ESTANCIA BASIN WATERSHED HEALTH AND MONITORING PROJECT: 2012 ANNUAL REPORT

Prepared for

ESTANCIA BASIN WATERSHED HEALTH, RESTORATION AND MONITORING STEERING COMMITTEE

Composed of: Claunch-Pinto Soil and Water Conservation District, Edgewood Soil and Water Conservation District, East Torrance Soil and Water Conservation District, Estancia Basin Water Planning Committee, Chilili Land Grant, Manzano Land Grant, New Mexico State Forestry, New Mexico Environment Department, New Mexico Forest and Watershed Restoration Institute, New Mexico Department of Agriculture
(with funding through the New Mexico Water Trust Board)

CLAUNCH-PINTO SOIL AND WATER CONSERVATION DISTRICT
Fiscal Agent
P.O. Box 129
Mountainair, New Mexico 87036
Telephone: 505.847.2243

Prepared by

David Lightfoot, Ph.D.
Cody Stropki, Ph.D.
Victoria Amato M.S.
Chris Garrett, M.S.
Anne Russell, B.S.

SWCA® ENVIRONMENTAL CONSULTANTS
5647 Jefferson Street NE
Albuquerque, New Mexico 87109
Telephone: 505.254.1115; Facsimile: 505.254.1116
www.swca.com

January 2013

EXECUTIVE SUMMARY

The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee) oversees forest thinning projects and monitoring of forest and watershed health in the Estancia Basin in coordination with the New Mexico Forest and Watershed Restoration Institute. The primary goals of the Steering Committee are to improve forest health and create defensible space from wildfire. Funding for forest and watershed monitoring has been provided by the New Mexico Water Trust Board.

In 2007, SWCA Environmental Consultants (SWCA) was awarded a contract to conduct monitoring for forest thinning effectiveness on the eastern slopes of the Manzano Mountains. SWCA finalized a comprehensive monitoring plan in March 2008—which is available online at the New Mexico Forest and Watershed Restoration Institute's website (http://www.nmfwri.org/images/stories/pdfs/Estancia_Basin_Monitoring/EstanciaBasinMonitoring.pdf)—that provides background information, research questions, and a discussion of methods relative to forest thinning and monitoring. The monitoring plan calls for two years of pre-thinning data to provide background information on all study sites prior to implementing thinning treatments and monitoring treatment effectiveness. Results from the 2008, 2009, 2010, and 2011 monitoring seasons are presented in the 2008, 2009, 2010, and 2011 annual reports, which can also be found on the New Mexico Forest and Watershed Restoration Institute's website. The principal goals of forest and watershed monitoring are to determine the effectiveness of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife. SWCA is responsible for planning and implementing forest thinning monitoring in order to evaluate these resources. SWCA has also assumed responsibility for the South Mountain Weather Station that was previously installed by another contractor in 2006. After monitoring began, three major wildfires (Ojo Peak, Trigo, and Big Spring) occurred in the monitoring area in late 2007 and early 2008. The Trigo fire destroyed one of the forest thinning monitoring sites, which was replaced during summer 2008. SWCA has additionally initiated a monitoring study of post-Trigo fire recovery on private forest lands.

This 2012 Annual Report provides information on the results of forest thinning and post-wildfire monitoring during the calendar year 2012. Summaries of weather data from the South Mountain Weather Station, which serve as a baseline for monitoring area climate data, are also provided. Initial 2008, 2009, and 2010 baseline pre-treatment monitoring data from permanent monitoring study sites provide information on rainfall, ambient and soil temperatures, soil moisture, soil surface profiles to assess erosion over time, soil surface stability, soil chemistry, bird and small mammal composition and relative abundance, and vegetation composition, structure, and cover. 2011 and 2012 monitoring data represent information on the above parameters along with data on medium to large sized wildlife and livestock for the first two years following thinning treatments. The monitoring sampling design employs paired monitoring plots at two piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodland sites and two ponderosa pine (*Pinus ponderosa*) sites. One plot of each pair was randomly selected and treated by thinning tree stands in late 2010/early 2011. Those thinning treatments were completed in early 2011, and SWCA will continue to monitor the above mentioned parameters through at least June 2013 to examine the impacts and effectiveness of forest thinning treatments. Not only are paired study plots being compared to each other in a treatment/control design, but each treated plot will be monitored over time in order to assess change resulting from thinning treatments.

Results from the second year of post-treatment monitoring data revealed similar differences in parameter values between treatment and control plots that occurred last year, but not prior to thinning treatments.

- Tree and woody vegetation structure was greatly changed from the thinning treatments, resulting in more open forest stands on the treated watersheds.
- Tree basal areas were reduced on the treatment plots according to New Mexico State Forestry guidelines: Chilili pre-treatment basal area was 210 square feet/acre and was reduced to 80 square feet/acre, Wester basal area was 220 square feet/acre pre-treatment and 99 square feet/acre post-treatment, Kelly was 155 square feet/acre pre-treatment and 47 square feet/acre post-treatment, and Vigil was 124 square feet/acre pre-treatment and 39 square feet/acre post-treatment.
- Tree diameter size class measurements of all treatment and control plots showed that control plots had on average a larger number of trees in the smaller diameter classes when compared to treatment plots where trees were more evenly distributed between diameter size classes.
- During the 2012 monitoring period, relatively few rainfall events generated surface runoff events basin wide. In fact flows only occurred at the Vigil watersheds where the treated watersheds had higher peak flows and runoff ratios when compared to the controls. Future monitoring of flow events will reveal if this increased runoff on thinned sites persists and for how long.
- Soil moisture was found to be higher on treated plots than control plots, especially during dry periods following rainfall events.
- Herbaceous vegetation canopy cover was higher on piñon/juniper treated plots compared to the control plots, but not treated plots at ponderosa pine sites. Herbaceous vegetation cover was probably even higher than measured on treated plots, because domestic livestock heavily grazed the treated plots prior to vegetation measurements.
- Bird densities and species richness were found to be higher on treated plots than control plots, especially at piñon/juniper sites, however the species composition of bird communities was more similar among pairs of control and treatment plots at each site and forest type than between control and treatment plots within sites and forest types.
- Rodent densities declined on treated plots at ponderosa pine sites (deer mice), but not piñon/juniper sites (piñon mice).
- Large and medium-sized native wildlife species were found to be more frequent on control plots than treated plots at piñon/juniper sites, and domestic livestock were found to be more frequent on treated plots at all sites.
- Other parameters such as soil chemistry, soil surface erosion and surface stability, and bird communities have not yet shown differences between treatment and control plots.

Given again that 2012, like 2011, was an extreme drought year in the region, some parameter responses may still have been dampened by a lack of rainfall.

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1.0 INTRODUCTION

This 2012 Annual Report provides summaries of monitoring data collected during the 2012 calendar year for the Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee). Details about research questions and the background and administration of this monitoring project may be found in the "Estancia Basin Watershed Health and Monitoring Project: Monitoring Plan Evaluation" (2008 Monitoring Plan) (SWCA Environmental Consultants [SWCA] 2008), which is available at the New Mexico Forest and Watershed Restoration Institute (Restoration Institute) website (http://www.nmfwri.org). The 2008 Monitoring Plan provides detailed information on the background knowledge of forest thinning in the Southwest and presents the goals and methodologies for the Estancia Basin forest thinning monitoring project. The 2008 Annual Report (SWCA 2009) also provides important background information for the Trigo wildfire monitoring project that was initiated in 2008. Previous years' annual reports for 2008, 2009, 2010, and 2011 summarize overall monitoring findings from those four years, and they also may be found at the Restoration Institute website.

The Steering Committee oversees forest thinning and effectiveness monitoring of forest thinning on ponderosa pine (*Pinus ponderosa*) forests and piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodlands on private and state lands on the eastern slopes of the Manzano Mountains, New Mexico. Principal members of the Steering Committee include the Claunch-Pinto, East Torrance, and Edgewood soil and water conservation districts; New Mexico State Forestry; and the Restoration Institute. The Restoration Institute is additionally providing oversight and public relations for forest thinning and monitoring activities.

The principal goals of the Steering Committee are to create defensible space around homes and other structures from wildfire and to improve overall forest health, following forest thinning prescriptions determined by New Mexico State Forestry. The primary goals of forest thinning monitoring are to determine the impacts of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife.

The scope of work for this monitoring project was described in the Steering Committee's 2007 request for proposals as follows:

1. Plan and implement methods to determine how vegetation thinning and removal affect water yield.
2. Plan and implement methods of establishing reliable and repeatable vegetation monitoring methods to allow for both qualitative interpretation and quantitative documentation of change in vegetative structure and composition over time.
3. Plan and implement methods of monitoring small mammal and avian populations, which are indicators of ecosystem health.

SWCA is currently under contract for five years of monitoring, beginning in 2008, and is responsible for study site maintenance, data collection, data management, data analysis and interpretation, and information dissemination (including monthly meetings, monthly reports, and annual reports). The current Steering Committee plan calls for three years of baseline pre-thinning treatment monitoring (2008–2010), thinning treatments implemented during the winter of 2010 and 2011, and two years of post-treatment monitoring (2011–2012).

Several new subprojects were added to the overall monitoring project in 2008, including post-fire monitoring of soils, hydrology, vegetation, and wildlife on private forest lands following the Trigo wildfire. These tasks involve developing and implementing ephemeral stream and groundwater monitoring to assess the effects of both forest thinning and the Trigo fire on water resources, as well as assuming the operation and reporting for the South Mountain Weather Station (SMWS), initiated by EnviroLogic in 2006. A map of all study sites for these projects is presented in Figure 1.1 (note that the SMWS is located north of Edgewood, New Mexico, and is not on the map presented in Figure 1.1, but is on the map presented as Figure 4.1 in Chapter 4.

This 2012 Annual Report is similar in format to the previous 2008, 2009, 2010, and 2011 annual reports, and it provides complete data files (appended on DVD) and summaries of findings from field monitoring measurements conducted during the calendar year 2012 for the primary subprojects: 1) forest thinning monitoring of weather, soils, hydrology, vegetation, and wildlife; 2) overall Manzano watershed ephemeral stream and groundwater monitoring, associated with both forest thinning and post-wildfire monitoring; and 3) SMWS weather and soil moisture data, including addenda representing the four quarterly 2012 reports. Data collected in 2008, 2009, and 2010 represent baseline conditions prior to forest thinning treatments, which were begun in late 2010 and were completed by May 2011. Data collected after thinning in 2011 will then provide measures of thinning treatment effectiveness and a comparison of post-treatment environmental conditions. Monitoring data from subsequent years will provide data on thinning treatment effects over time.

This report provides analyses of parameter changes over the five years of monitoring and comparisons of paired treatment and control plots to evaluate treatment effects. Some statistical tests of parameter values between paired study plots are also provided to compare pre-thinning treatment baseline conditions to post-treatment conditions in order to determine if the paired plots differ in parameter values resulting from imposed thinning treatments. Additionally, post-Trigo fire monitoring data collected in 2008, 2009, 2010, and 2011 provide information on the recovery of soils and vegetation following the fire. In late 2011, Trigo fire monitoring was suspended due to safety issues regarding falling dead trees. Post-Trigo fire monitoring may resume at some future date.

Numerous discrete datasets have been collected, and SWCA has been active in creating data collection, storage, and management plans for each of the subprojects. SWCA has created metadata for each of these datasets that outline the date range of each dataset, the collection methods, the unit measurements, and the abbreviations and codes used within each data file. The metadata files will also state any caveats or general comments to which the viewer should be aware before analyzing the data.

SWCA is making these data available in a form that can be easily disseminated, using readily available software packages such as Microsoft Word and Excel. Some information, such as those data collected from the WatchDog Mini Weather Stations, is collected using proprietary software. These data are converted into Microsoft Excel files so they can be viewed by the general public. SWCA also intends to make the data available in forms that are easy to analyze. Some data, such as those related to the flumes, which are recorded in five-minute intervals, must be partitioned into several files, as the data exceeds Microsoft Excel's capacity of data rows. All of these data are being made available to the Restoration Institute for dissemination on its website. Note that measurements from various aspects of monitoring are reported in English units (e.g., feet, acres), while others are reported in metric units (meters, hectares). The protocols for monitoring measurements were obtained from different sources that use different units of measure. The U.S. Department of Agriculture (USDA) Agricultural Research Service Rangeland Monitoring Manual (Herrick et al. 2005) uses metric units, while the U.S. Forest Service (USFS) Forest Inventory and Analysis Guide (USFS 2005) uses English units. In general, scientific research worldwide has adopted the metric system as the standard for measurements, while some federal and state agencies use English units of measure. For ease of comparison, values are presented in this report with both English and metric units, except where not feasible.

This 2012 Annual Report provides summaries of findings from field monitoring measurements conducted during the calendar year 2012 and compares them with previous years for the above mentioned projects and subprojects. This report is partitioned into different sections for each subproject: 1) Introduction (this section), 2) forest thinning monitoring, 3) ephemeral stream and groundwater monitoring, 4) SMWS data, and 5) planned monitoring for 2013 (year six).

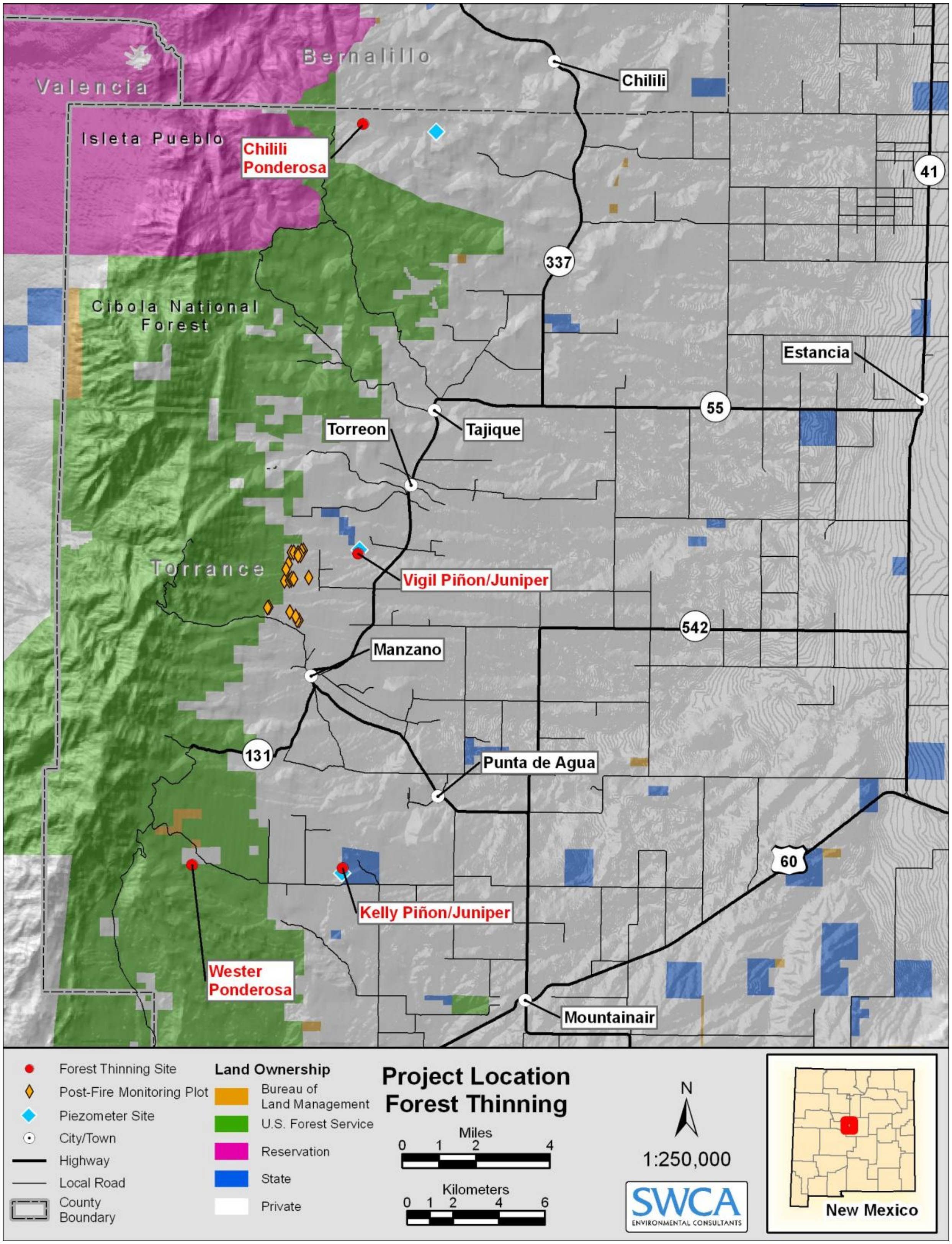


Figure 1.1. Map of all Estancia Basin forest and watershed monitoring locations addressed in this report.

2.0 FOREST THINNING MONITORING

Details of forest thinning monitoring protocols are provided in the 2008 Monitoring Plan (SWCA 2008). Background information on the known environmental effects of forest thinning on southwestern forest ecosystems is also presented in the 2008 Monitoring Plan, along with detailed discussions of the experimental study design and methods used in this research to measure various environmental responses to forest thinning treatments.

Forest thinning projects on private lands on the eastern slopes of the Manzano Mountains are overseen by the Steering Committee and include projects in both ponderosa pine forests and piñon/juniper woodlands. Forest thinning monitoring has been designed to address forest thinning in both of these forest types, so four monitoring study sites have been established: two in ponderosa pine forests and two in piñon/juniper woodlands. Each ponderosa pine site has been paired with a piñon/juniper site in the same watershed, so that each of two watersheds has a ponderosa pine and a piñon/juniper monitoring site. One pair of sites is situated at the northern end of the study area (eastern slopes of the Manzano Mountains), and the other at the southern end (see Figure 1.1). Two paired study plots have been installed at each of the four study sites. Descriptions of physical site characteristics such as slope, aspect, parent materials, plant associations, and habitat types are provided in the 2008 Monitoring Plan (SWCA 2008). Surface elevations of the flumes on the thinning plots can be seen in the Table 2.1 below. All study sites chosen are representative of the surrounding area; for example, all sites, excluding the Wester property, undergo a livestock grazing regime, which is typical of the private land use in the Manzano Mountains. One plot of each pair was randomly selected for forest thinning treatments, and the other plot of the pair will serve as an untreated control. Parameters being measured for monitoring at each of the eight study plots include rainfall, ambient temperature, soil moisture and temperature, soil chemistry, soil movement, soil surface stability, soil surface hydrology runoff, vegetation canopy cover and species composition, vegetation vertical structure, tree stand structure, density, composition and health, and bird and small mammal species composition and abundance.

Table 2.1. Surface Elevations of the Flumes on the Forest Thinning Plots

Site	Elevation (m)	Elevation (feet)
Chilili (treatment)	2,288	7,507
Chilili (control)	2,292	7,520
Wester (treatment)	2,267	7,436
Wester (control)	2,275	7,466
Kelly (treatment)	2,114	6,937
Kelly (control)	2,111	6,925
Vigil (treatment)	2,068	6,783
Vigil (control)	2,073	6,802

Actual forest thinning treatments were implemented in November 2010 and were completed by May 2011. This 2012 report presents the second year of post-thinning treatment data and comparisons of paired study plots. From 2011 on, the various environmental parameters being measured will be compared between the treatment and control study plots, and each study plot will be compared to itself over time.

2.1 FOREST THINNING TREATMENTS

One study plot of each forest thinning monitoring pair (plots 1 and 2) was randomly selected to be treated with the standard New Mexico State Forestry prescribed thinning treatment (piñon/juniper or ponderosa pine prescriptions) in late 2010 and early 2011 with the other plot being left as a control (plots T and C, respectively). The minimum area and boundaries for thinning treatments were determined for each of those four plots and mapped with a sub-meter accuracy global positioning system (GPS) unit in October and November 2009. Those GPS coordinates were used to produce geographic information system (GIS) maps of the treatment areas and boundaries for each of the four treatment study plots (maps of the thinning areas are presented in the 2009 Annual Report [SWCA 2010]). The thinning treatment areas for each of those plots included the entire subwatershed that was previously defined and mapped in 2007, the vegetation/soils measurement plot, and the mammal and bird sampling plot, all within the area of each treatment plot to be thinned. A minimum treatment buffer area of 10 m (33 feet) was extended from the boundaries of each subwatershed and study plot to ensure that all areas from which soil, hydrology, vegetation, and animal measurements are being collected were thinned on those treatment plots. Table 2.2 shows which plots were treated by tree thinning and which ones remained undisturbed as controls.

Table 2.2. Treated and Control Plots across the Four Monitoring Study Sites

Site	Treated Plot	Control Plot
Chilili	Plot 1	Plot 2
Kelly	Plot 2	Plot 1
Vigil	Plot 1	Plot 2
Wester	Plot 1	Plot 2

Note that results presented above refer to plot number, and all treated plots were plot number 1 except at the Kelly site where the treated plot was number 2.

Tree thinning treatments were conducted as planned and were inspected by New Mexico State Forestry to ensure that all protocols were followed and that the thinning was conducted to the agency’s standards developed for the region for both ponderosa pine and piñon/juniper woodland. In addition to reducing the density of trees on treatment monitoring plots, the thinning process also required that small branches from cut trees be chipped on-site and spread on the ground surface. Large-diameter wood was removed from the sites for firewood. Figure 2.1 through Figure 2.4 show views of both the non-treated control plots and adjacent treatment plots where trees were thinned from each of the four monitoring sites. Plots were photographed in late fall 2010 and early spring 2011, following tree thinning treatments. Note the open structure of the trees stands and wood chips spread over the ground surfaces of the thinned plots.

a. Non-thinned control plot (plot C).

b. Thinned treatment plot (plot T).

Figure 2.1. Kelly piñon/juniper site thinning treatment plot after excess trees have been removed in late 2010.

a. Non-thinned control plot (plot C).

b. Thinned treatment plot (plot T).

Figure 2.2. The Vigil piñon/juniper site following tree thinning treatments in late 2010. Note the open stand and wood chips. Stacked wood was removed shortly after the photograph was taken.

a. Non-thinned control plot (plot C).

b. Thinned treatment plot (plot T).

Figure 2.3. **The Chilili ponderosa pine site following tree thinning.**

a. Non-thinned control plot (plot C).

b. Thinned treatment plot (plot T).

Figure 2.4. The Wester ponderosa pine site in early spring 2011 following tree thinning. The stacked wood was removed in early summer.

