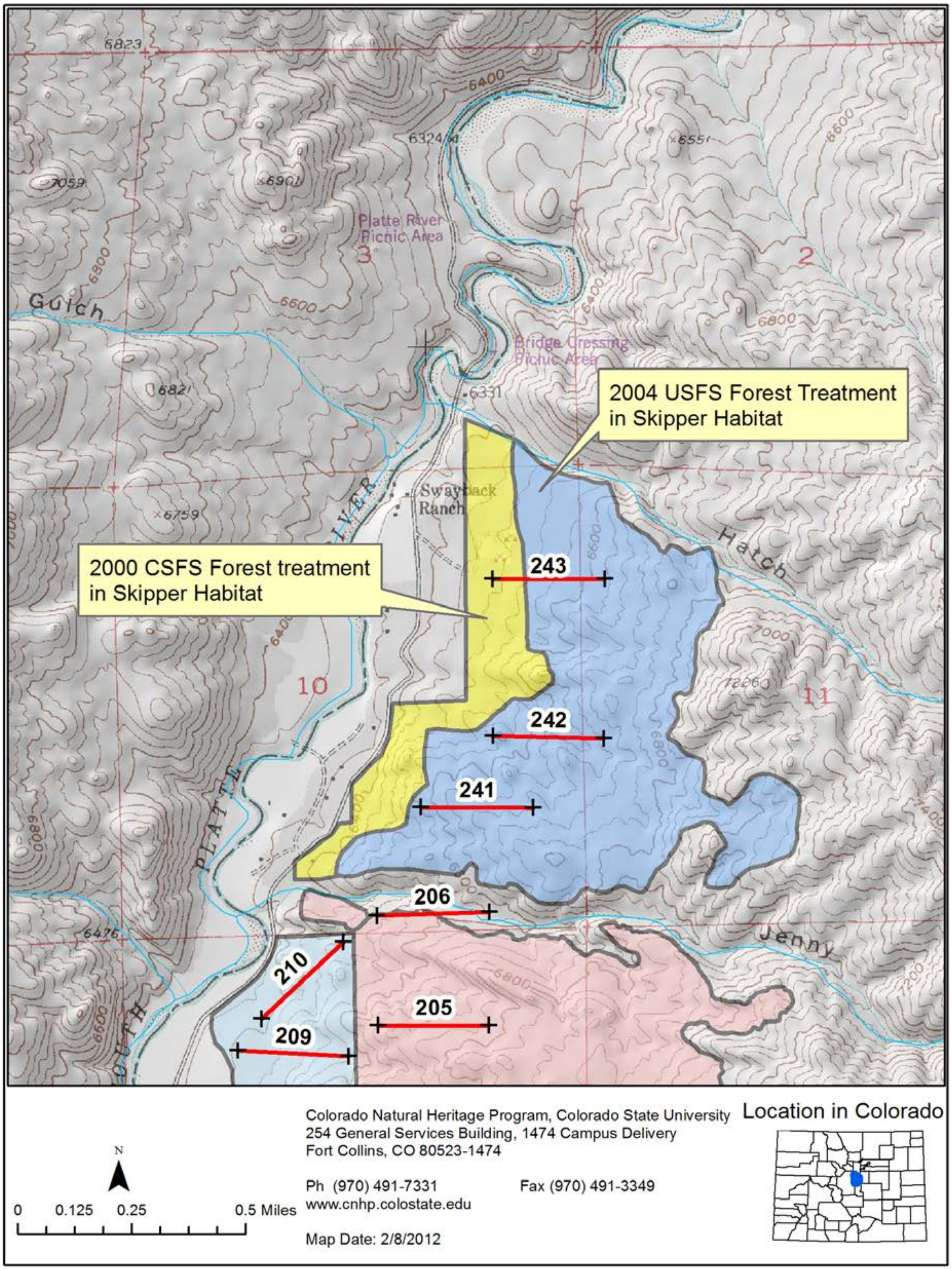

Figure A2. 2004 Treatment Area transects in the vicinity of Trumbull, Jefferson and Douglas Counties, Colorado.

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 PMS and the Western branded skipper (*H. comma)* 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 comma*), 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

**[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.

observed within a rectangle that 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 comma*, *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.

APPENDIX B

DIFFERENCES/SIMILARITIES AMONG SAMPLE YEARS 2000 TO 2013

- **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**. The majority 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. As a consequence, 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 (PMS) (*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 PMS 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 PMS 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. comma*) decreased in numbers and when the density of the primary adult food plant (gayfeather flowers) declined, suggests that the PMS 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 PMS 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 PMS 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 PMS 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 PMS 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.

- **Year 2008.** The density of gayfeather flowering stems increased in only the 2004 Treatment Area in 2008; it decreased dramatically by 2-4 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 2004 Treatment Area (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 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 eighth straight year, the 2000 Treatment Area 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 PMS 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 PMS 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 PMS 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.
- **Year 2009.** 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 2000 Treatment Area, 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 Control Area (108%) and the 2002 Treatment Area (15%). By contrast, the overall mean density of the PMS increased by 104% over 2008 (from 0.56 to 1.15/acre). This increase occurred in all but the 2004 Treatment Area, where the density of PMS remained virtually unchanged from 2008. For the ninth straight year, the 2000 Treatment Area retained its place as the forest treatment type where the majority of skippers were counted, with 38% more skippers than the next highest area (2002 Treatment Area). The high skipper count here matches the high *Liatris* flowering stem density found in the 2000 Treatment Area, illustrating the strong and significant correlation between *Liatris* flowering stem densities and skipper densities

Year 2010. 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, PMS increased as well, by 1.2 skippers/acre across all 15 transects, also an increase of just over 100%. The 2000 Treatment Area, at 8 *Hesperia* skippers/acre, had the highest number of skippers recorded at it followed by the Control Area where 7.3 *Hesperia* skippers/acre were recorded. For PMS the Control Area contained the most skippers, 4 PMS/acre contain followed by the 2000 Treatment Area where 2.6 PMS/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 skippers densities did not respond to this decline in gayfeather and instead numbers of both the pooled skipper sample and PMS 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 PMS. However, these associations are not statistically evident in the correlation analysis. The decrease in both PMS 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 PMS sample as precipitation rebounded slightly. This increase in numbers of the pooled skipper sample occurred at all treatment areas and for PMS, 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 PMS 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 PMS densities. The increase in both PMS 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 PMS 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 PMS, 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 PMS samples on the 2002 Treatment Area remain significantly correlated with dotted gayfeather flowering stem density