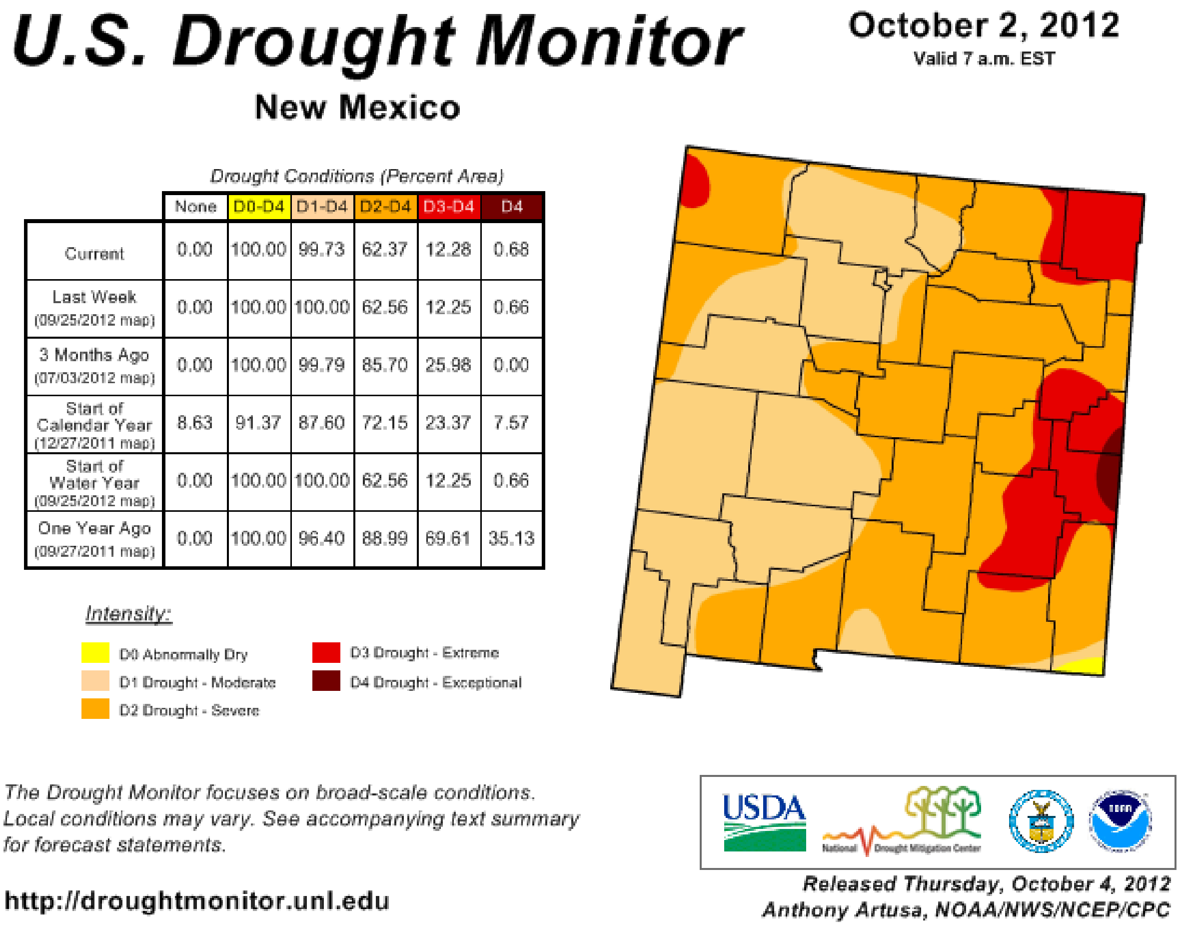
2.2 RAINFALL AND TEMPERATURES

Spectrum WatchDog automated data-logging rain gauges installed at each of the paired vegetation and soils monitoring plots at all of the study sites (see Figure 1.1) have run continuously since they were installed in November 2007 (Figure 2.5). The WatchDog stations are located in openings in the tree canopy in order to reduce effects of interception. Additional details regarding the setup of the weather stations are provided in the 2008 Monitoring Plan (SWCA 2008). The tipping bucket rain gauges on the WatchDog stations are set to record rainfall and snowmelt sums at one-hour intervals continuously. In fall 2008, a graduated cylinder rain gauge was added to each of the automated rain gauge locations to serve as backups in case of power failure or other malfunction of the data logger (Figure 2.6). These graduated rain gauges and their recorded values are checked monthly when Time Domain Reflectometer (TDR) soil moisture and temperature readings are taken; mineral oil is also added to these gauges at this time to prevent evaporation of water collected. The WatchDog stations are set to record ambient temperature, soil moisture 10 cm (4 inches) below the soil surface (-10 cm), and soil temperature -10 cm, all at one-hour increments. Soil moisture and temperature data from each WatchDog station provides baseline comparisons for the Field Scout TDR 200 soil water content and soil temperature data that are sampled monthly at each study plot. All data from the stations are off-loaded approximately every three months and entered into a database. Summaries for precipitation, ambient temperature, soil moisture, and soil temperature from 2012 on all thinning plots are presented as examples below. Also presented below are long-term graphs of each of these variables (2009–2012) showing any trends that may be occurring climatically within the region.

During the 2012 monitoring period the drought that was present in 2011 was still persisting throughout the state of New Mexico, particularly over the project area (Figure 2.7). The project area fell within the category of exceptional drought in 2011, which means there are exceptional and widespread crop/pasture losses, and shortages of water in reservoirs, streams, and wells, creating water emergencies, while in 2012 the drought was categorized as severe. A severe drought can cause water shortages resulting in a loss in crops and pasture lands.

Figure 2.5. WatchDog mini weather station at the Wester ponderosa pine site.

Figure 2.6. Graduated rain gauges are used for backup in the case of failure from one of the WatchDog weather stations.



U.S. Drought Monitor

New Mexico

October 2, 2012
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	99.73	62.37	12.28	0.68
Last Week (09/25/2012 map)	0.00	100.00	100.00	62.56	12.25	0.66
3 Months Ago (07/03/2012 map)	0.00	100.00	99.79	85.70	25.98	0.00
Start of Calendar Year (12/27/2011 map)	8.63	91.37	87.60	72.15	23.37	7.57
Start of Water Year (09/25/2012 map)	0.00	100.00	100.00	62.56	12.25	0.66
One Year Ago (09/27/2011 map)	0.00	100.00	96.40	88.99	69.61	35.13

Intensity:

🟨 D0 Abnormally Dry	🟥 D3 Drought - Extreme
🟧 D1 Drought - Moderate	🟫 D4 Drought - Exceptional
🟧 D2 Drought - Severe	

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu

Released Thursday, October 4, 2012
Anthony Artusa, NOAA/NWS/NCEP/CPC

Figure 2.7. Drought monitor map of New Mexico from the week of October 2, 2012, showing the project area located within Torrance County experiencing a severe drought (U.S. Drought Monitor 2012).

2.2.1 PRECIPITATION

Hourly precipitation totals have been summed to monthly totals and show similar monthly precipitation totals between the paired study plots at the Kelly piñon/juniper study sites (Figure 2.8). This graph show similar monthly precipitation values between the paired study plots, as was typical at all of the study sites. Annual precipitation values for 2009–2012 averaged for the ponderosa and piñon/juniper sites are shown below in Figure 2.9. This figure clearly shows the variability in precipitation values throughout the study period with the last two years being well below the long-term average of 14.4 inches (Western Regional Climate Center 2013). The total precipitation received in 2012 was 11.5 inches at the piñon/juniper sites and 6.8 inches at the ponderosa sites, which typically receive more precipitation because of the increased elevation. This long-term average is from a weather station in Mountainair that has a period of record beginning May 1, 1902 (Western Regional Climate Center 2013).

All tipping bucket rain gages were functioning properly during the 2012 monitoring season.

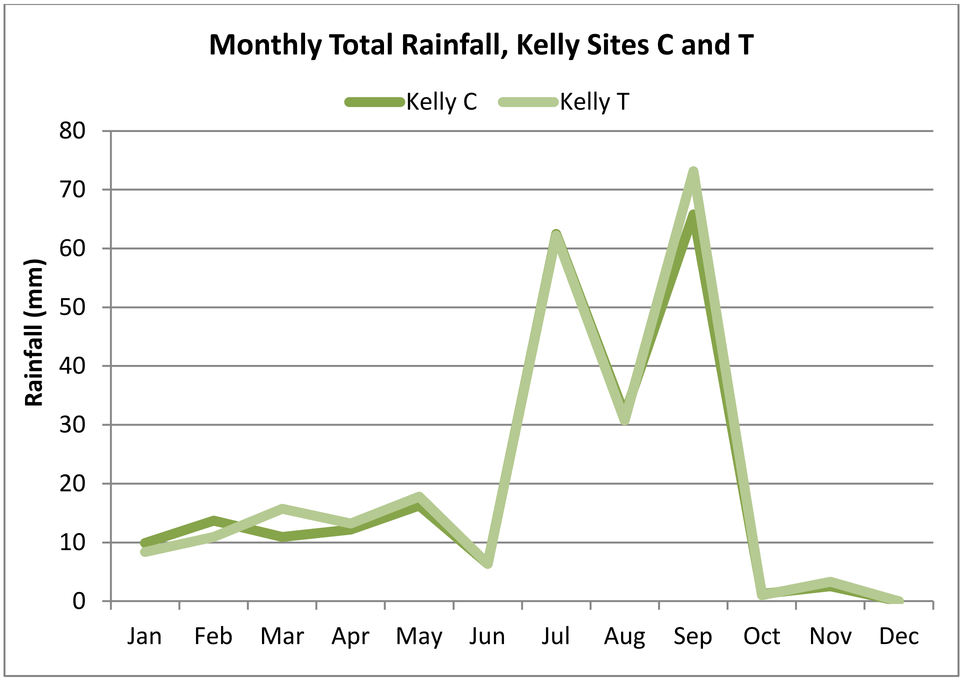


Figure 2.8. **Monthly cumulative precipitation (rainfall and snow) from the two paired Kelly piñon/juniper study plots in 2012.**

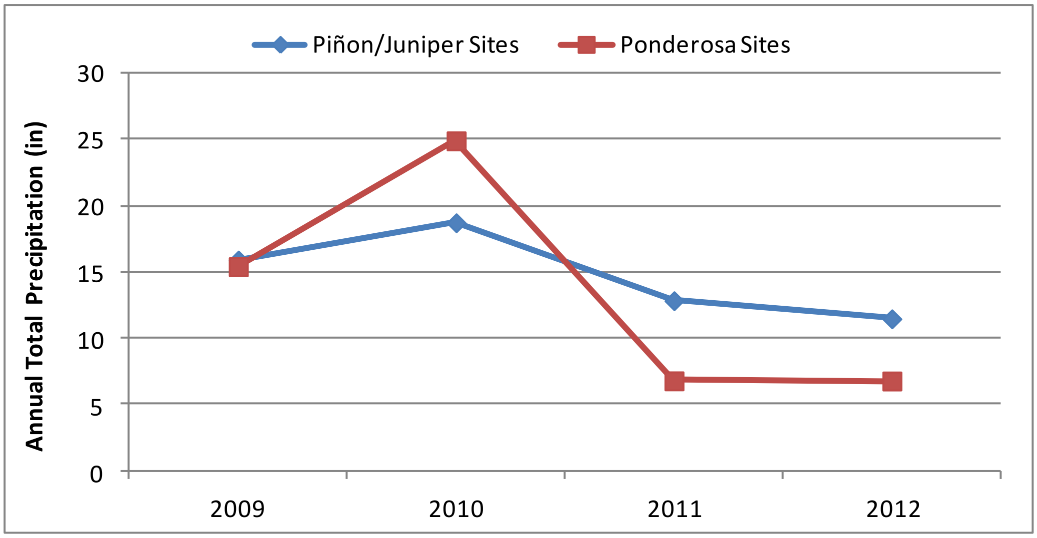


Figure 2.9. **Annual precipitation values from 2009–2012 on the piñon/juniper and ponderosa pine sites, which highlight the drought in 2011–2012.**

2.2.2 AMBIENT TEMPERATURE

An example of monthly averages of hourly ambient temperatures is presented for the Kelly piñon/juniper study sites (Figure 2.10). This graph show similar monthly average ambient temperatures between the paired study plots, as was typical at all of the study sites. The average ambient temperatures are also presented for years 2008–2012, which show a steady rise in temperature since the study begun in 2008 (Figure 2.11). The average temperature at the piñon/juniper (13°C [55°F]) site was well above the long-term average for the area, while the ponderosa sites (10.7°C [51.3°F]), which are higher in elevation, were equal to the long-term average for the region (10.8°C [51.5°F]). This average was taken from the long-term weather station located in Mountainair (Western Regional Climate Center 2013). The temperature increase seen in this study is also what has been occurring statewide and even at a national scale.

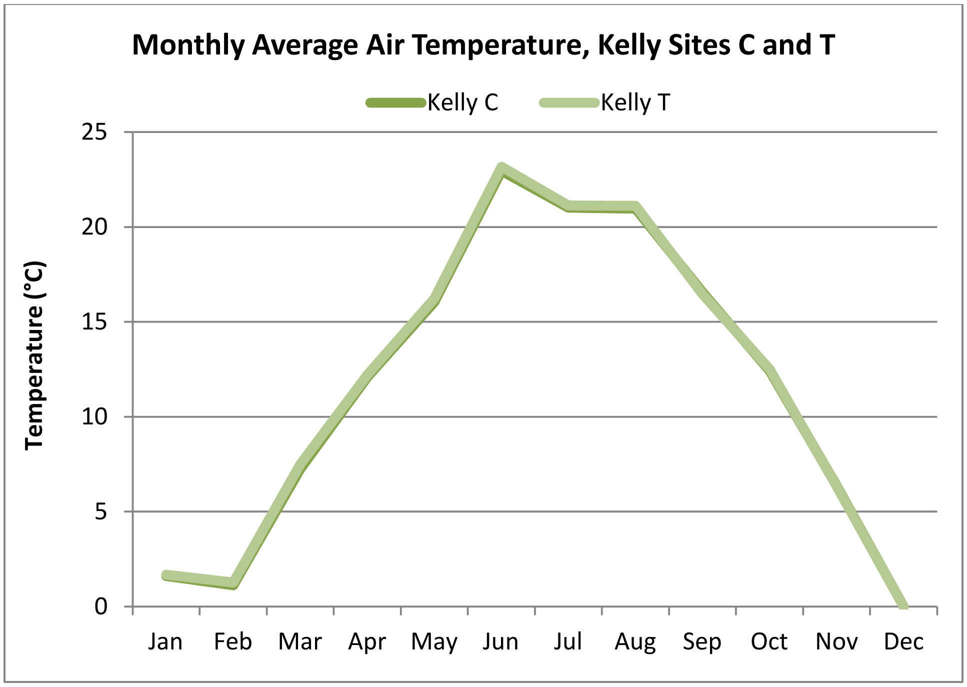


Figure 2.10. Monthly average ambient temperatures from the two paired Kelly piñon/juniper study plots in 2012.

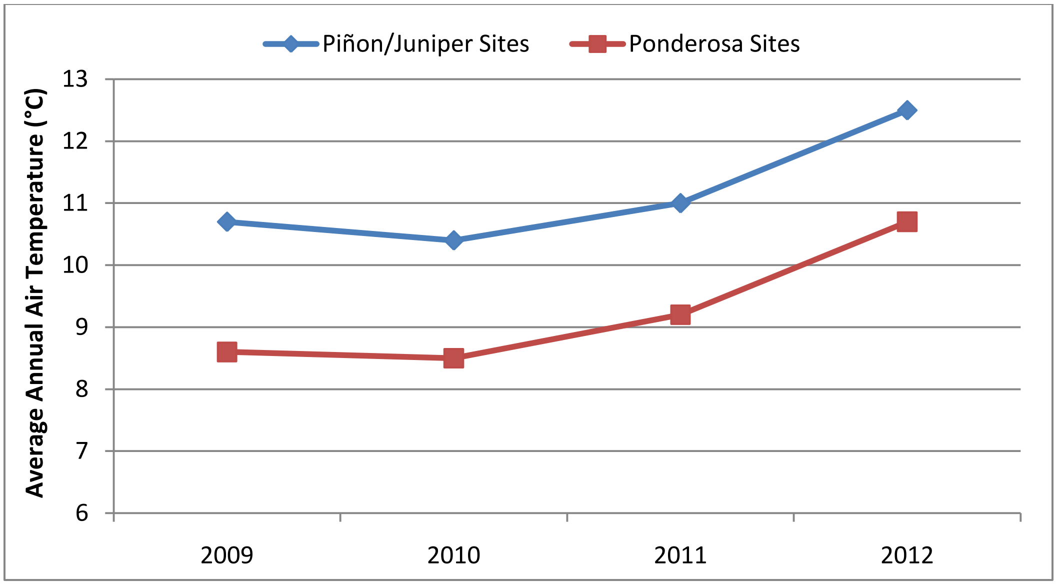


Figure 2.11. Annual average ambient temperature values at the piñon/juniper and ponderosa pine sites, 2009–2012.

2.2.3 SOIL MOISTURE

An example of monthly averages of hourly -10 cm soil moisture readings are presented for the paired study plots at the Kelly piñon/juniper site (Figure 2.12). Soil moisture was measured with Watermark soil moisture probes that measure soil water tension in kilopascal (kPa) values that are directly equivalent to California Bearing Ratio (cbr) values for soil water saturation. Results for paired plots were generally similar. More detailed information on the trends in soil moisture can be found in the Section 2.3.1 below on soil TDR measurements.

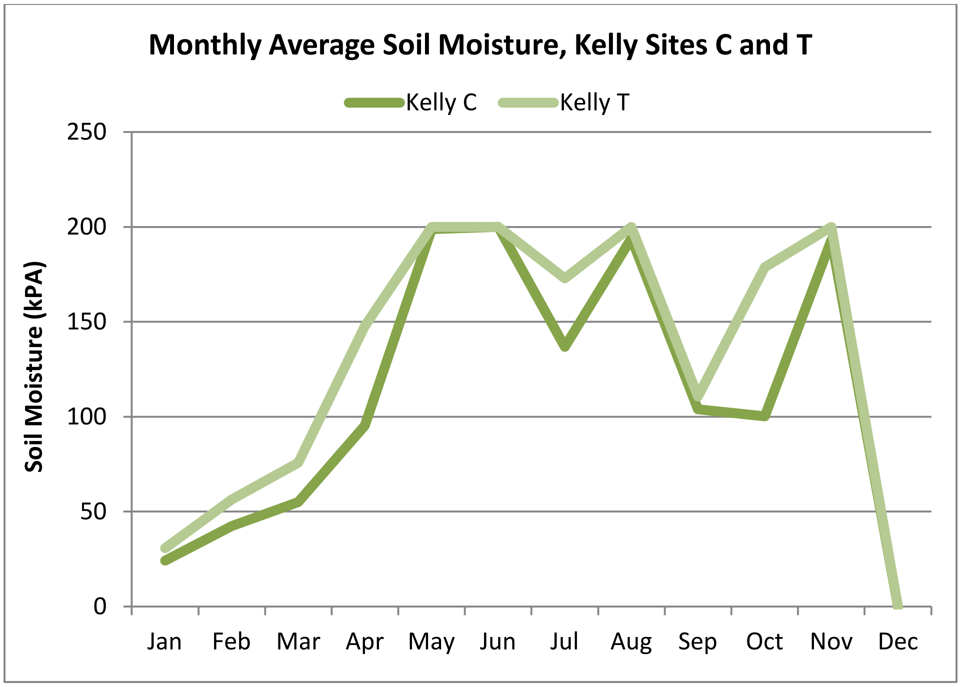


Figure 2.12. Monthly average soil moisture tensions (-10 cm) from the two paired Kelly piñon/juniper study plots in 2012.

2.2.4 SOIL TEMPERATURE

An example of monthly averages of hourly -10 cm soil temperature readings are presented for the paired study plots at the Kelly piñon/juniper sites (Figure 2.13). The graphs show similar monthly average soil temperatures between the paired study plots (T and C) at both study sites, which was generally the pattern across all sites.

A figure showing the annual soil temperatures for both the ponderosa and piñon/juniper sites is also presented below (Figure 2.14).

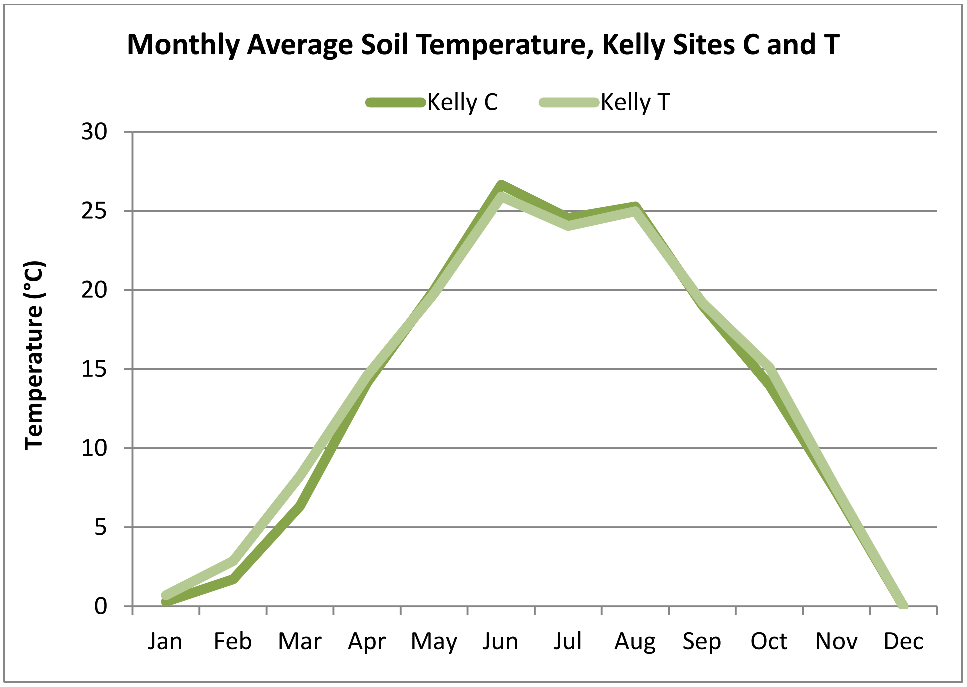


Figure 2.13. Monthly average soil temperature (-10 cm) from the two paired Kelly piñon/juniper study plots in 2012.

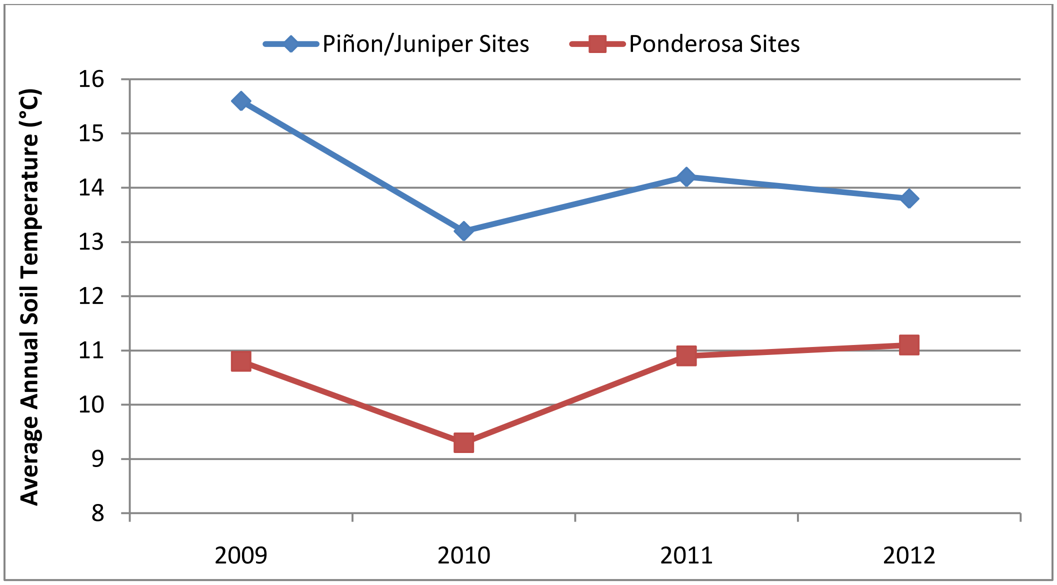


Figure 2.14. Annual average soil temperature values at the piñon/juniper and ponderosa pine sites, 2009–2012.

2.3 SOILS

2.3.1 ENTIRE STUDY PLOT SOIL WATER CONTENT AND TEMPERATURE (TDR)

Continuous hourly soil moisture and temperature measurements recorded by the WatchDog station at each plot only provide a single reference point measurement for each plot, measured and recorded hourly. In order to sample soil moisture and temperature from locations throughout each vegetation and soil monitoring plots, a portable Field Scout TDR 200 soil moisture meter was used. Further information on the detailed methods can be found in the 2008 Annual Report (SWCA 2009).

Average percent soil volumetric water content on the piñon/juniper and ponderosa plots from 2008 through 2012 is displayed below in Figure 2.15 and Figure 2.16. These results show that the piñon/juniper and ponderosa sites are acting in similar fashion prior to the thinning treatments completed in 2011. Average annual soil moisture between the paired plots is presented below for 2008–2012 from all forest thinning plots (Figure 2.17–Figure 2.20). These figures indicate that the treated sites retain on average more soil moisture throughout the year, especially after storm events and during times of drought. These figures also show the difference in soil moisture between the treatment and control is more pronounced on the piñon/juniper plots than the ponderosa pine plots. This finding can likely be contributed to the decrease in canopy cover and the increase in ground cover in the form of wood chips. Whether these findings continue to persist into the future remains to be seen.

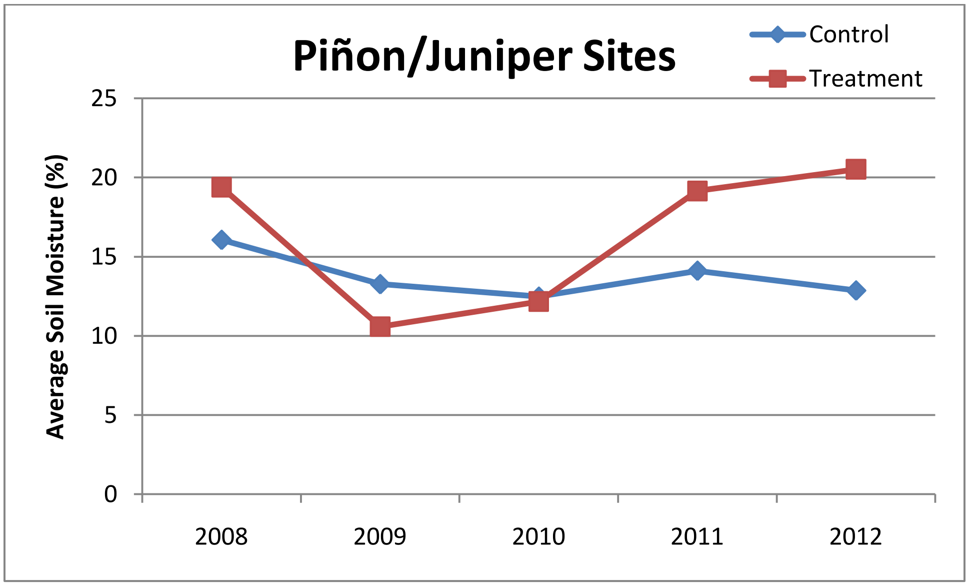


Figure 2.15. Annual average soil moisture percentage for the piñon/juniper sites, 2008–2012; moisture readings were averaged annually from the monthly readings.

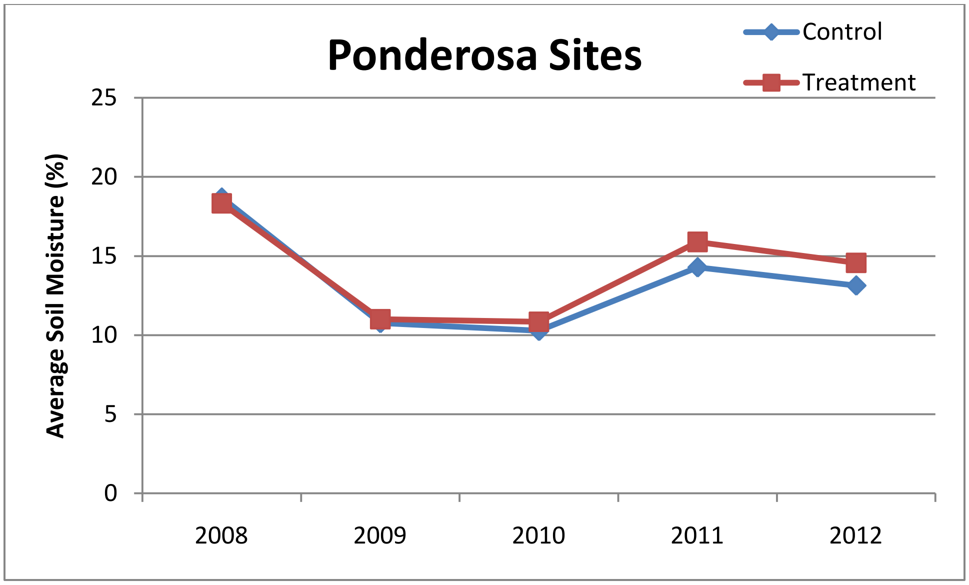


Figure 2.16. Annual average soil moisture percentage for the ponderosa sites, 2008-2012; moisture readings were averaged annually from the monthly readings.

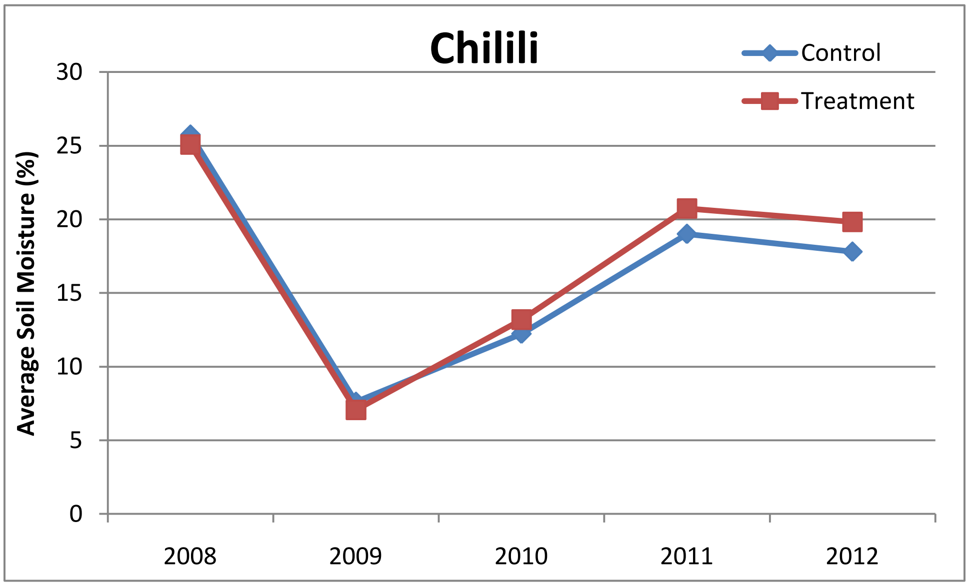


Figure 2.17. Average annual soil moisture readings taken in at the Chilili site, 2008–2012.

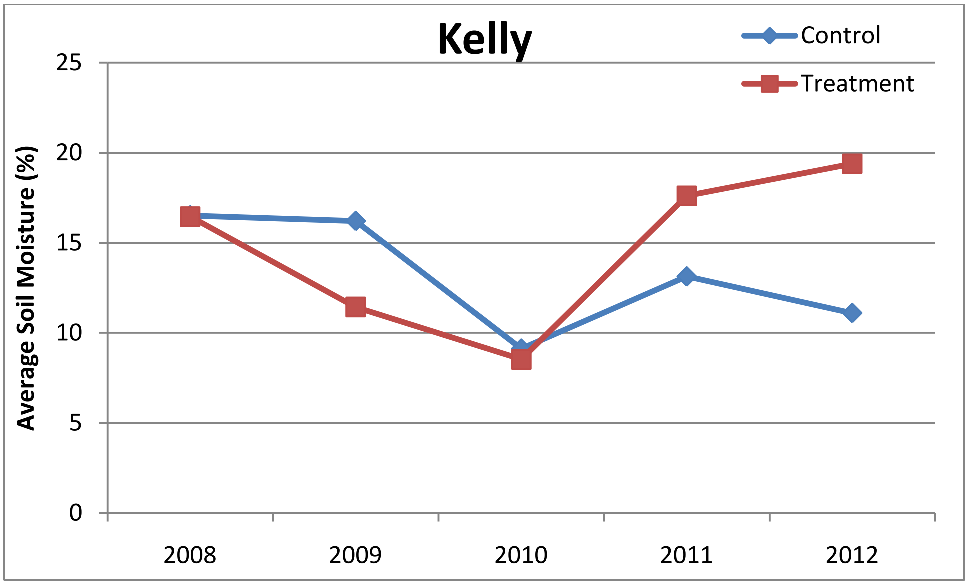


Figure 2.18. Average annual soil moisture readings taken at the Kelly site, 2008–2012.

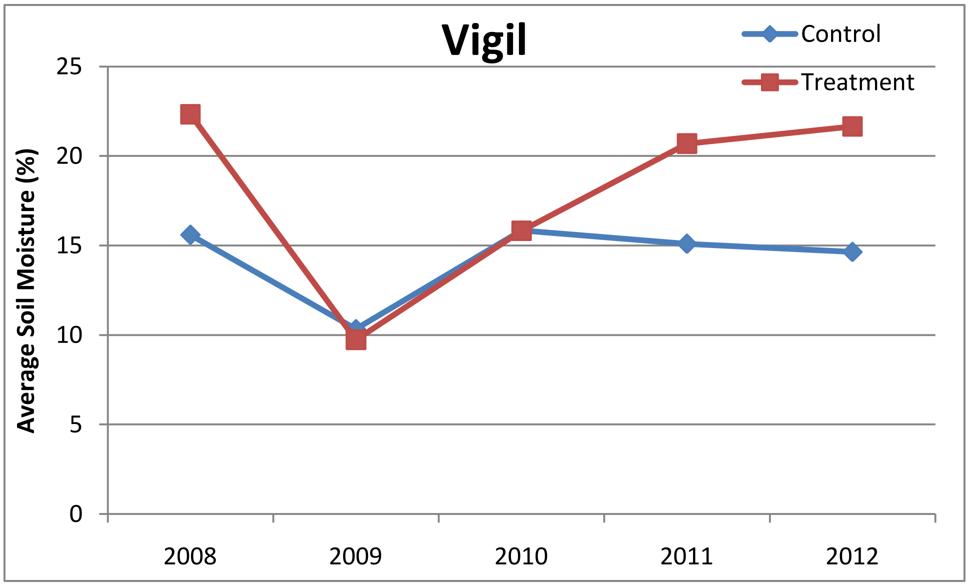


Figure 2.19. Average annual soil moisture readings taken at the Vigil site, 2008–2012.

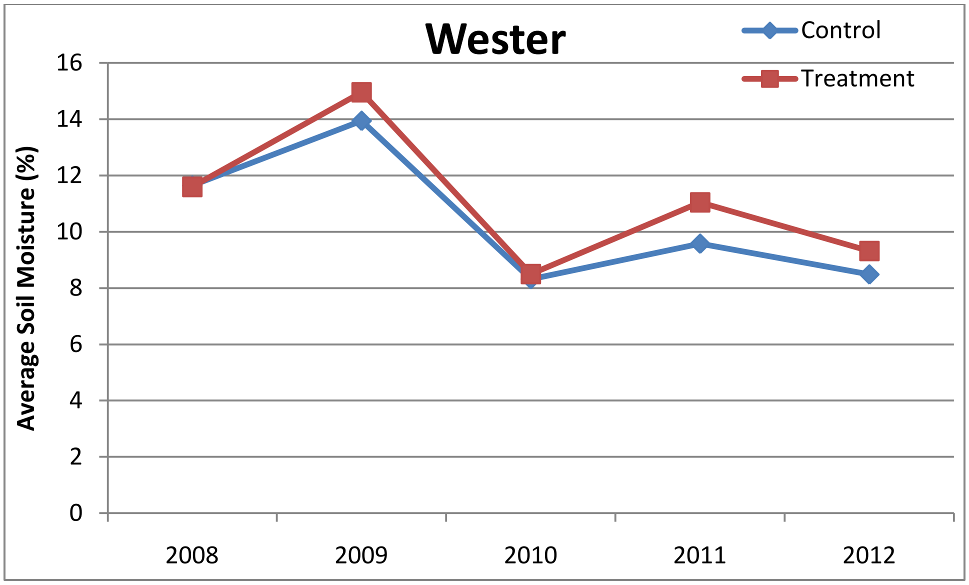


Figure 2.20. Average annual soil moisture readings taken at the Wester site, 2008–2012.

2.3.2 SOIL SURFACE STABILITY

Soil surface stability was measured and scored in June 2012 using the Soil Stability Test Kits developed by the U.S. Department of Agriculture Agricultural Resource Service (Herrick et al. 2005) (Figure 2.21). Further details of the measurement methods and a review of the literature can be found in the 2008 Monitoring Plan (SWCA 2008). Figure 2.22 through Figure 2.25 provide average soil surface stability scores for each of the four sample sites for 2008–2012, except for Chilili, which is 2009–2012. Figure 2.26 through Figure 2.29 provide average subsurface (1 cm below the soil surface, or -1 cm) soil stability scores for each of the four sampling sites for 2008–2012, except for Chilili, which is 2009–2012.

In general, the data show there was not much of a change in soil surface or subsurface stability from 2008 to 2012, meaning the thinning practices did not initially affect stability. The data do show, however, that the stability scores are higher on the ponderosa pine sites (Chilili and Wester) than on the piñon/juniper sites (Kelly and Vigil) (Figure 2.30 and Figure 2.31). This difference can largely be attributed to the large accumulation of organic matter that occurs underneath tree canopies in the ponderosa pine vegetation type, which can add as much as 2,000 pounds/acre/year of fine fuels (Ffolliott et al. 1968). Most soils at the sites measured were underneath litter layers and contained organic material and fungi.

Figure 2.21. Soil stability test in use on the study sites.

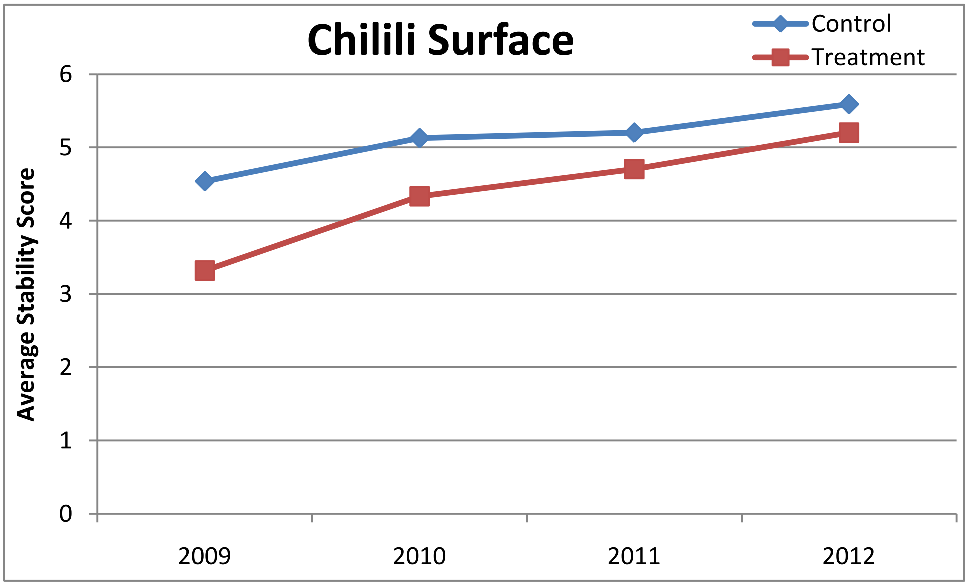


Figure 2.22. Soil surface stability average scores for Chilili, 2009–2012 (18 subsamples/subplot).

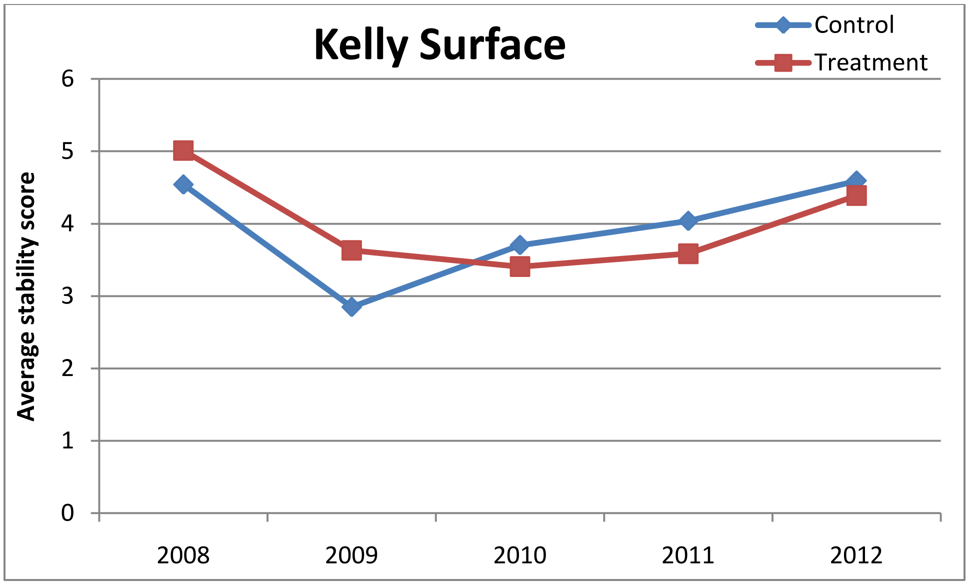


Figure 2.23. Soil surface stability average scores for Kelly, 2008–2012 (18 subsamples/subplot).

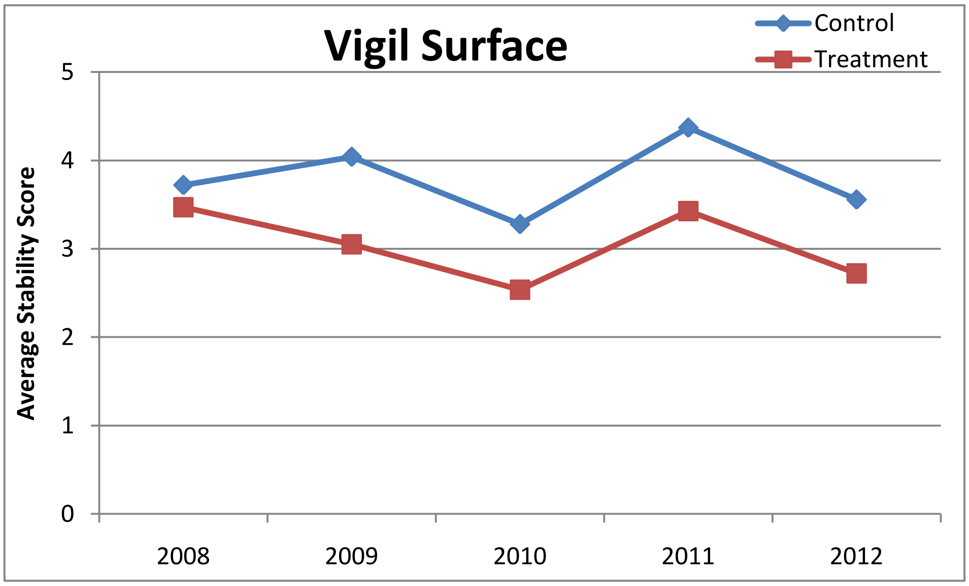


Figure 2.24. Soil surface stability average scores for Vigil, 2008–2012 (18 subsamples/subplot).

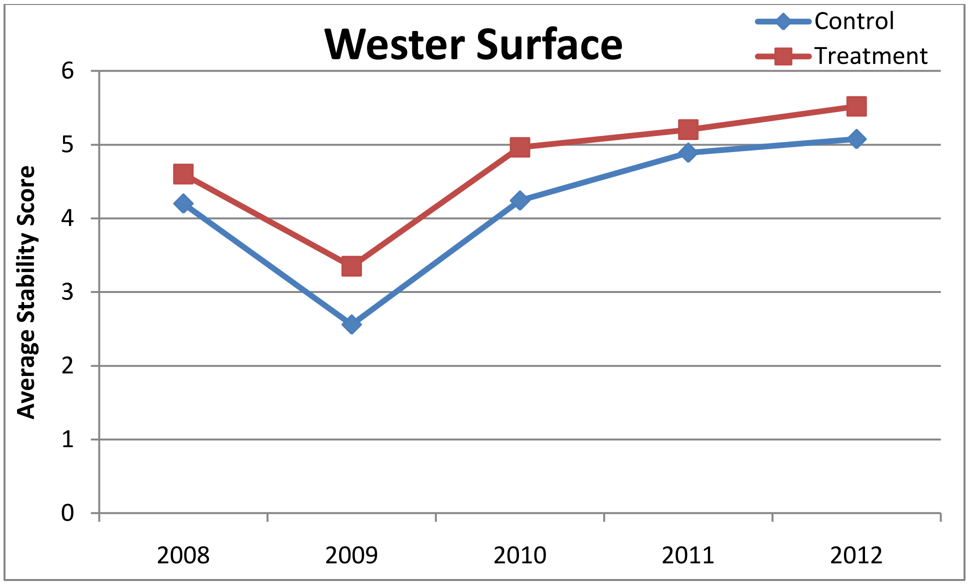


Figure 2.25. Soil surface stability average scores for Wester, 2008–2012 (18 subsamples/subplot).

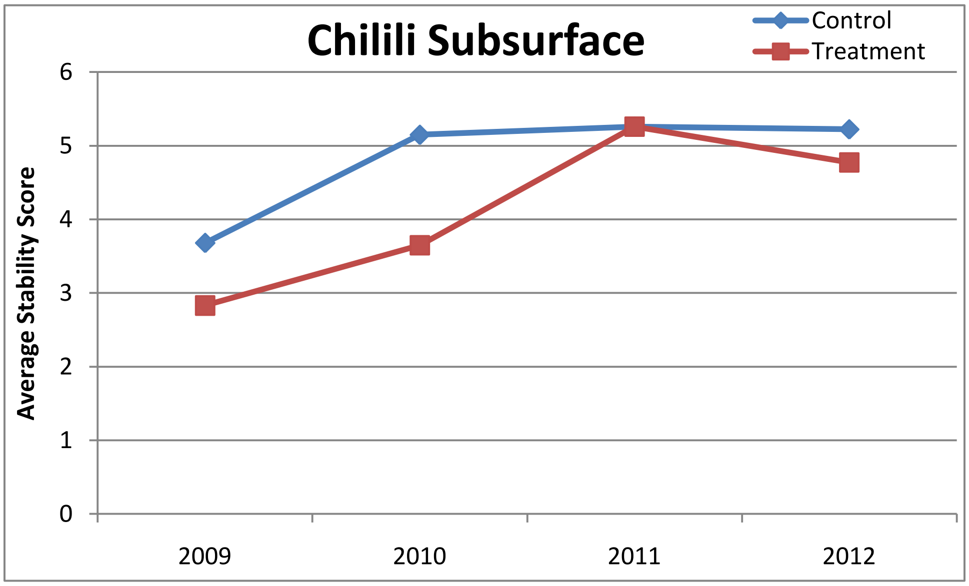


Figure 2.26. Soil subsurface (-1 cm) stability average scores for Chilili, 2009–2012 (18 subsamples/subplot).

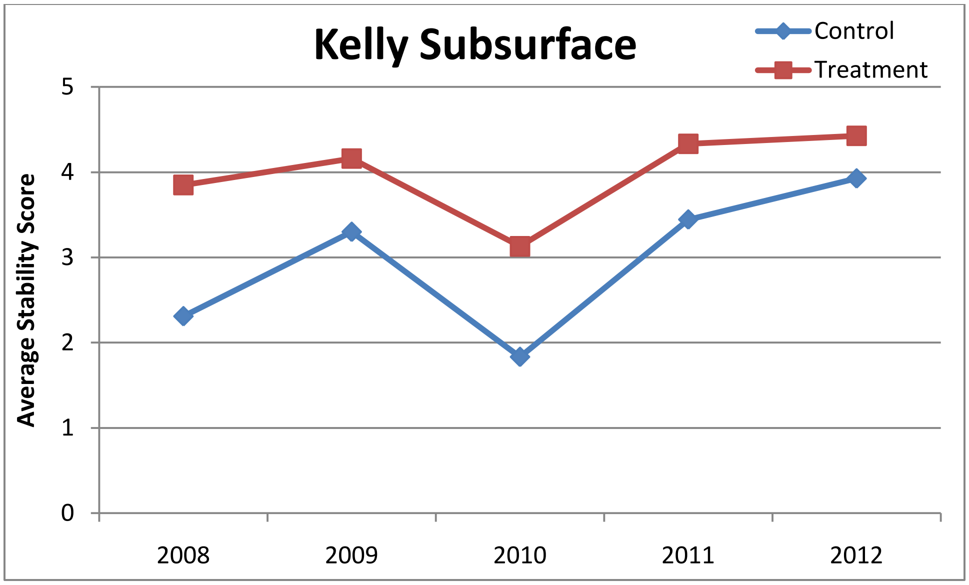


Figure 2.27. Soil subsurface (-1 cm) stability average scores for Kelly, 2008–2012 (18 subsamples/subplot).

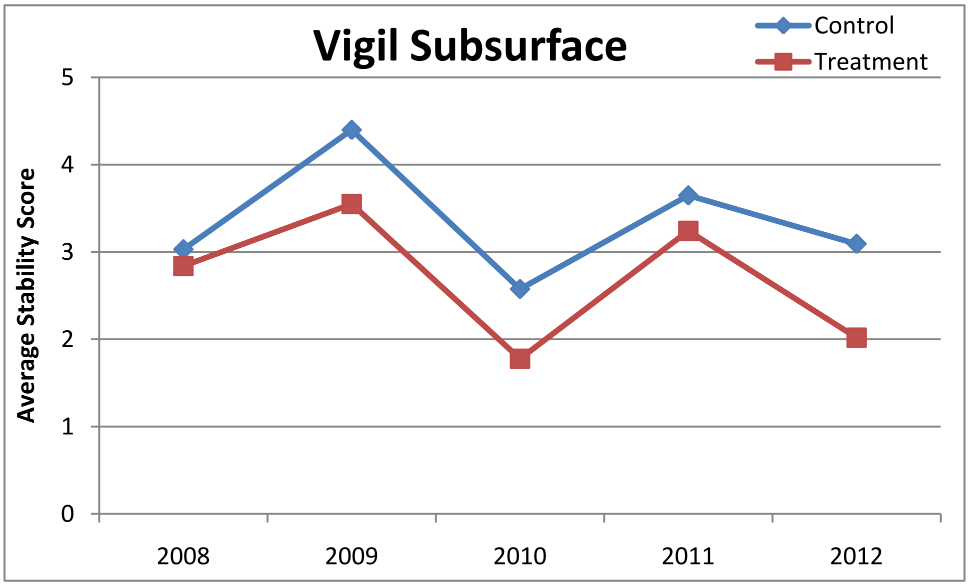


Figure 2.28. Soil subsurface (-1 cm) stability average scores for Vigil, 2008–2012 (18 subsamples/subplot).

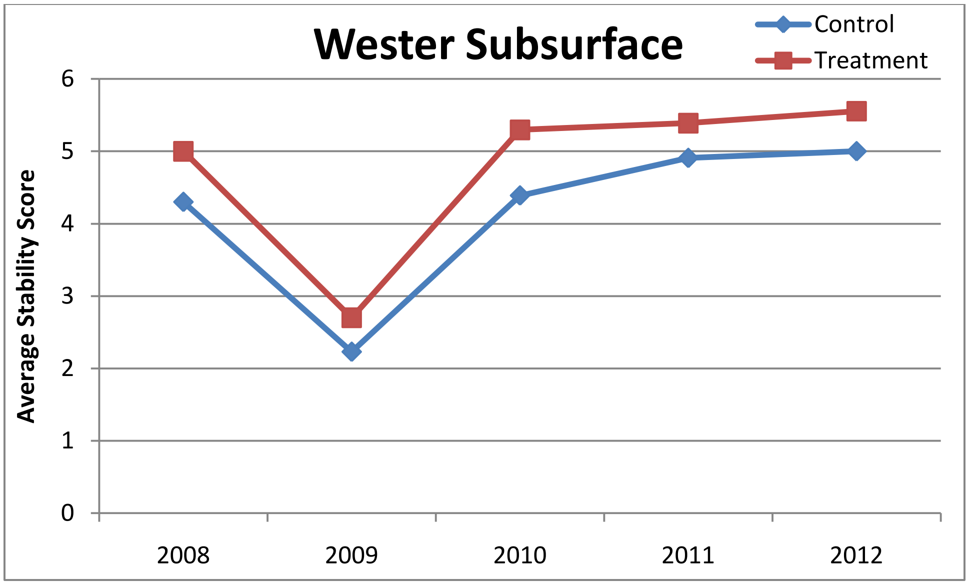


Figure 2.29. Soil subsurface (-1 cm) stability average scores for Wester, 2008–2012 (18 subsamples/subplot).

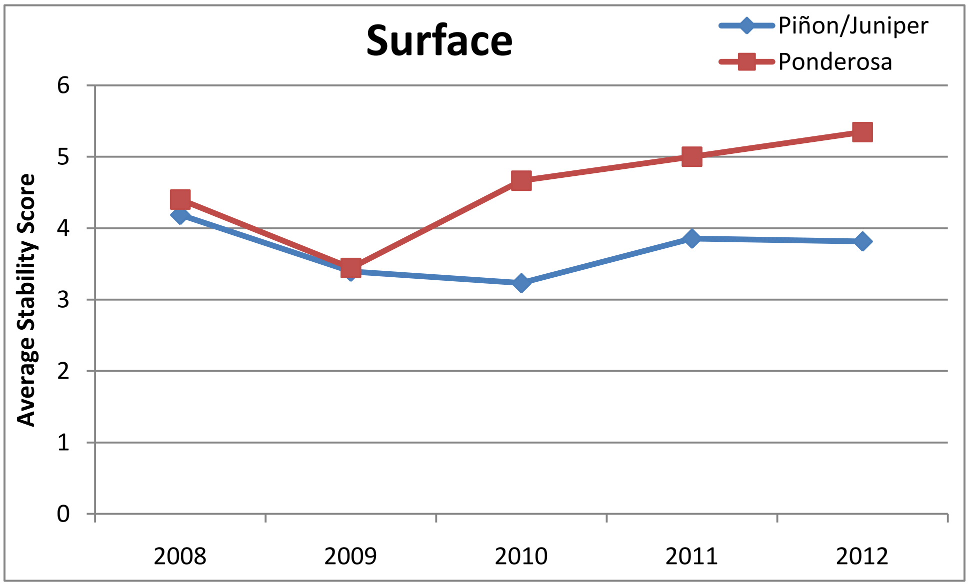


Figure 2.30. Soil surface stability average scores for the piñon/juniper and ponderosa sites, 2008–2012.

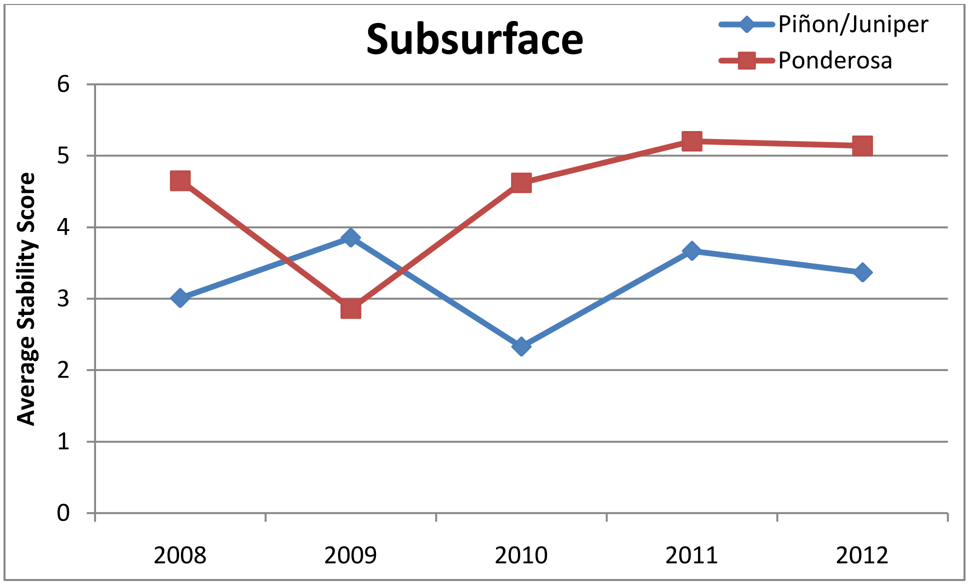


Figure 2.31. Soil subsurface (-1 cm) stability average scores for the piñon/juniper and ponderosa sites, 2008–2012.

2.3.3 SOIL MOVEMENT

Soil movement was monitored using soil movement bridges (called soil erosion bridges in the 2008 report) (Figure 2.32) modeled after White and Loftin (2000). Permanent bridge support posts were installed at consistent, systematically determined, and unbiased locations at one of each of the vegetation and soil subplots for a total of three bridges at each paired plot at all four sites. Please refer to the 2008 Annual Report for detailed monitoring protocols and literature associated with soil movement (SWCA 2009). Figure 2.33 shows the micro-soil topography profile from one of the three sampling points at the Kelly piñon/juniper site for 2008–2012. The graph clearly shows the yearly variability associated with soil movement on a plot and a slight trend for overall soil loss over the Five-year period. Figure 2.34 through Figure 2.37 show average soil profile values averaged over all points per bridge, and over three bridges per paired plot, for 2008, 2009, 2010, 2011, and 2012. These figures show little overall change in average soil surface levels over that five-year period and between the control and treatment. The processes of soil erosion and soil deposition can clearly be seen when plotting data from all five years. Over a series of years, this study will document losses and/or gains to the soil surface profiles at each bridge site and will provide average values for each of the eight plots in this study.

Through two years of post-treatment monitoring, no differences have been observed between the control and treatment. However, one factor to take into consideration is the lack of large precipitation events. For the past two years the project area has been in a severe drought that has resulted in very few overland flow events occurring that typically move large amounts of sediment. Overall, it does not appear that the treatments have caused damage to the soil resources. Whether these results persist into the future is still up for debate with only future monitoring providing a conclusive answer.

Figure 2.32. Measurement of soil surface topography using a soil movement bridge helps understand the yearly variability associated with soil topography.

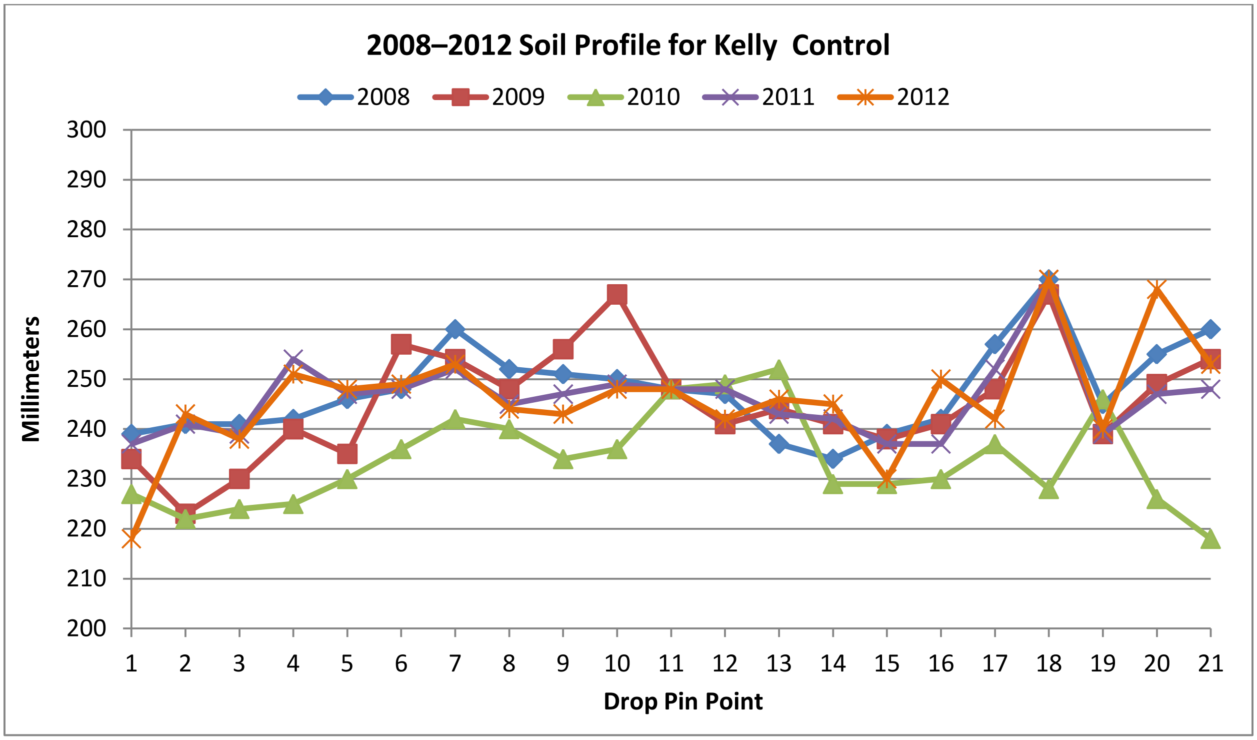


Figure 2.33. Soil surface profile from the soil movement bridge located at the Kelly piñon/juniper control site over 2008–2012, showing variation in the soil surface profile over a five-year period. Each point 1–21 on the X axis represents one measurement point from the soil surface to the level bridge above the surface. Point 11 is the set point (head of a spike) for calibration.

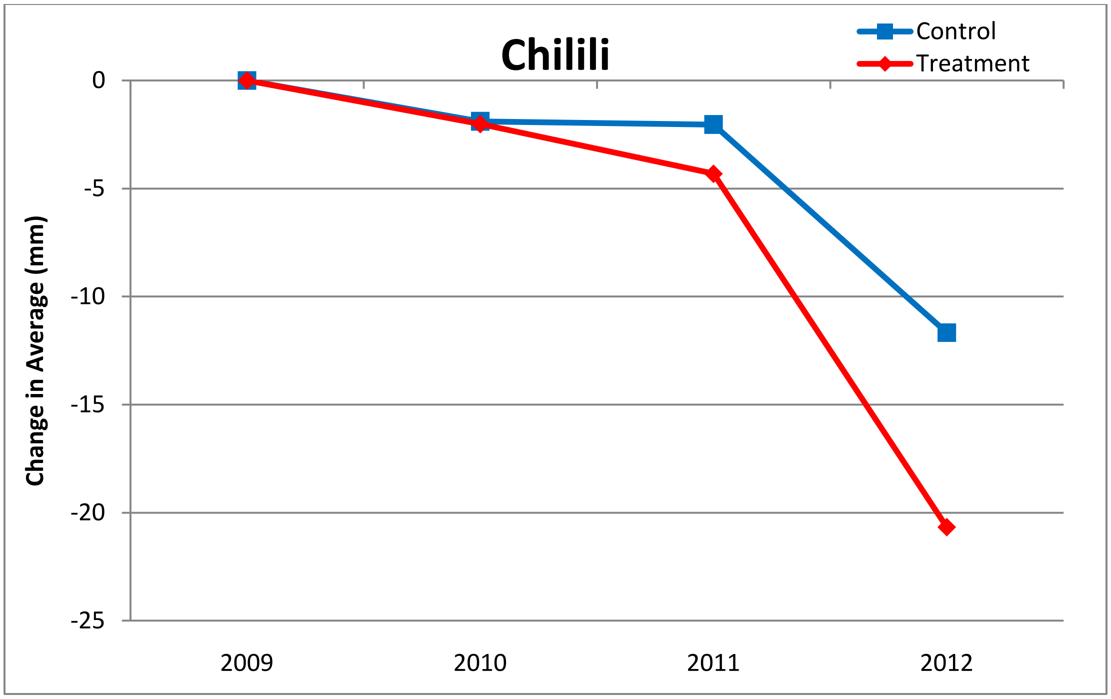


Figure 2.34. Average soil surface profiles for the Chilili sites, averaged from three soil movement bridges located on each of the paired study plots over the three-year period, 2009–2012.

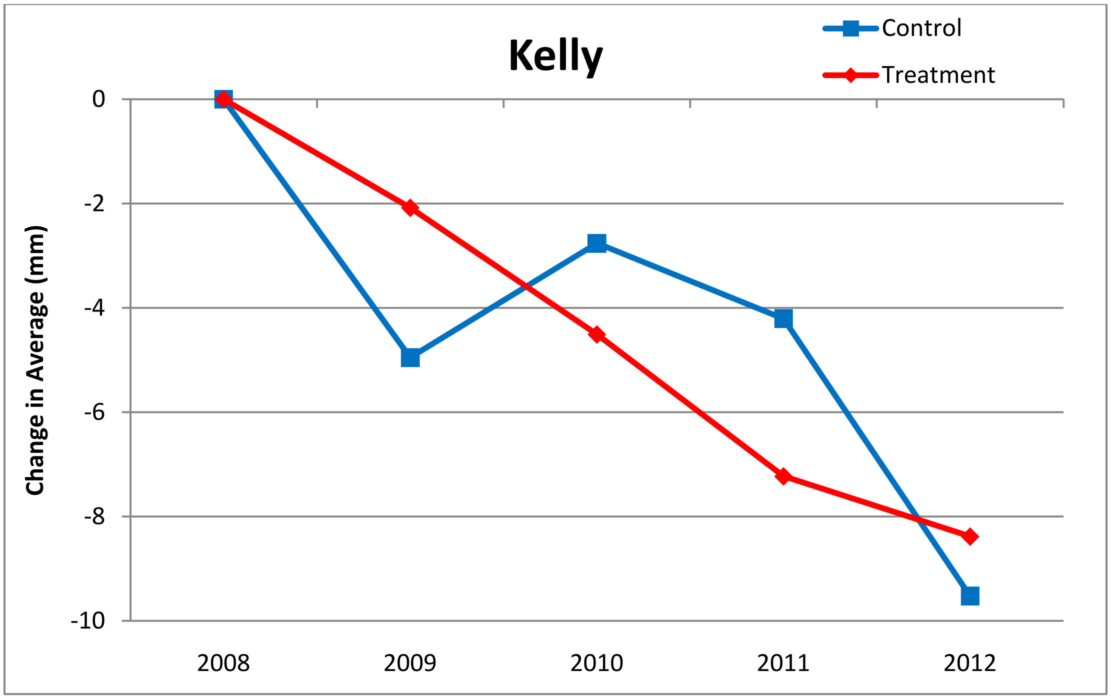


Figure 2.35. Average soil surface profiles for the Kelly sites, averaged from three soil movement bridges located on each of the paired study plots over the five-year period, 2008–2012

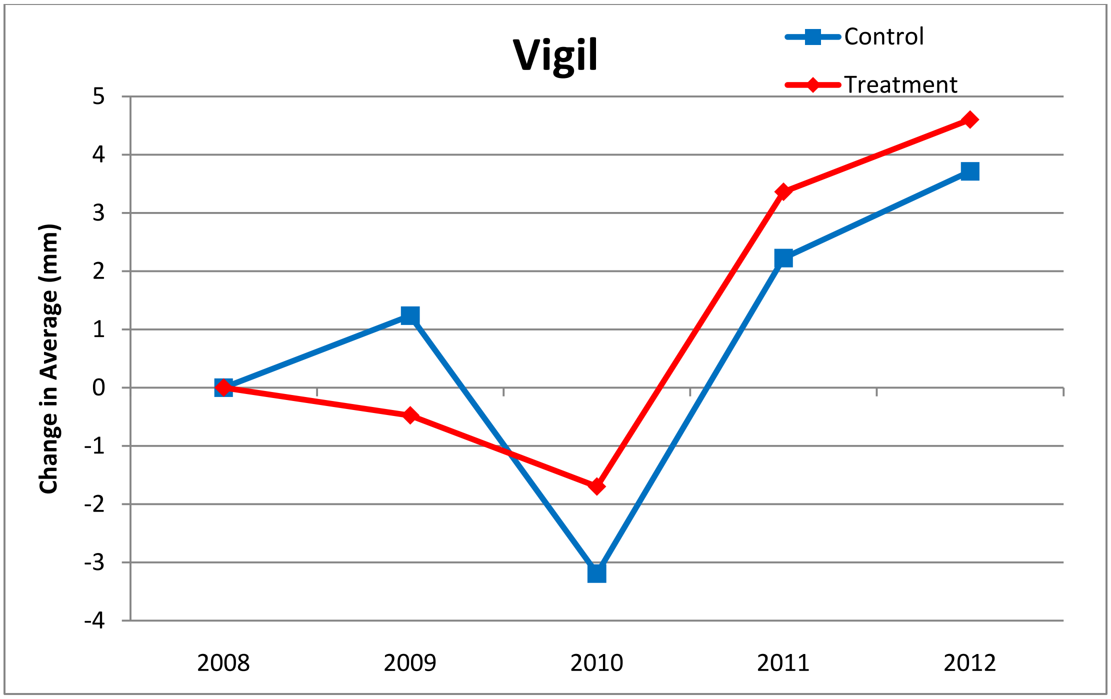


Figure 2.36. Average soil surface profiles for the Vigil sites, averaged from three soil movement bridges located on each of the paired study plots over the five-year period, 2008–2012

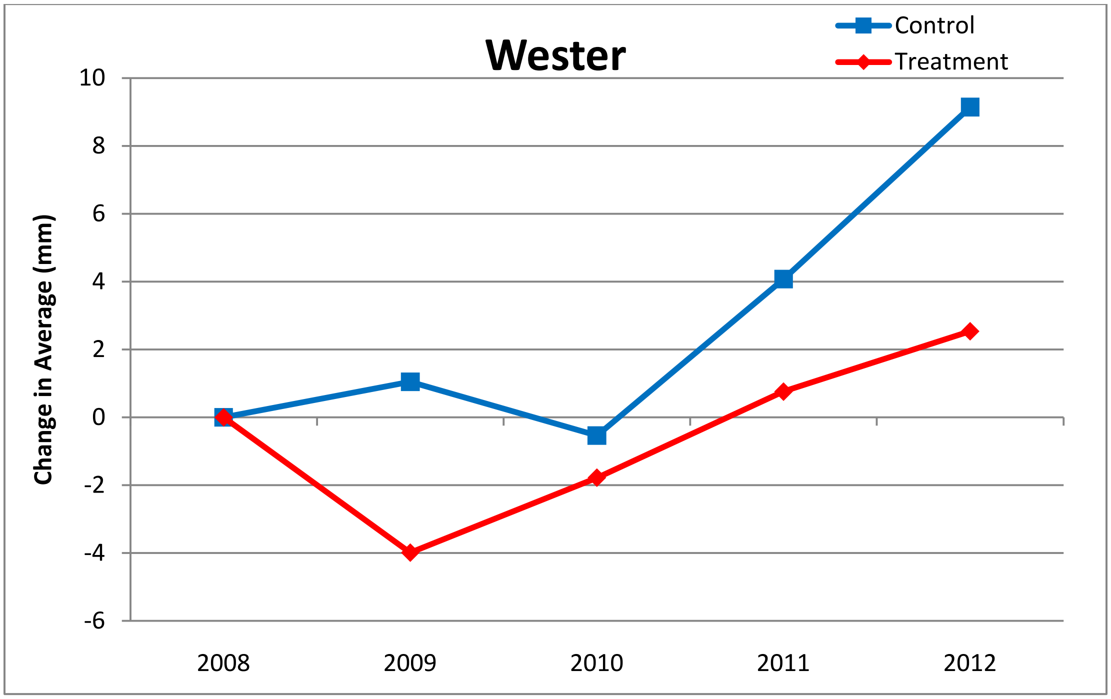


Figure 2.37. Average soil surface profiles for the Wester sites, averaged from three soil movement bridges located on each of the paired study plots over the five-year period, 2008–2012

2.3.4 SOIL CHEMISTRY

The chemistry comprising the soil is an important parameter in the overall health and functioning of a watershed. In particular, the top layer of soil, the A-horizon, is important because it is the zone where most biological activity occurs and is therefore the most fertile layer. The A-horizon is also the layer of soil most susceptible to disturbance because it is exposed at the surface to the elements of nature and man. Soil chemistry plays a key role in sustaining the productivity of plants and soil biota, which directly affect the ability of soil to infiltrate water. Understanding the chemical makeup of a soil before treatment or disturbance can shed light on how restoration techniques affect the chemical composition of the soil.

Baseline measurements of soil chemistry were obtained in 2008, 2009, and 2010 before thinning treatments at the Kelly, Vigil, and Wester sites; Chilili was not included until the 2009 sampling because this plot had yet to be established. The purpose of taking these measurements is to quantify changes to soil chemistry potentially caused by thinning activities. The methods used in 2008, however, were slightly different than those used in 2009 and 2010 and can be a reason for any large differences seen between years. The soil samples were obtained using a 4-cm-diameter (1.6-inch-diameter), 20-cm-deep (8-inch-deep) impact soil corer at the four corners of the three established vegetation plots (Figure 2.38). In 2008 the 12 subsamples were placed in labeled separate bags in order to attempt in house analysis with Cardy soil kits. The variability associated with these kits, however, proved to be too great for reliable results, so the subsamples were combined into one bag for each site and sent to the New Mexico State University Soils and Water Testing (SWAT) laboratory for further analysis. In 2009, 2010, 2011, and 2012 the collection of the 12 subsamples was combined into the same bag at the time of sampling. These pooled samples were considered to be representative of the study areas. The 2009, 2010, and 2011 samples were sent to the SWAT laboratory for analysis. The New Mexico State University SWAT laboratory closed in early 2012, so the 2012 samples were sent to the Soil, Water, and Plant Testing Laboratory at Colorado State University (CSU). These methods followed the USFS Forest Inventory and Analysis Guide procedures (USFS 2005).

Figure 2.38. Soil cores were taken using an impact corer, shown above, for chemical analysis.

The variables measured by the SWAT and CSU laboratories included saturated paste pH, electronic conductivity, total soluble salts (sodium, calcium, and magnesium), sodium adsorption ratio, organic matter, nitrogen (nitrate) (NO_3), bicarbonate phosphorous, potassium, and a texture estimate. The results of the soil organic matter content and the macro nutrient nitrogen, from samples taken from 2008–2012, are presented in Figure 2.39 through Figure 2.46.

The various soil chemistry compounds varied quite a bit at a given plot, between paired plots, between sites, and between years. This amount of background variation will be important to consider in determining if thinning treatments affect soil chemistry. Such treatment differences will need to be above this background variation.

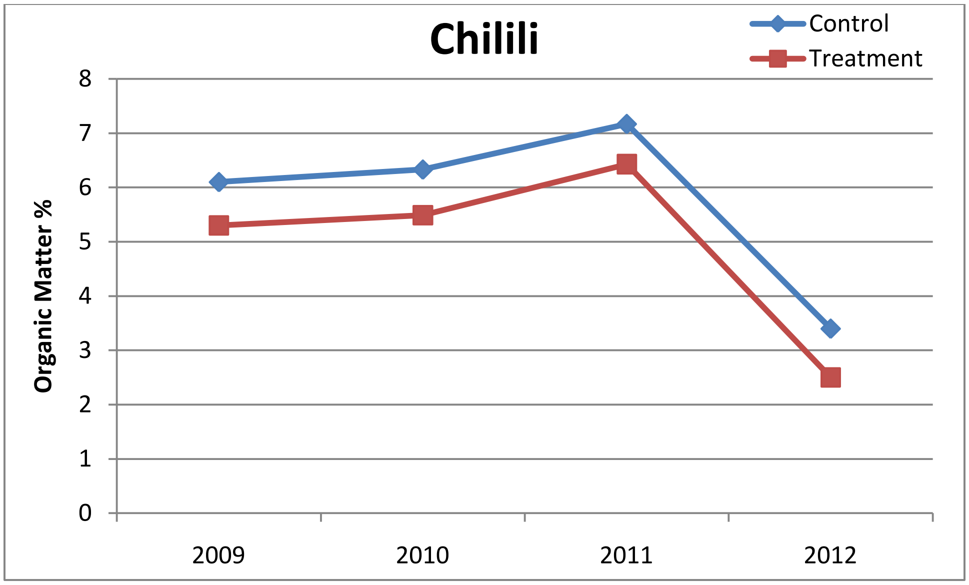


Figure 2.39. Organic matter concentrations measured at the Chilili sites, 2009–2012.

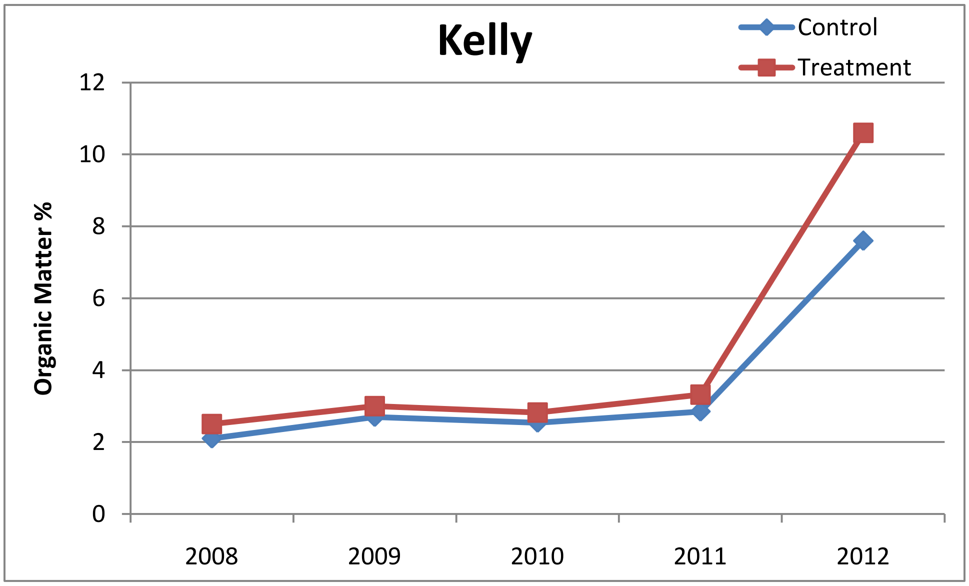


Figure 2.40. Organic matter concentrations measured at the Kelly sites, 2008–2012.

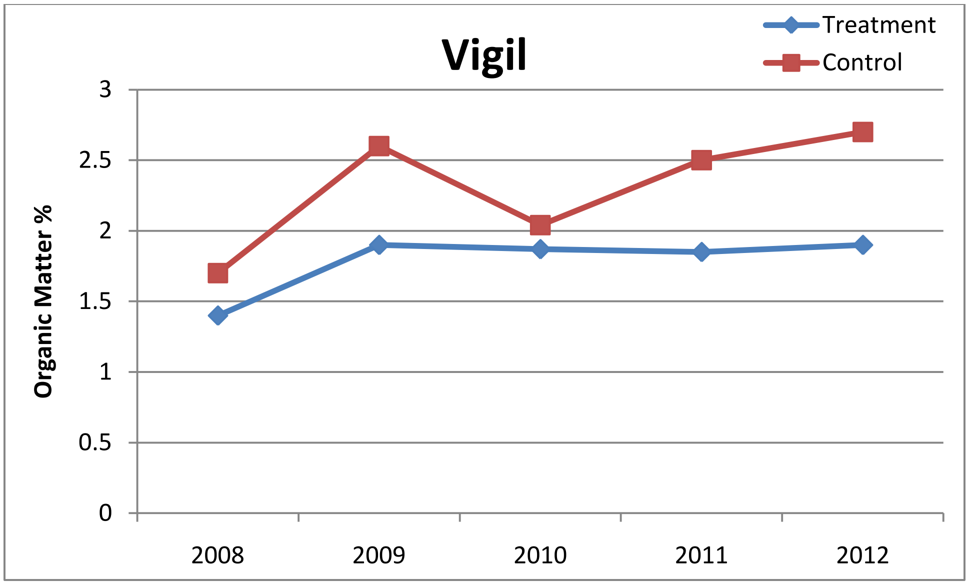


Figure 2.41. Organic matter concentrations measured at the Vigil sites, 2008–2012.

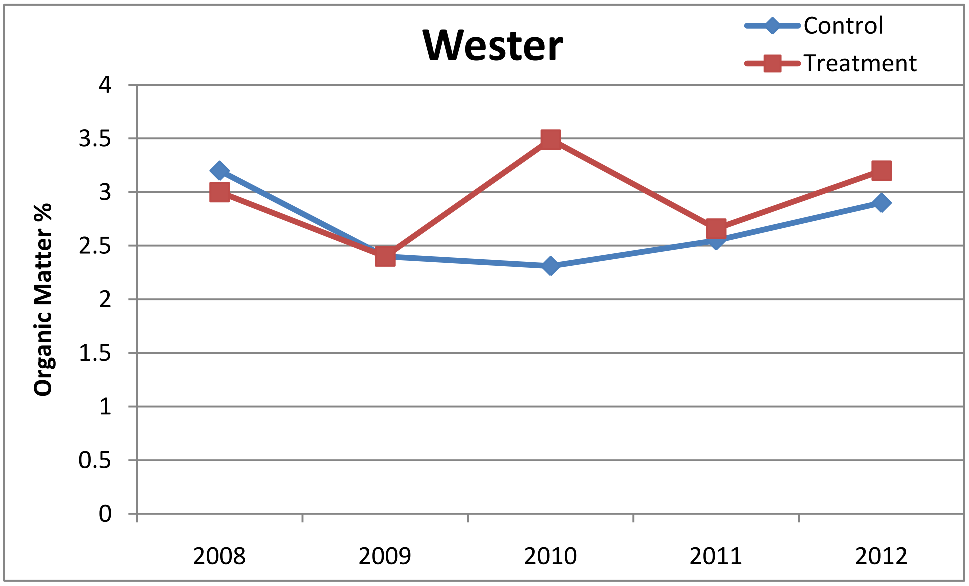


Figure 2.42. Organic matter concentrations measured at the Wester sites, 2008–2012.

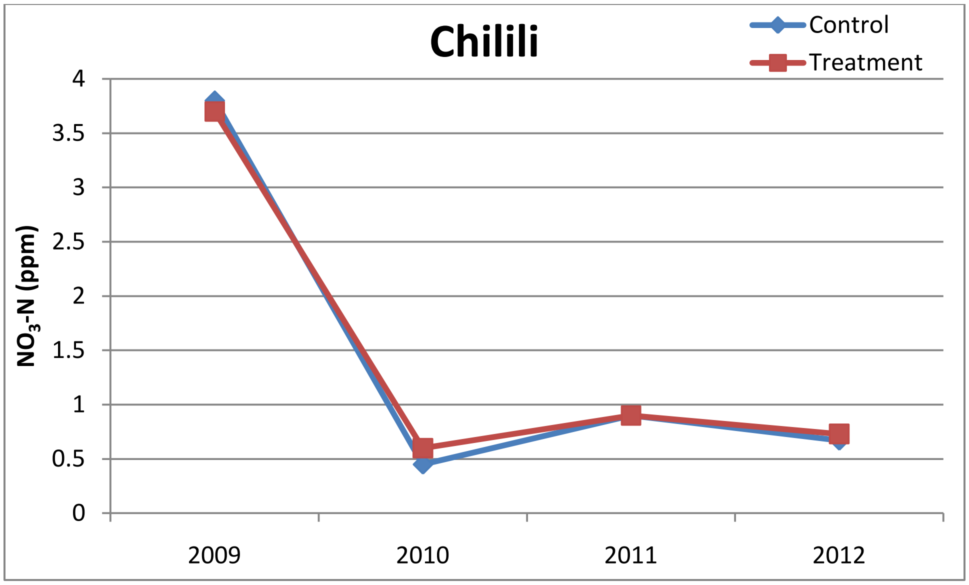


Figure 2.43. Nitrate concentrations measured at the Chilili sites, 2009–2012.

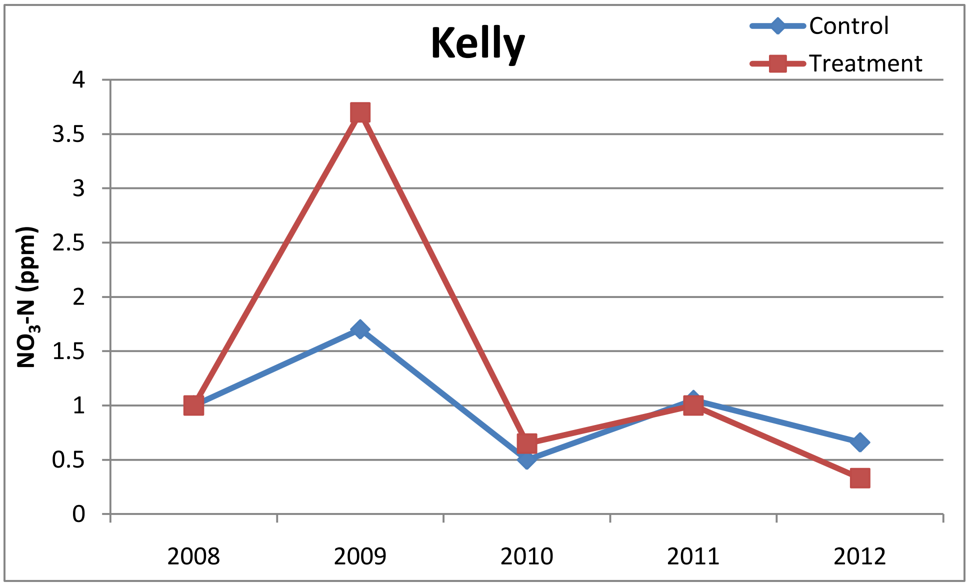


Figure 2.44. Nitrate concentrations measured at the Kelly sites, 2008–2012.

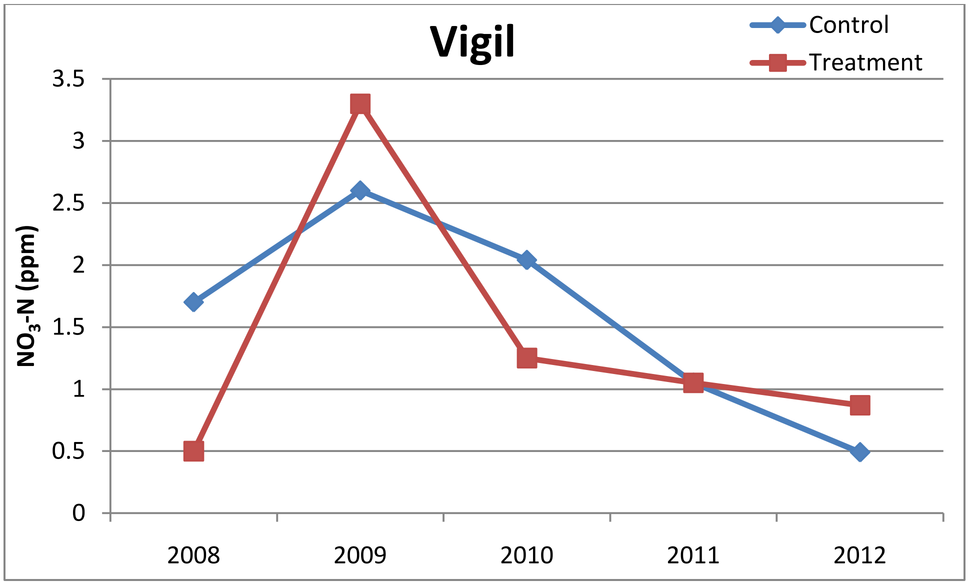


Figure 2.45. Nitrate concentrations measured at the Vigil sites, 2008–2012.

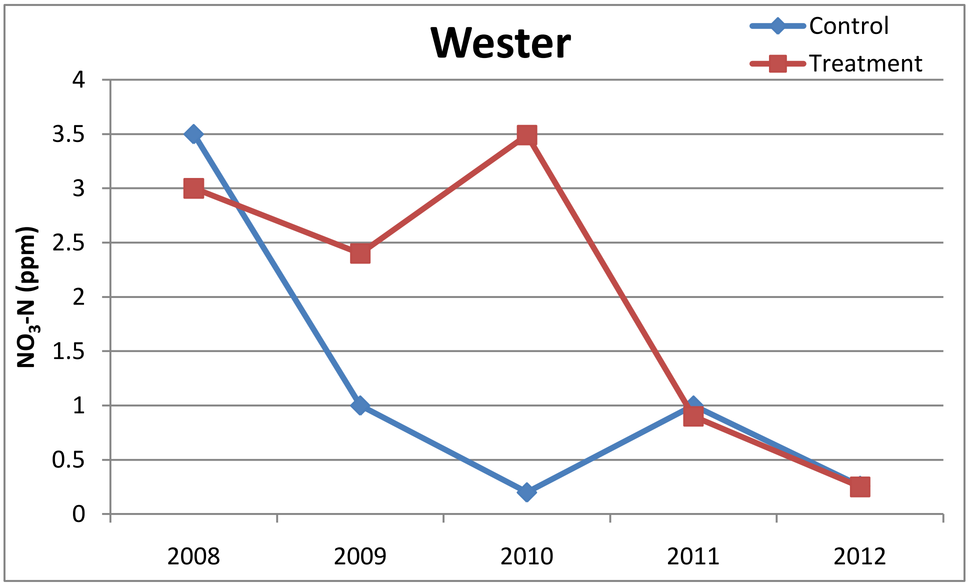


Figure 2.46. Nitrate concentrations measured at the Wester sites, 2008–2012.

2.4 FOREST THINNING HYDROLOGIC MONITORING

Monitoring flumes (Parshall flumes) complete with pressure transducers were installed at all four study sites in order to study impacts of tree thinning to surface flow (Figure 2.47). For more detailed information on the methodology, site location and relevant background information, please refer to the 2008 Monitoring Plan (SWCA 2008).

Figure 2.47. Parshall flume located at the thinned Chilili site.

During the 2012 monitoring period, rainfall occurred in the project area on 17% of the days monitored compared with 26% of the days monitored in 2011. However, about 80% of these rainfall events were relatively small and totaled less than 2.5 mm (0.1 inch). During the same monitoring period, only eight flow events were recorded across all watersheds, which were considerably lower than in 2010 where 16 flow events were recorded, but greater than 2011 where only five flow events occurred. Flows generally did not occur without at least 7.6 mm (0.3 inch) of rainfall, which has been the case since the beginning of the project. The sites located in the ponderosa pine study plots generated runoff with slightly less rain (7.6 mm [0.3 inch]), whereas the piñon/juniper sites required about 12.7 mm (0.5 inch) of rain to generate runoff events.

During the 2012 monitoring period there were no basin-wide storm events that generated flow across all study sites simultaneously. Many of the flumes did not even record flow events during the 2012 monitoring season, which is a product of the persistent drought over the region. The flumes that did not record surface flow events during the 2012 season included both Kelly sites and both Chilili sites. Even though there were very few recordable storm events, trends that were beginning to show in 2011 are still persisting. The flumes that did record events were Vigil treatment and control, which recorded seven flow events, and Wester control, which recorded one (Figure 2.48). The results of these flows can be found in Table 2.3 through Table 2.7.

Whether the differences in peak flows on the treated watershed versus the control watershed persist remains to be seen, and with more future flows this picture will become more clear.

There were three flow events each that were recorded at both of the Vigil sites in 2012. These events occurred on July 5, August 5, and August 12, 2012. The only other flow event that was recorded on the treated Vigil site occurred on July 7, 2012. The flow events that occurred on the Vigil control and treatment sites showed the trends that were seen in 2011 where the treatments generally have a higher peak flow and runoff ratio (Figure 2.49–Figure 2.52). During all paired events in 2012 the peak flows were higher on the treated watersheds while the runoff ratios varied. Whether these results persist and if they occur at all sites is yet to be determined. Given the lack of paired events across all sites, a complete understanding of the effects of the treatments is unknown. All Parshall flumes were functioning properly during the 2012 season.

Table 2.3. Summary of Runoff Events for Wester Control on August 5–6, 2012

Runoff Parameters	Study Site
	Wester Control
Flow start	8/5/2012 23:32
Flow stop	8/6/2012 1:57
Peak stage (feet)	0.184
Peak flow (cubic feet/second)	0.07
Flow duration (minutes)	150
Total volume of flow (cubic feet)	178
Watershed area (acres)	1.03
Volume of flow per acre (cubic feet/acre)	173
Total rainfall (inches)	2.79
Total volumetric rainfall (cubic feet)	10,447
Rainfall/Runoff ratio	0.02

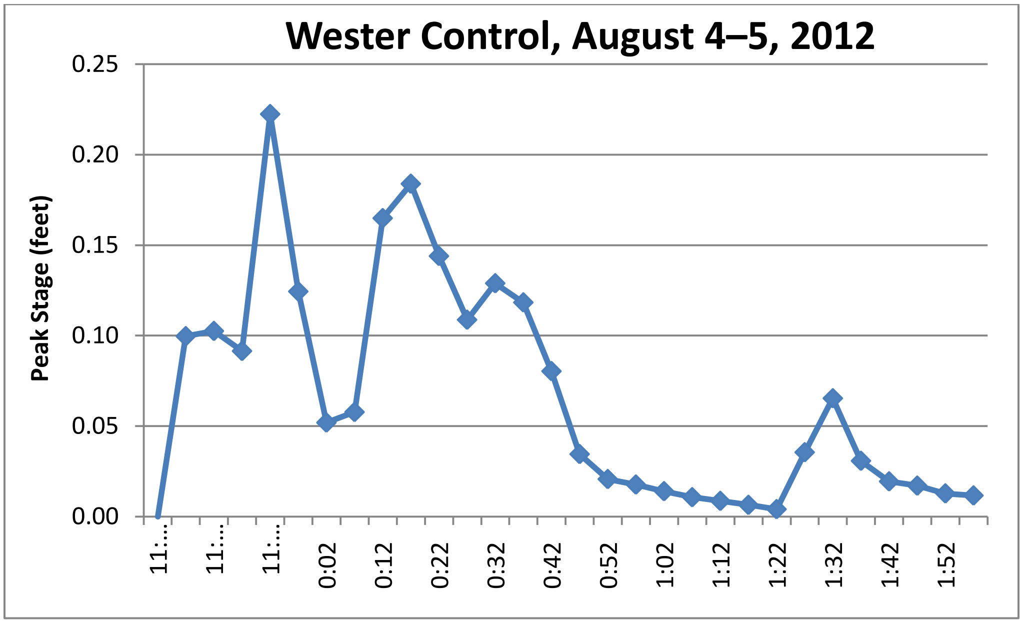


Figure 2.48. Hydrograph showing the storm flow at the control Wester site that occurred on August 5–6, 2012.

Table 2.4. Summary of Runoff Event for Both Vigil Sites, July 5, 2012

Runoff Parameters	Study Sites	
	Vigil Treated	Vigil Control
Flow start	15:20	15:07
Flow stop	15:45	15:37
Peak stage (feet)	0.12	0.095
Peak flow (cubic feet/second)	0.04	0.028
Flow duration (minutes)	20	30
Total volume of flow (cubic feet)	33	27.3
Watershed area (acres)	0.68	0.1
Volume of flow per acre (cubic feet/acre)	48.53	273
Total rainfall (inches)	0.63	0.76
Total volumetric rainfall (cubic feet)	1,555	275.88
Rainfall/Runoff ratio	0.02	0.10

Table 2.5. Summary of Runoff Event for the Vigil Treatment Site, July 7, 2012

Runoff Parameters	Study Site
	Vigil Treated
Flow start	12:40
Flow stop	13:15
Peak stage (feet)	0.06
Peak flow (cubic feet/second)	0.01
Flow duration (minutes)	35
Total volume of flow (cubic feet)	16.5
Watershed area (acres)	0.68
Volume of flow per acre (cubic feet/acre)	51.47
Total rainfall (inches)	0.3
Total volumetric rainfall (cubic feet)	741
Rainfall/Runoff ratio	0.02

Table 2.6. Summary of Runoff Events for Both Vigil Sites, August 5, 2012

Runoff Parameters	Study Sites	
	Vigil Treated	Vigil Control
Flow start	12:40	12:42
Flow stop	13:15	13:07
Peak stage (feet)	0.18	0.113
Peak flow (cubic feet/second)	0.07	0.032
Flow duration (minutes)	35	25
Total volume of flow (cubic feet)	85.2	25.5
Watershed area (acres)	0.68	0.1
Volume of flow per acre (cubic feet/acre)	125	255
Total rainfall (inches)	0.99	1.12
Total volumetric rainfall (cubic feet)	2,444	406.56
Rainfall/Runoff ratio	0.03	0.06

Table 2.7. Summary of Runoff Events for Both Vigil Sites, August 12, 2012

Runoff Parameters	Study Sites	
	Vigil Treated	Vigil Control
Flow start	18:40	18:47
Flow stop	19:20	19:07
Peak stage (feet)	0.30	0.156
Peak flow (cubic feet/second)	0.153	0.058
Flow duration (minutes)	40	20
Total volume of flow (cubic feet)	119	24.6
Watershed area (acres)	0.68	0.1
Volume of flow per acre (cubic feet/acre)	175	246
Total rainfall (inches)	0.89	0.86
Total volumetric rainfall (cubic feet)	2,197	312
Rainfall/Runoff ratio	0.05	0.08

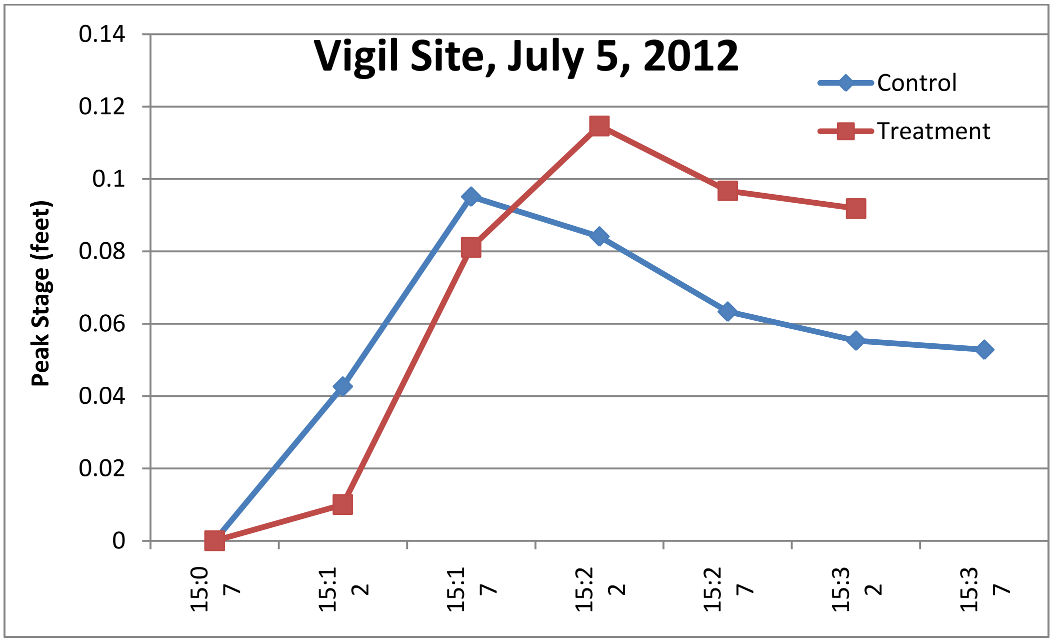


Figure 2.49. Hydrograph showing both paired plots from a Vigil storm flow event on July 5, 2012.

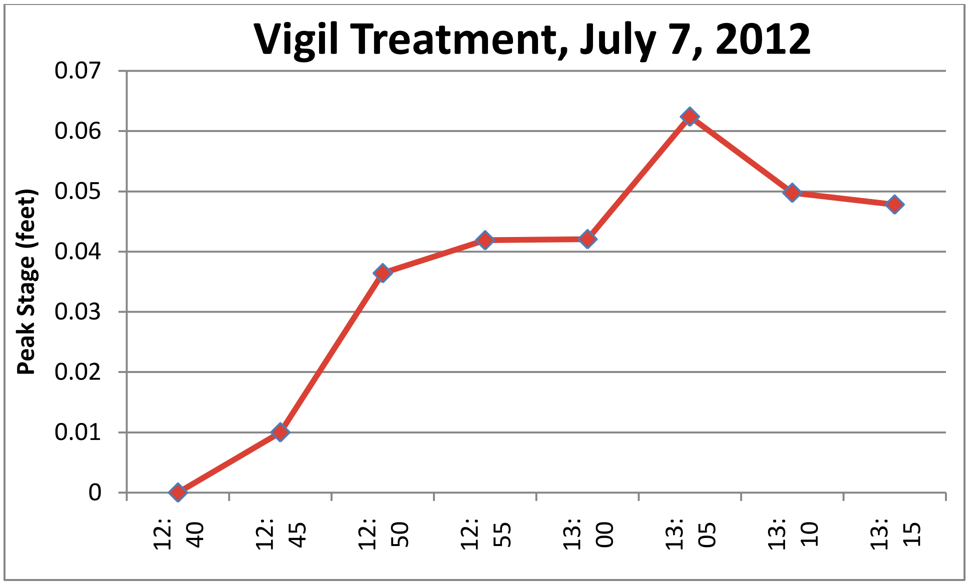


Figure 2.50. **Hydrograph showing the peak flow at the treated Vigil site during the flow event on July 7, 2012.**

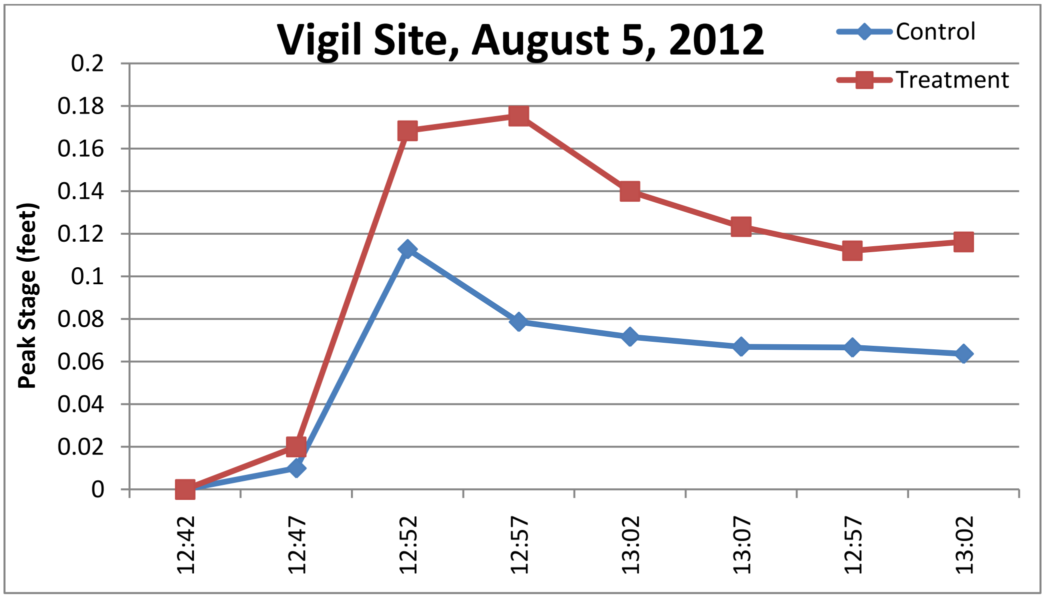


Figure 2.51. **Hydrograph showing both paired plots from a Vigil storm flow event on August 5, 2012.**

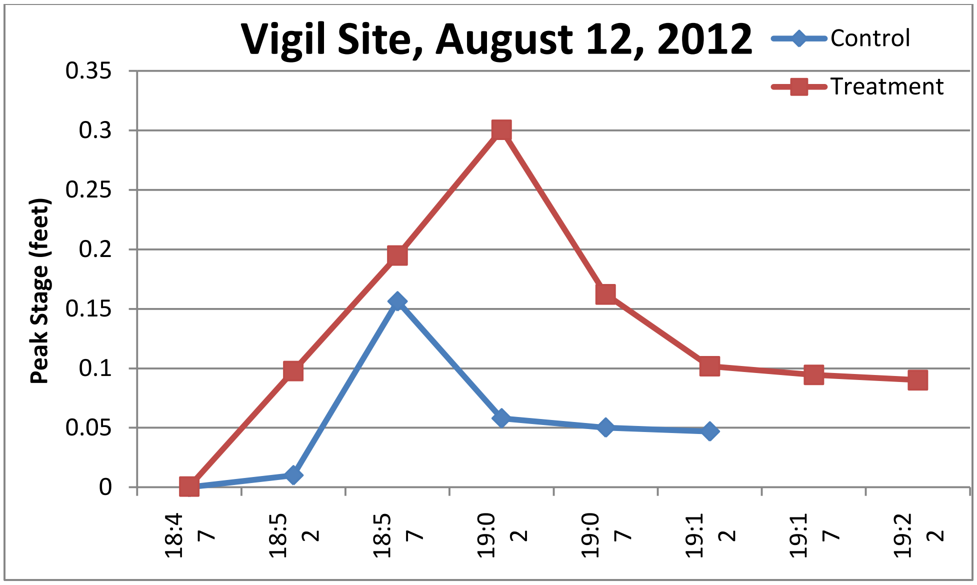


Figure 2.52. Hydrograph showing both paired plots from a Vigil storm flow event on August 12, 2012.

With respect to site hydrology, there are four conditions that could change because of forest thinning or from the effects of wildfire: 1) increased frequency of flow, 2) greater duration and volume of flow, 3) increased peak flow, and 4) a greater ratio of runoff to rainfall.

2.4.1 FLOW FREQUENCY, DURATION, AND VOLUME

Frequency of flow will be analyzed over time as data are collected; however, based on the period of record so far a baseline has been established for the remaining parameters. The parameters of flow duration and volume will likely be the least useful in assessing effects from forest thinning, as these parameters are highly dependent on rainfall duration and intensity. In general, the ponderosa sites generated flows of longer duration and greater volume than those in the piñon/juniper sites, which can likely be attributed the elevation differences (see Table 2.1). A summary of all the number of flow events (frequency), flow duration, and flow volume for the observed runoff events is shown in Table 2.8.

Table 2.8. Summary of Flow Frequency, Duration, and Volume, 2008–2012

Location	Number of Flow Events	Range of Duration (minutes)	Median Duration (minutes)	Range of Volume (cubic feet)	Median Volume (cubic feet)
Chilili treatment	3	55–840	512.5	245–17,751	9,197
Chilili control	8	25–715	167.5	36–2,564	920.5
Kelly control	4	25–35	30	38–392	54.5
Kelly treatment	1	15	15	69	69
Vigil treatment	13	15–115	40	46–197	117
Vigil control	7	20–80	50	123–290	218
Wester treatment	5	10–235	102.5	39–4,765	210
Wester control	7	10–760	90	42–9,458	444
All ponderosa	**23**	**10–840**	**95**	**35–9,458**	**468.5**
All piñon/juniper	**22**	**15–115**	**32.5**	**38–392**	**93**

2.4.2 PEAK FLOW/STAGE

Peak flow can be affected by the intensity of rainfall, but it is also a measure of the flashiness of flow; particularly in post-fire monitoring, runoff can occur rapidly with large peaks appearing very quickly. The highest peak stage was recorded at the Chilili treatment site during 2011 (0.11 m [0.37 feet]), while the greatest recorded peak flow of 1.29 feet was recorded at the Wester control site on July 2, 2010 (coinciding with the greatest observed daily rainfall). A summary of peak stage runoff events for all years is shown in Table 2.9.

Table 2.9. Peak Stage of Runoff Events, 2008–2012

Location	Number of Flow Events	Range of Peak Stage (feet)	Median Peak Stage (feet)
Chilili treatment	3	0.19–0.76	0.475
Chilili control	8	0.11–0.57	0.375
Kelly control	4	0.14–0.39	0.175
Kelly treatment	1	0.02–0.23	0.23
Vigil treatment	13	0.06–0.46	0.19
Vigil control	7	0.22–0.28	0.27
Wester treatment	4	0.15–0.85	0.19
Wester control	8	0.12–1.29	0.38
All ponderosa	**23**	**0.11–1.29**	**0.35**
All piñon/juniper	**22**	**0.02–0.46**	**0.175**

2.4.3 RAINFALL/RUNOFF RATIO

The rainfall/runoff ratio is perhaps the most useful parameter to observe. All other parameters can vary due solely to the magnitude or intensity of rainfall; the rainfall/runoff ratio normalizes the flow events, although intensity and antecedent soil moisture conditions will still affect the amount of runoff. The rainfall/runoff ratio looks at the percentage of rainfall falling on the watershed and leaving as surface runoff. A value of zero indicates no water left the watershed, and a value of 1 would indicate all water falling on the watershed was observed leaving as surface runoff (this is highly unlikely). In natural settings, the rainfall/runoff ratio typically falls in the 0.1 to 0.3 range. The rainfall/runoff ratios observed during flow events from the watersheds are summarized in Table 2.10. Note that some rainfall/runoff values were not calculated due to missing rainfall data. In general, rainfall/runoff ratios were highly variable, including some extremely high values; however, almost 70% of the flow events had rainfall/runoff ratios of less than 0.10. Ponderosa sites exhibited a slightly lower rainfall/runoff ratio than piñon/juniper sites, which can likely be attributed to the large amounts of litter and duff that serve as a sponge and retain the water.

Table 2.10. Rainfall/Runoff Ratio for Observed Flow Events, 2008–2012

Location	Number of Flow Events	Range of Rainfall/Runoff Ratio	Median Rainfall/Runoff Ratio
Chilili treatment	3	0.01–0.561	0.056
Chilili control	8	0.003–0.550	0.022
Kelly control	4	0.045–0.460	0.088
Kelly treatment	1	–	–
Vigil treatment	14	0.022–0.160	0.056
Vigil control	7	0.063–0.654	0.439
Wester treatment	4	0.029–0.058	0.044
Wester control	8	0.015–0.848	0.407
All ponderosa	**23**	**0.003–0.848**	**0.058**
All piñon/juniper	**22**	**0.022–0.479**	**0.075**

2.5 TREES

For details regarding the research questions, monitoring protocols, and plot design for vegetation monitoring, as well as a full literature review, please refer to the 2008 Monitoring Plan (SWCA 2008).

2.5.1 TREES AND WILDFIRE FUELS

Tree monitoring measurements in the fall of 2012 included observations of canopy dieback, disease or damage, live and dead status, and canopy and bole measurements.

Basal Area Measurements

Basal area measurements were taken in spring 2011. Since basal areas are unlikely to have changed between 2011 and 2012, no basal area measurements were taken during this field season. 2011 basal area measurements are shown in Table 2.11.

Table 2.11. Treatment Designation for All Plots (with basal area totals), 2011

Site	Average Basal Area (square feet/acre) 2008	Average Basal Area (square feet/acre) 2011
Chilili treatment	210	79
Chilili control	194	194
Kelly control	106	106
Kelly treatment	155	47
Vigil treatment	124	39
Vigil control	129	129
Wester treatment	220	99
Wester control	213	213

Stand Structure

Diameter measurements of trees are used below to demonstrate the stand structure and various size classes at each site. Figure 2.53 and Figure 2.54 show the size class structure of ponderosa pine trees (diameter at breast height [DBH]) at the ponderosa sites, Chilili and Wester. Figure 2.55 and Figure 2.56 show the size class structure of piñon and juniper trees (diameter at root crown [DRC]) at the piñon/juniper sites, Kelly and Vigil.

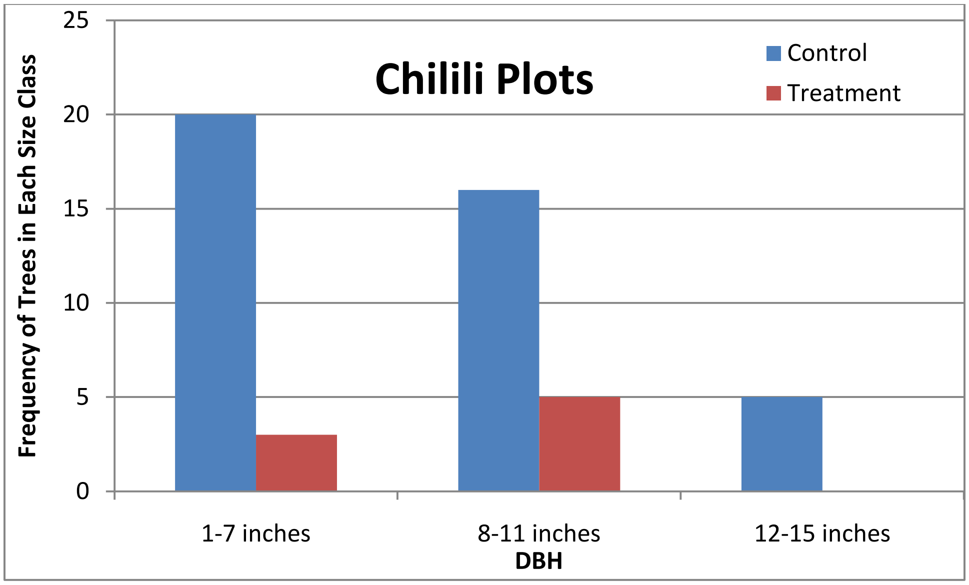


Figure 2.53. Size classes of ponderosa pine trees measured at DBH on the Chilili control and treatment plots.

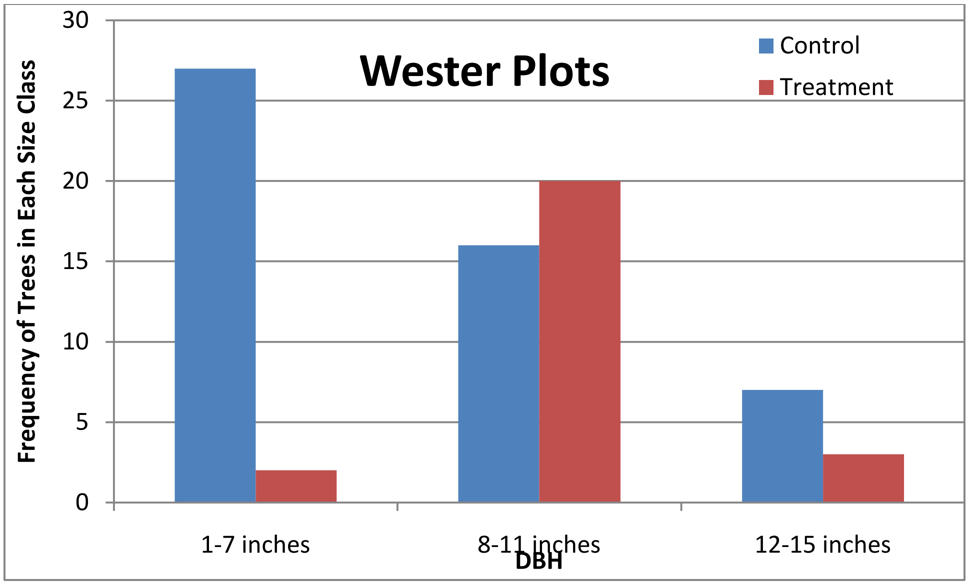


Figure 2.54. Size classes of ponderosa pine trees measured at DBH on the Wester control and treatment plots.

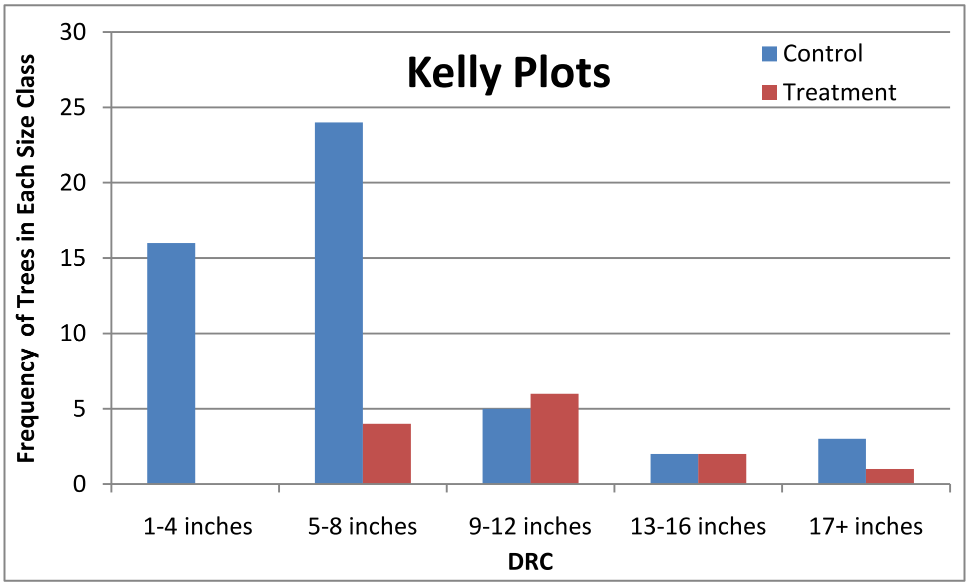


Figure 2.55. Size classes of piñon/juniper trees measured at DRC on the Kelly control and treatment plots.

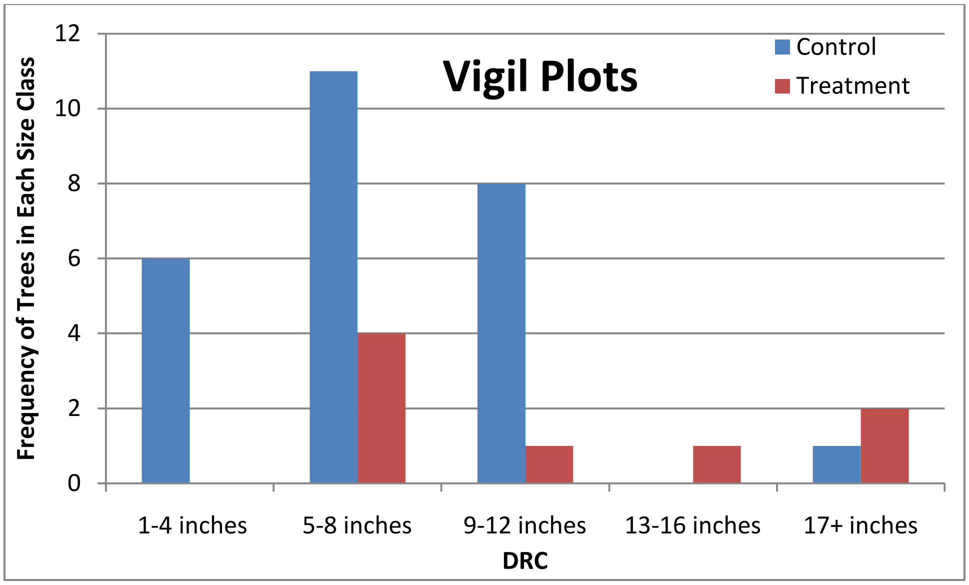


Figure 2.56. Size classes of piñon/juniper trees measured at DRC on the Vigil control and treatment plots.

Figure 2.53 through Figure 2.56 illustrate the difference in size class distribution between control and treatment plots for each site. At both ponderosa sites (Chilili and Wester), the control plots have a greater number of trees distributed in the lower size classes (1–7 inches, and to a lesser extent 8–11 inches), compared to the treatment plots where trees are more uniformly distributed across size classes and the number of smaller-diameter trees (1–4 inches) are much reduced. For the piñon/juniper control plots on both sites (Kelly and Vigil), the greatest numbers of trees fall in size classes 5–8 and 9–12 inches DRC, respectively, and there are fewer large-diameter trees relatively. Both piñon/juniper treatment plots had no trees less than 4 inches DRC, and the remaining trees are more evenly distributed across size classes than the control plots.

Crown Dieback

Percent crown dieback is the percentage of the leafy canopy of each tree that showed signs of physiological stress (i.e., brown needles and leaves). Crown dieback could result from a number of environmental factors, for example, drought, insect attack, competition, and disease. Measurement of crown dieback is highly dependent on the time of year; as a result, efforts are made to take measurements consistently during late September to early October each year. Figure 2.57 illustrates crown dieback across all sites.

Crown dieback levels from 2008 to 2012 are presented below by site and year (see Figure 2.57). This graph clearly shows the inherent variability associated with measuring crown dieback. Crown dieback of individual trees can be highly variable across a plot based on tree size and position and the environmental factors it is exposed to. Die back levels for 2012 were low compared to previous years across all plots, except on the Chilili plots where dieback had increased by 8% to 10% on both plots. We believe that dieback levels are within the normal range of variability for all five years.

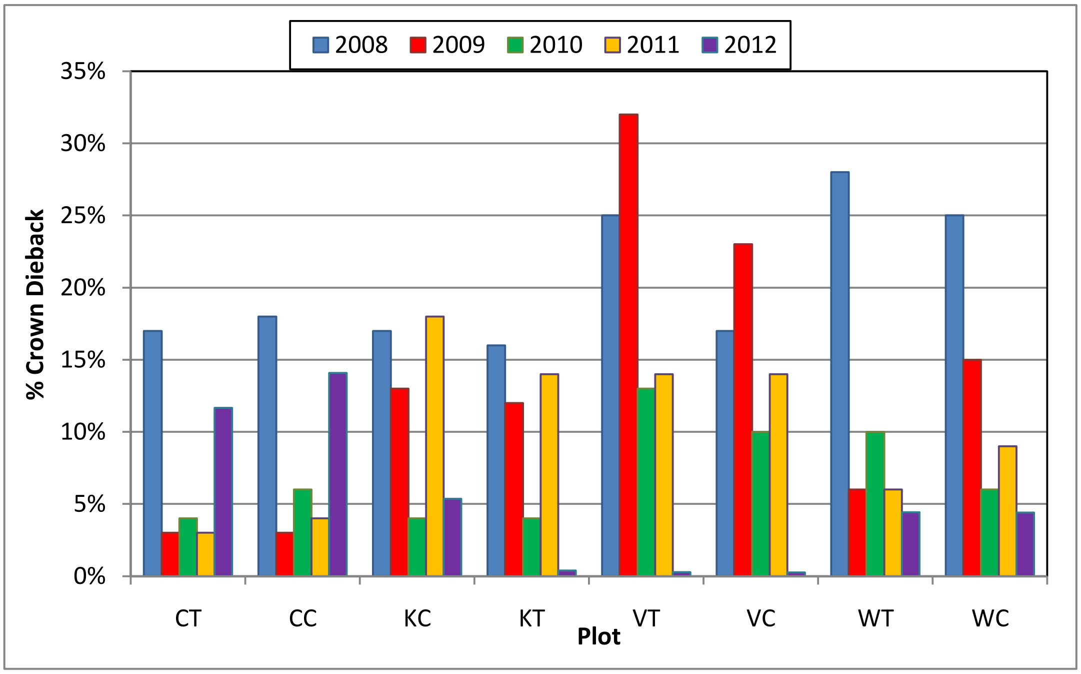


Figure 2.57. Average percent crown dieback of tree canopies for each thinning plot, 2008–2012.

Tree Mortality

In total, 613 trees were tagged across all watersheds in this study with species composition from ponderosa pine, piñon pine, oneseed juniper, and alligator juniper (*Juniperus deppeana*). In 2008 there were no dead trees tagged on any plots. Natural tree mortality has been low across all plots in all five years (Figure 2.58).

The 2012 season saw the highest mortality (not attributed to tree cutting) of all five years, with most mortality recorded on previously thinned plots (with the exception of Wester). The greatest mortality was recorded on the Vigil treatment plot where 36% of the remaining live trees died between 2011 and 2012. The Vigil treatment plot also exhibited higher crown dieback than other plots in previous years, suggesting that the trees on that plot were experiencing environmental stress possibly leading to the high mortality in 2012. Conversely, the Vigil control plot showed no tree mortality in any of the five years. The Chilili and Kelly treatment plots also suffered tree mortality of a little less than 10% in 2012. The Wester control plot was the only control plot that exhibited mortality in 2012. This plot had suffered tree mortality in 2009, 2011, and 2012, which is likely a result of competitive stress and/or beetle damage. A number of trees at the Wester site suffered broken/dead tops and showed signs of drought stress. Mortality at both treatment and control plots, which may continue to suffer in subsequent years, will be monitored every fall.

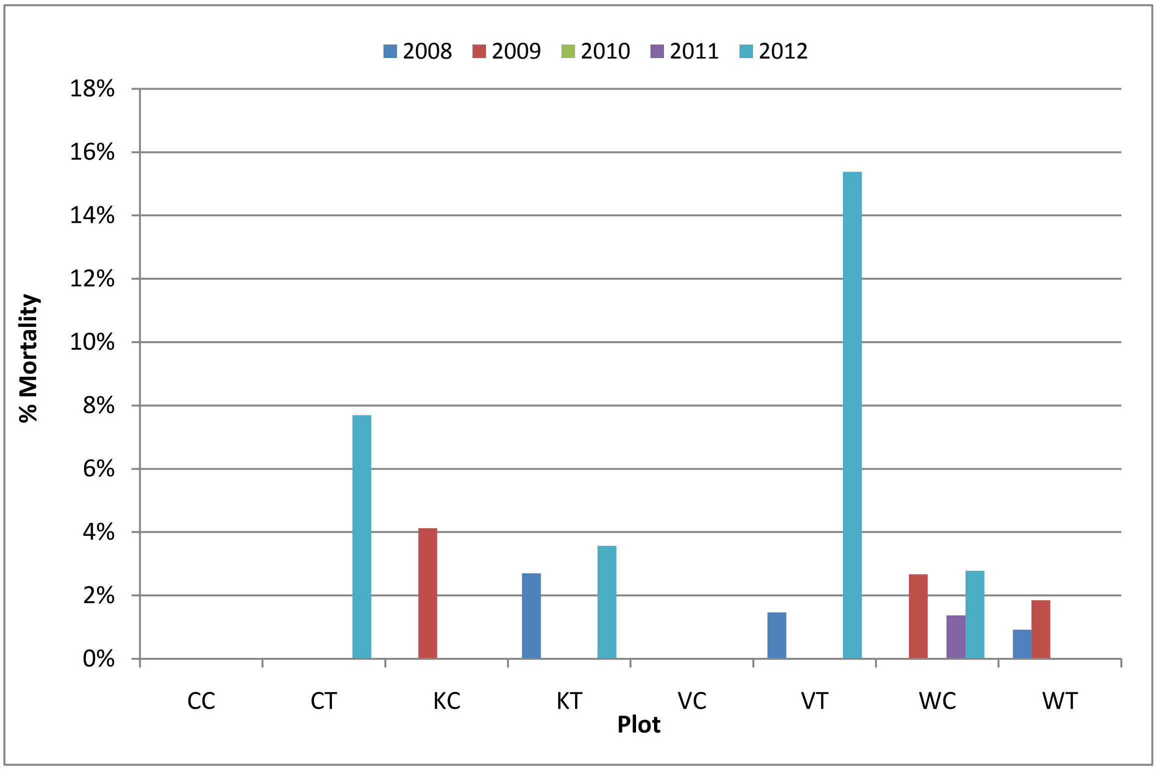


Figure 2.58. Percent tree mortality recorded across all thinning plots from 2008–2012. Percent mortality is recorded in relation to tree status in 2008.

Wildfire Fuels

Fuel measurements have been taken using Brown's transect protocols (Brown 1974) during the fall monitoring season from 2009 to 2012. Measurements are taken within the four circular tree plots on each paired watershed. Refer to the 2008 Monitoring Plan for detailed monitoring protocols and an explanation of fuel class sizes (SWCA 2008). Figure 2.59 and Figure 2.60 illustrate the percent cover by the various fuel classes on each thinning plot measured in 2011 and 2012, respectively.

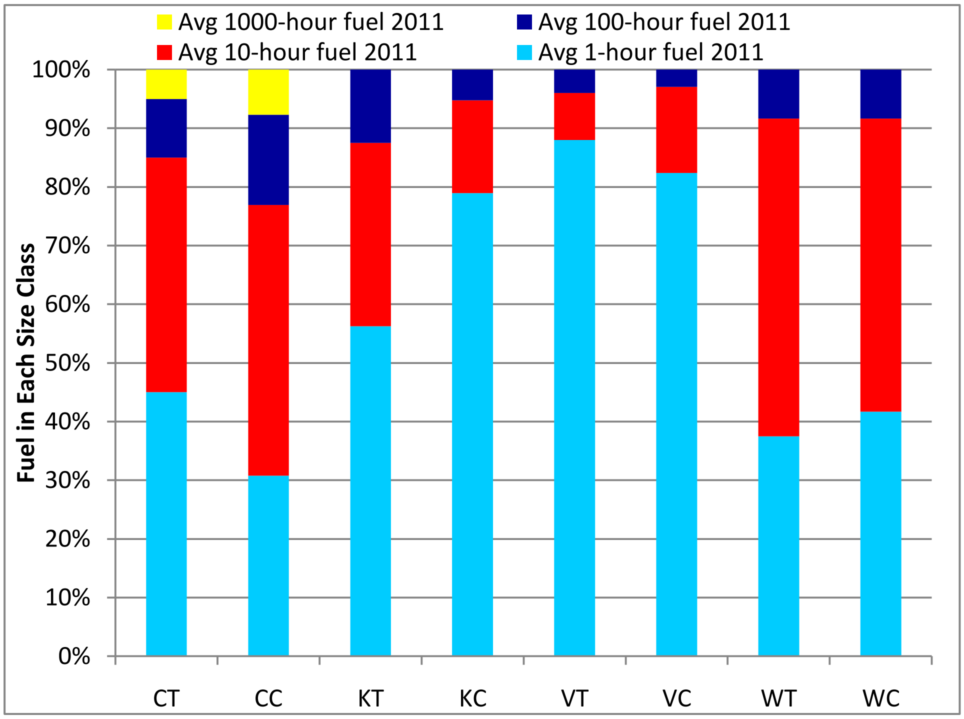


Figure 2.59. Percentage of fuel in each fuel particle size class for 2011 (1-hour, 10-hour, 100-hour, 1,000-hour) on all thinning plots.

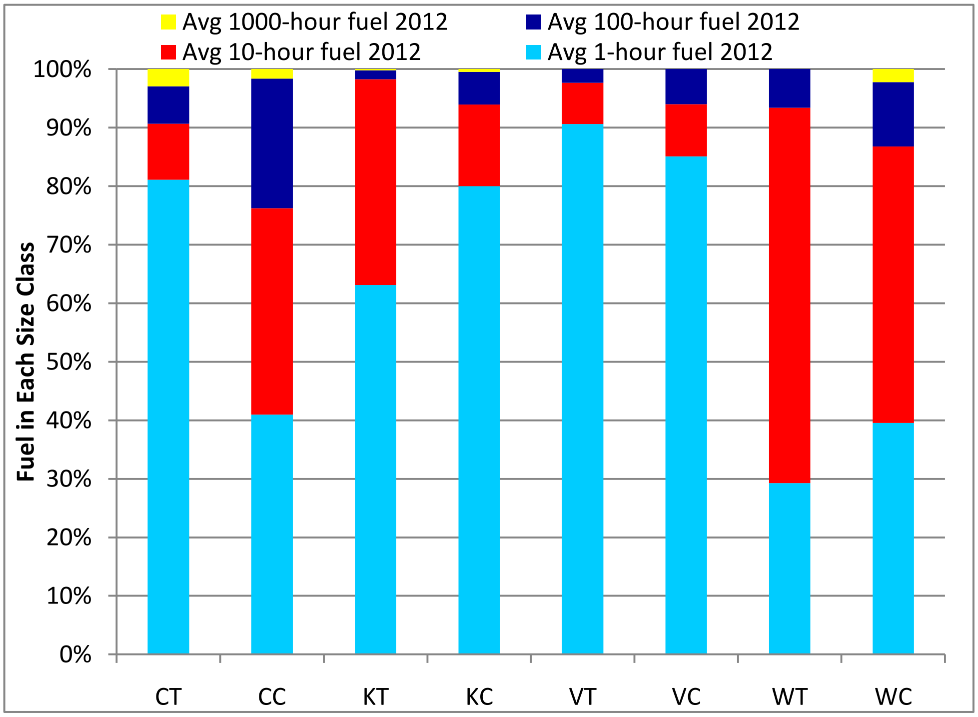


Figure 2.60. Percentage of fuel in each fuel particle size class for 2012 (1-hour, 10-hour, 100-hour, 1,000-hour) on all thinning plots.

With reference to Figure 2.59 and Figure 2.60, the piñon/juniper plots tended to have a slightly higher accumulation of 1-hour fuels (fine fuels 0.0–0.6 cm [0.00–0.25 inch] in diameter) compared to the ponderosa plots, with the exception of the Chilili treatment plot. Conversely, 100-hour and 1,000-hour fuels (woody debris > 2.5 cm [1 inch] in diameter and > 8 cm [3 inches] in diameter, respectively) were more common at the ponderosa sites. Each paired plot was relatively consistent in terms of fuel loading by size class, except in the case of Chilili where the treatment plot had significantly higher 1-hour fuels; 1-hour fuels at the treatment plot have increased on 2011 levels.

Figure 2.61 shows that both Chilili plots had considerably more duff and litter than the other plots. The volume of litter and duff found on the forest floor is related to both productivity and decomposition. There is very little difference in duff and litter depths between treatment and control sites because residual wood chips left over from treatment were spread thinly following the required prescription, so as not to significantly alter the fuel loading at each site.

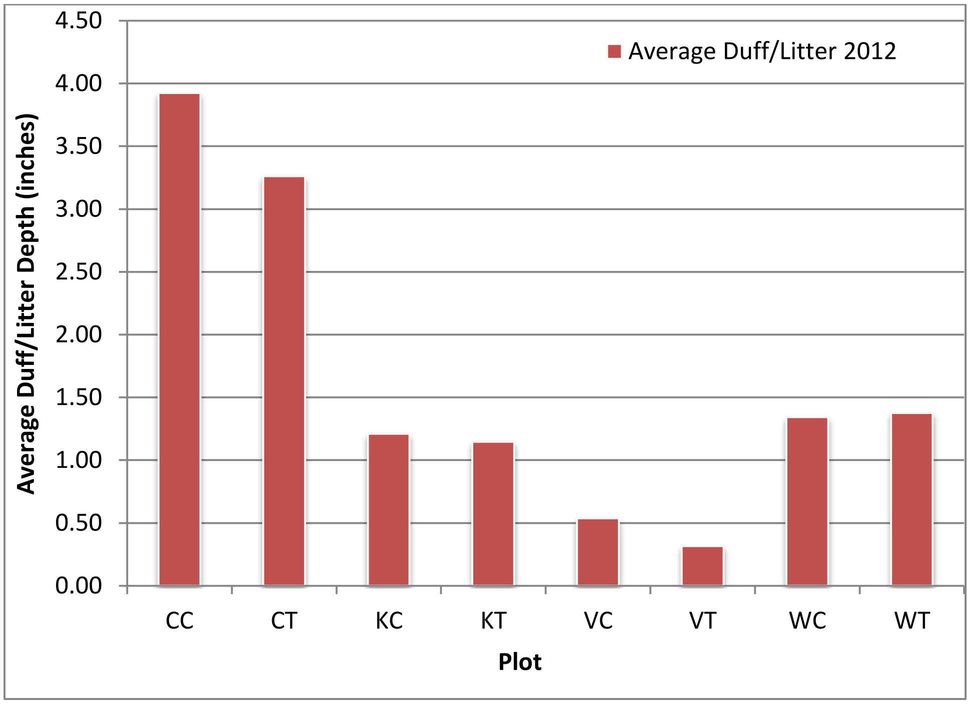


Figure 2.61. Average combined duff and litter depths on all thinning plots, measured in inches for 2012.

The variation in litter and duff between the Wester and Chilili sites could be related to differing decomposition rates as a result of differences in elevation and moisture regimes. Decomposition has been found to be positively correlated with moisture gradient with greater decomposition on more productive sites (Keane 2008); this would explain the greater depths of duff at Chilili (a higher elevation and more productive ponderosa pine forest) versus Wester (a lower elevation, drier and more open stand ponderosa pine forest). Overall duff and litter depths were higher on the ponderosa sites than the piñon/juniper sites, which is to be expected since litter and duff cover in ponderosa pine is almost continuous across the landscape, while litter and duff is isolated in patches immediately below the canopies of trees in piñon/juniper woodlands.

Figure 2.62 shows the tons/acre of woody dead and downed fuels at each site. The piñon/juniper sites had relatively low fuel loading compared to the ponderosa sites, because the piñon/juniper sites tended to have fewer large-diameter woody fuels. The piñon/juniper sites exhibited greater fine fuel loading, however, likely due to lower canopy cover that permits the growth of graminoids and forbs (Figure 2.63 and Figure 2.64). Shrub cover was limited at both piñon/juniper sites. The Wester plots also had low loading compared to the Chilili plots (see Figure 2.64); this site was relatively open, with fewer 1,000-hour fuels consequently lowering the tons/acre totals. Chilili treatment and control plots have noticeably higher fuel loadings than all other sites; these are dense plots with many more 1,000-hour fuels (many downed trees and stumps) (see Figure 2.64), which raised their total tons/acre. The fuel loading at the Chilili treatment site increased considerably in 2012, while the control site had lower fuel loading than 2011 levels; this can be attributed to a reduction in 1,000-hour fuels on the control plot from 2011 to 2012. The high levels for the Chilili control in 2012 are likely due to heavy concentrations of large-diameter fuels that have accumulated at that site.

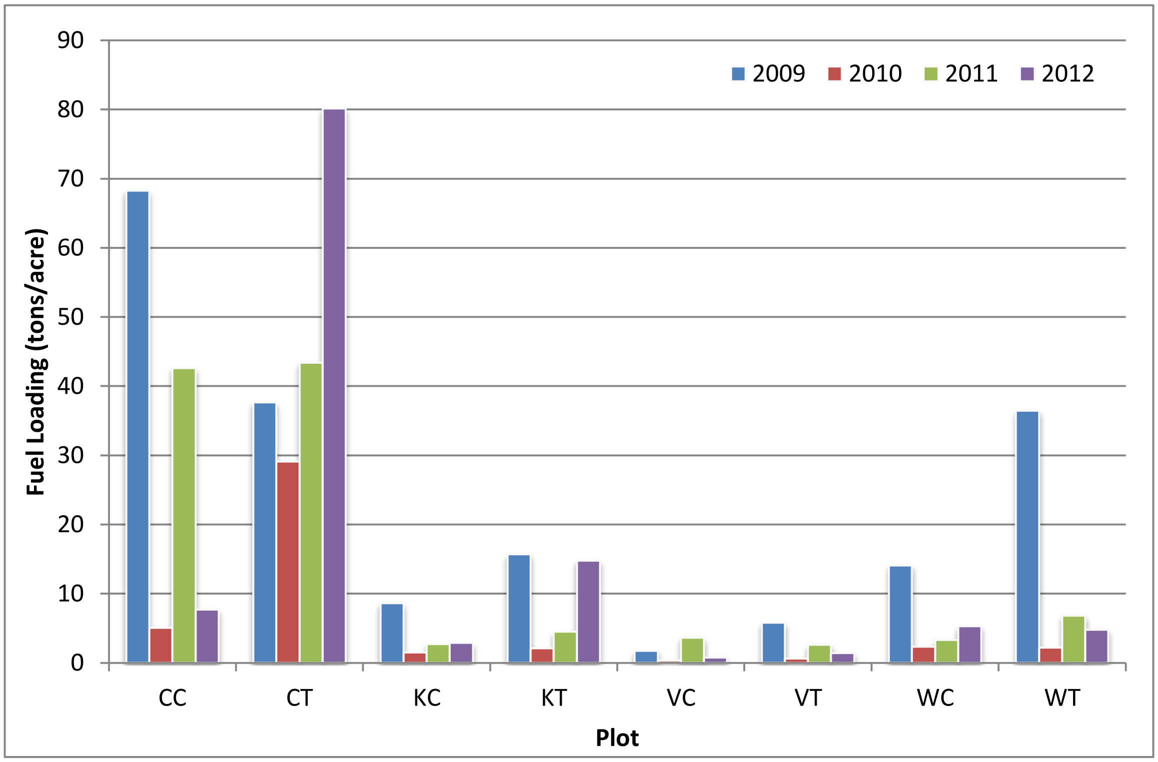


Figure 2.62. Fuel loading (in tons/acre) of dead and downed woody debris for all thinning plots, 2009–2012.

Figure 2.63. **Wester control, showing the low fuel loading on the plot and lack of large-diameter dead and downed fuels.**

Figure 2.64. **Chilili control, showing high fuel loading with evidence of large-diameter dead and downed fuels.**

2.6 VEGETATION AND GROUND SURFACE COVER AND TREE CANOPY VISUAL STRUCTURE MONITORING

Herbaceous vegetation was again measured along line intercepts and quadrats from the vegetation and soils plots at each site as presented in the 2009 Annual Report. Additionally, in 2010, SWCA initiated more extensive vegetation measurements on the wildlife plots in order to characterize vegetation composition and structure as habitat for wildlife on those plots and to provide quantitative data to determine how vegetation or habitat changed on the wildlife plots relative to forest thinning treatments. Those vegetation measurements were taken again in 2011 and 2012 and will be used to characterize vegetation changes on study plots relative to forest thinning treatments. Vegetation was measured from thirty-six 1-m² (10.8-square-foot) quadrats located at each of the 36 permanently marked rodent trapping stations on each wildlife plot in a six by six grid, with stations at 10-m (33-foot) intervals (50 × 50–m [164 × 164–foot] plot). All plant species including woody trees and shrubs were measured on each of those square-meter quadrats. A list of all plant species from all study sites is presented in Appendix A. The total canopy cover and maximum height in centimeters of each species was measured per quadrat. Vegetation quadrat data were also categorized by growth form (e.g., tree, shrub, cacti, grass, forb) and life history (annual or perennial). Tree canopy cover was often high above the quadrats and was estimated by visually projecting the dimensions of the quadrat above to minimize optical parallax. In addition to vegetation, soil surface cover categories also were measured on the quadrats, including bare soil, leaf litter (and dead and downed woody material), rock, and cryptobiotic (cryptogam) soil surface crusts. Measures of wood chip coverage on the ground resulting from forest thinning practices were added in 2011 and are continued each year including 2012.

The vegetation and ground cover data measured from the replicated quadrats on wildlife plots provides the most appropriate data for statistical testing for differences in those cover values resulting from thinning treatments, because there is sufficient sample replication to perform parametric statistical tests. Also, those 36 sampling quadrats were evenly distributed over relative large areas (plots 50 m [164 feet] on a side), providing a good sampling representation of each of the paired study plots. Data from each vegetation and ground cover type were used to test for differences between paired plots using a standard parametric t-test. Ideally, there should be no significant differences between paired plots prior to thinning treatments. If thinning has an effect on any of those cover types, then a significant difference would be expected following thinning treatments.

Tree canopy structure on the wildlife plots was measured by using a standard spherical densiometer for measuring tree upper canopy closure, and the vertical structure method as presented below to measure lower tree canopy closure. Tree canopy structure was measured in the fall of 2010 and 2011 when other vegetation measurements were made. Vegetation vertical canopy structure was measured on each of the four vegetation and soils subplots, and on all of the wildlife monitoring plots. The method was adapted from Herrick et al. (2005) and consisted of a 2-m-long (6.6-foot-long), 5-cm-diameter (2-inch-diameter) white polyvinyl chloride (PVC) pipe pole partitioned into three different 2-m (6.6-foot) height layers, each with continuous 10-cm (4-inch) black/white increment markings. The 2-m (6.6-foot) PVC measurement pipe was partitioned into four different vertical 0.5-m (1.6-foot) segments or heights above the ground surface: segment one = 2.0–1.5 m (6.6–4.9 feet), segment two = 1.5–1.0 m (4.9–3.3 feet), segment three = 1.0–0.5 m (3.3–1.6 feet), and segment four = 0.5–0.0 m (1.6–0.0 feet) above the ground surface. An observer recorded vegetation canopy obstruction of the black and white marked areas on the pole, while another person held the pole vertical at three locations across the center line of each 30-m (98-foot) vegetation and soils monitoring subplots, one reading at 10 m (33 feet), one at 20 m (66 feet), and one at 30 m (98 feet). On the vegetation/soils plots, the observer was located 10 m (33 feet) toward the center of the plot from the pole for each canopy measurement. An overall visual obstruction average score was then calculated for each segment of the pole over each of the three lines per subplot, and an overall average score for each segment was then calculated for each plot.

On the wildlife monitoring plots, both vertical structure and densiometer measurements were taken at 11 locations on each wildlife plot at 12 existing vegetation quadrat points, along the middle lines of six quadrats running north-south, and east-west through the middle of each plot, at 10-m (33-foot) intervals. Vertical vegetation structure profiles are not only important for assessing wildlife habitat, but also for fire fuels structure.

Changes in tree canopy cover as measured by a spherical densitometer showed a reduction in tree upper canopy cover on all of the treatment plots in 2011 and 2012 compared to the control plots following tree thinning in late 2010 (Figure 2.65). However, apparently due to large variation values from measurement points, those differences were not statistically different except for the Wester ponderosa pine site where tree canopy cover was significantly less on the plot that was thinned. Changes in tree lower canopy vertical structure from ground level to a height of 2 m (6.6 feet) also showed a reduction in lower tree canopy density on the plots that were thinned when comparing the treatment to control plots after thinning in 2011, and in 2012 (Figure 2.66). In 2010 prior to tree thinning, paired plots and the two ponderosa pine sites, Chilili and Wester, had significantly different lower canopy structure ($P = 0.006$, $P = 0.02$, respectively), but treatment and control plots at the Kelly and Vigil piñon/juniper sites were not different. In 2011 following tree thinning, lower tree canopy densities were significantly different at the Chilili and Wester ponderosa pine sites, even more than in 2010 ($P > 0.0001$, $P = 0.001$, respectively), and significantly different at the Vigil piñon/juniper site ($P < 0.0001$), but not at the Kelly piñon/juniper site. These differences were still present in 2012. These findings indicate that forest thinning had a greater effect on lower canopy structure of trees than the upper canopy and that forest thinning did open the tree canopy on thinned plots compared to adjacent non-thinned control plots. Over time, the reduced tree upper and lower canopy structures will likely develop on the treated plots, but such change will take many years as new trees become established.

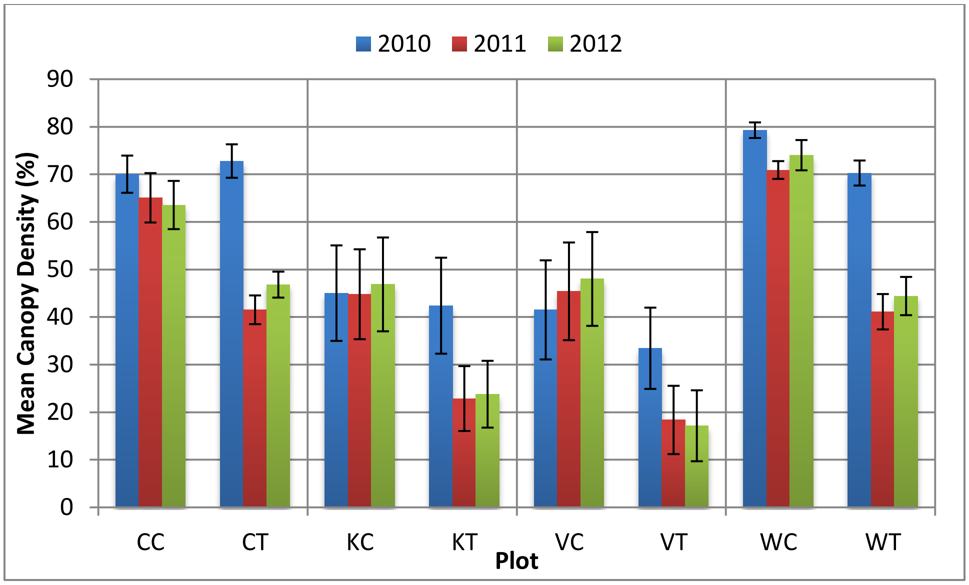


Figure 2.65. Upper tree canopy cover scores as measured from a spherical densiometer on each of the monitoring plots. Densiometer scores range from 0 to 96, similar to percent cover.

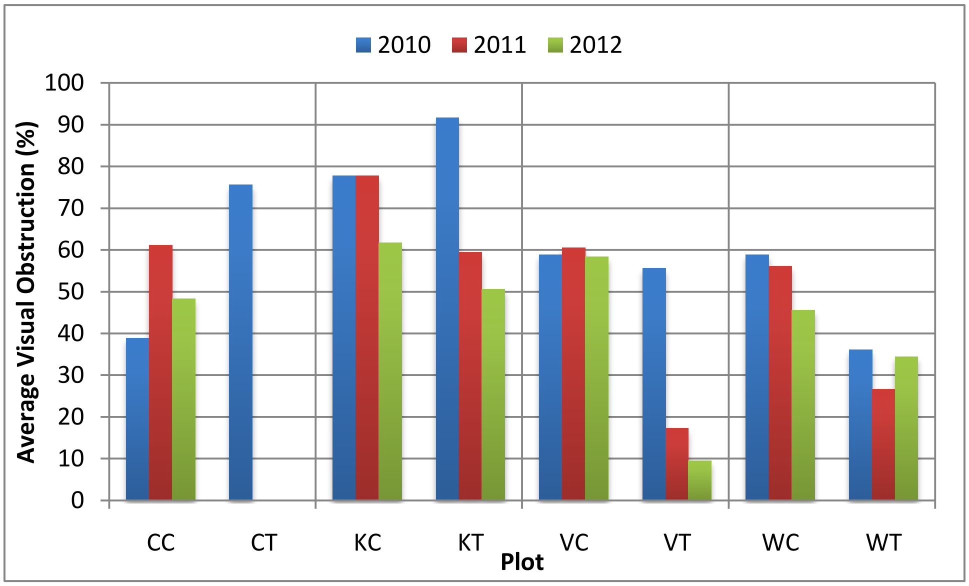
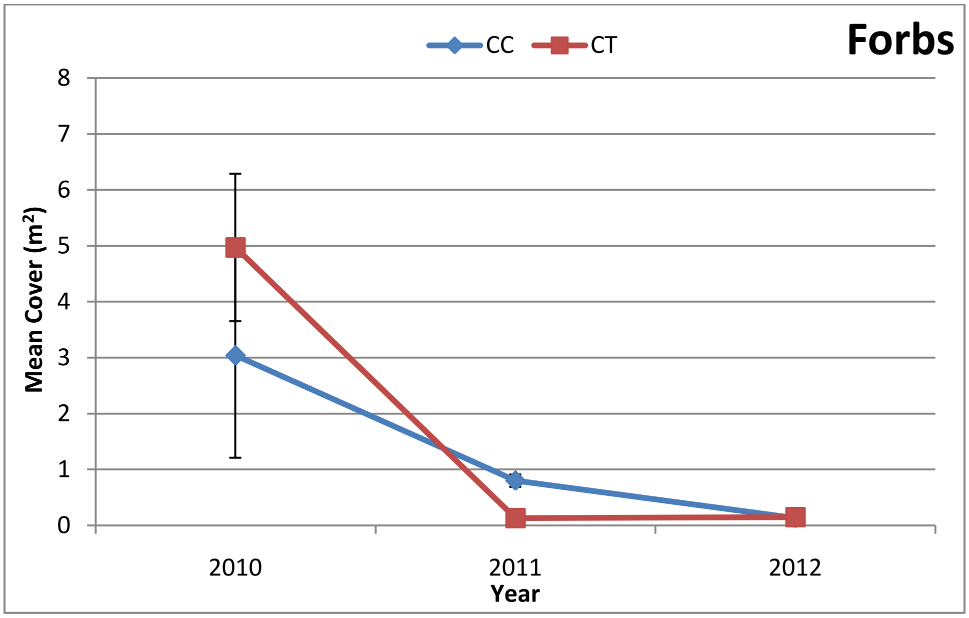
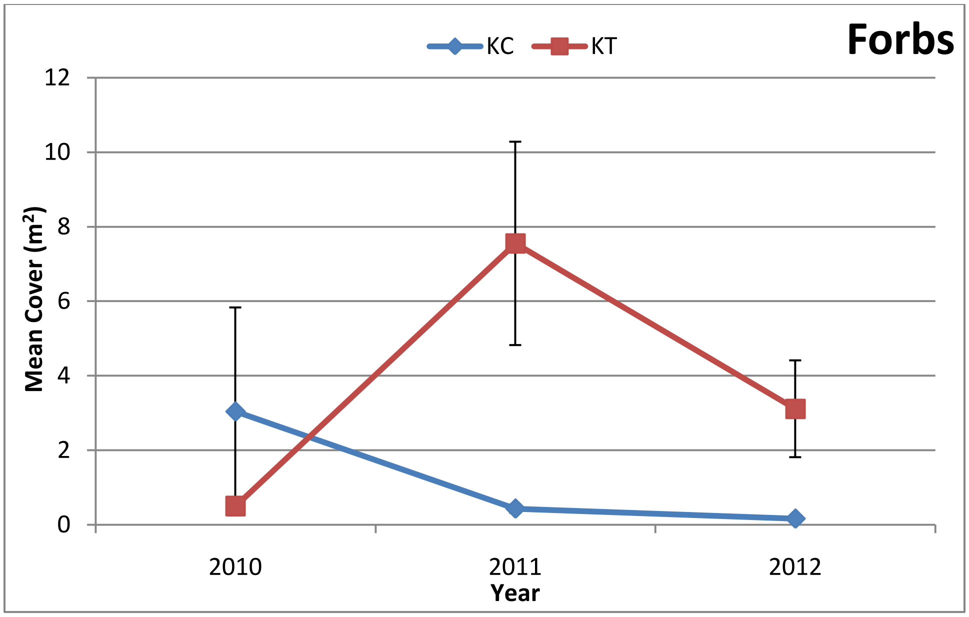


Figure 2.66. Vegetation vertical structure cover from ground level to a height of 2 m (6.6 feet), measured with a vertical structure pole. The higher the score, the denser the canopy cover (note that Chilili treatment plot had a value of zero in 2011 and 2012).

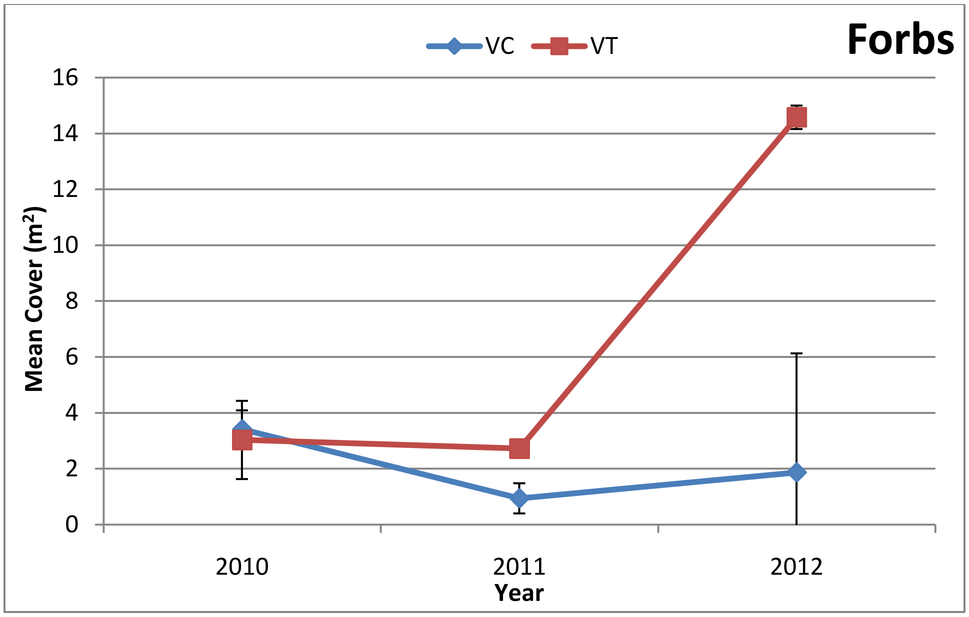
Results for herbaceous understory vegetation and soil surface cover types measured from the thirty-six 1-m^2 (10.8-square-foot) quadrats in the fall 2012 are presented in Figure 2.67, a–x, providing separate graphs for forbs, grasses, and each soil surface cover type. Results from 2010 prior to tree thinning treatments and in 2011 one year following thinning treatments also are presented in Figure 2.67, a–x, to show annual change in those variables over time. Results of statistical paired t-tests of differences between mean cover values for each of the different vegetation and ground surface cover types measured in 2012 and shown in Figure 2.67 are presented in Table 2.12.



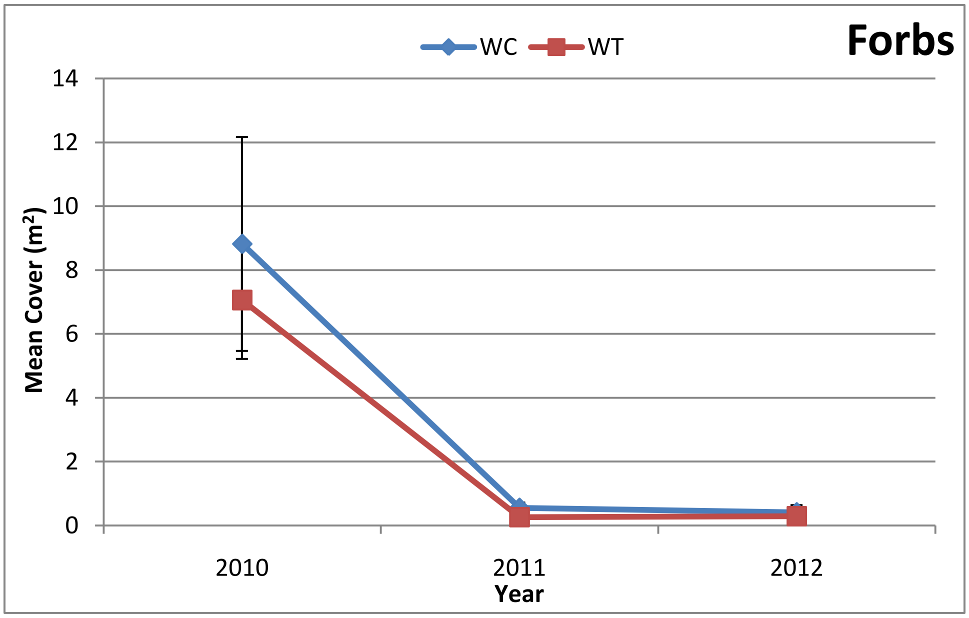
a. Forbs, Chilili.



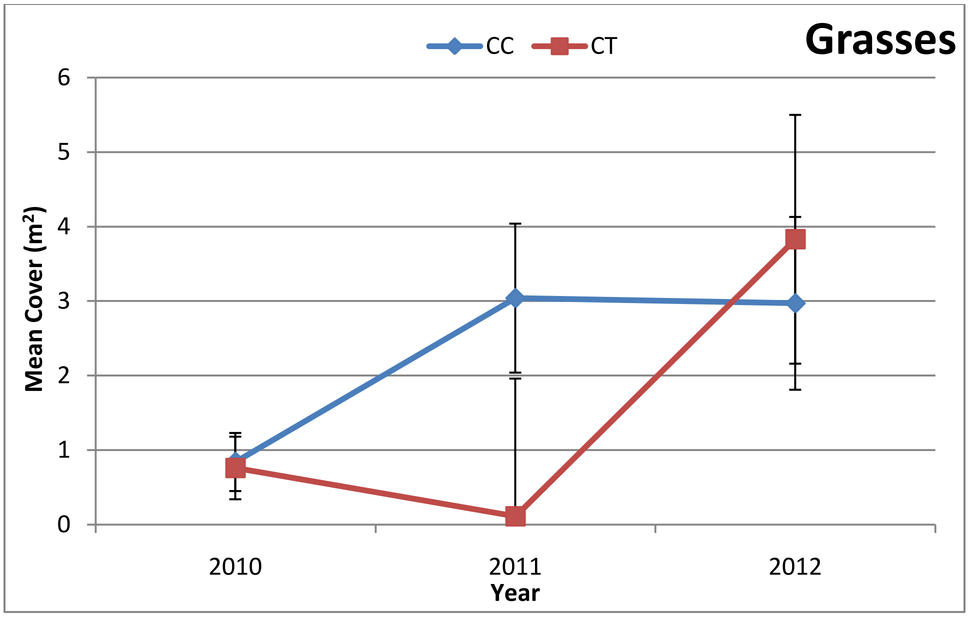
b. Forbs, Kelly.



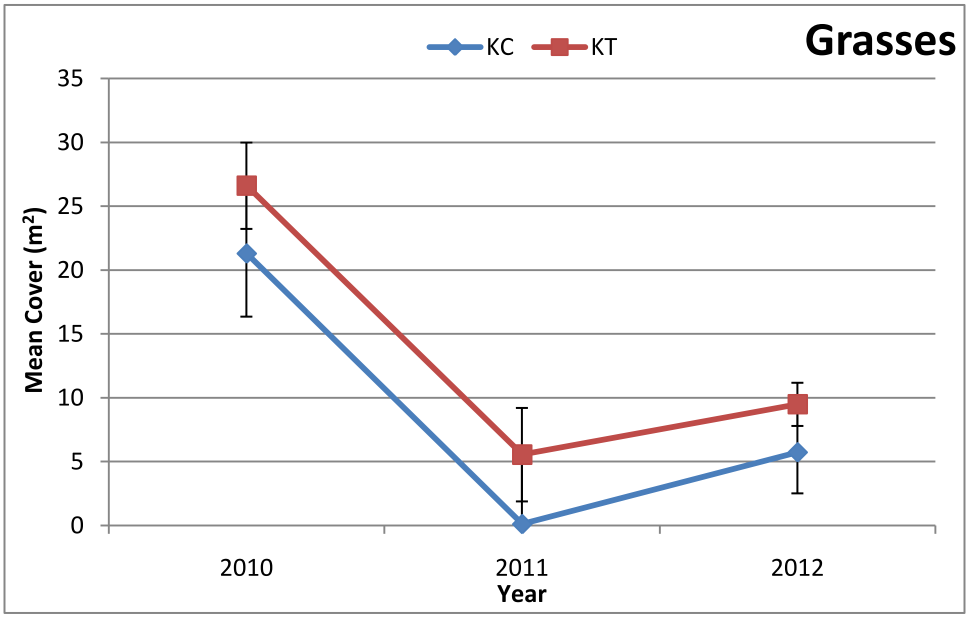
c. Forbs, Vigil.



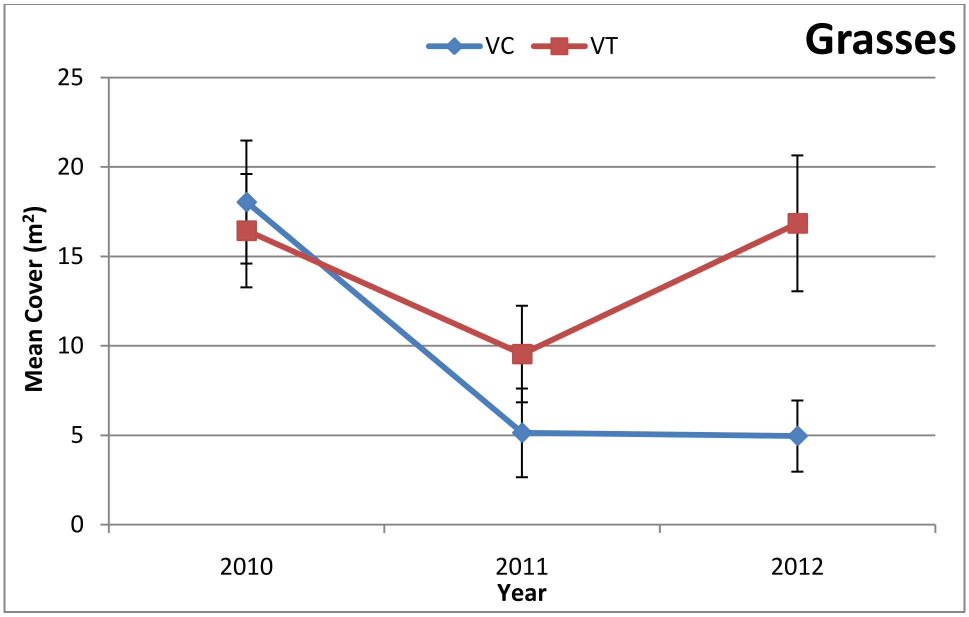
d. Forbs, Wester.



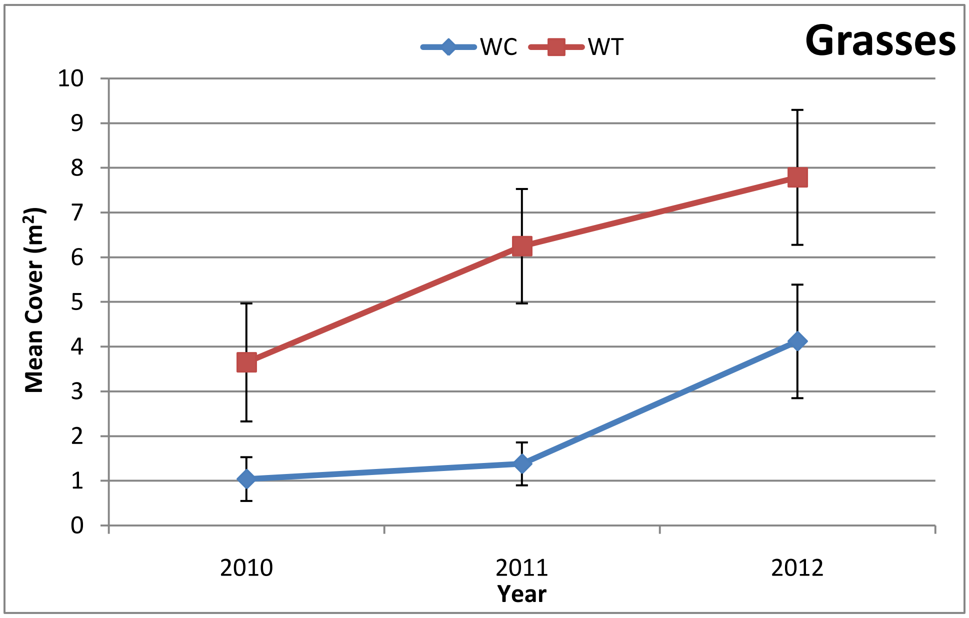
e. Grass, Chilili



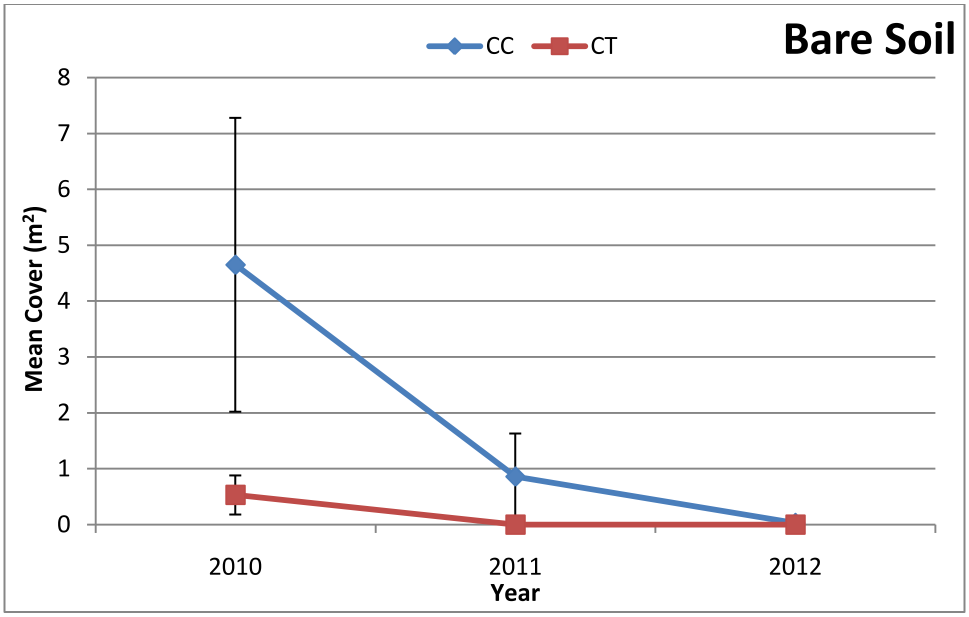
f. Grass, Kelly.



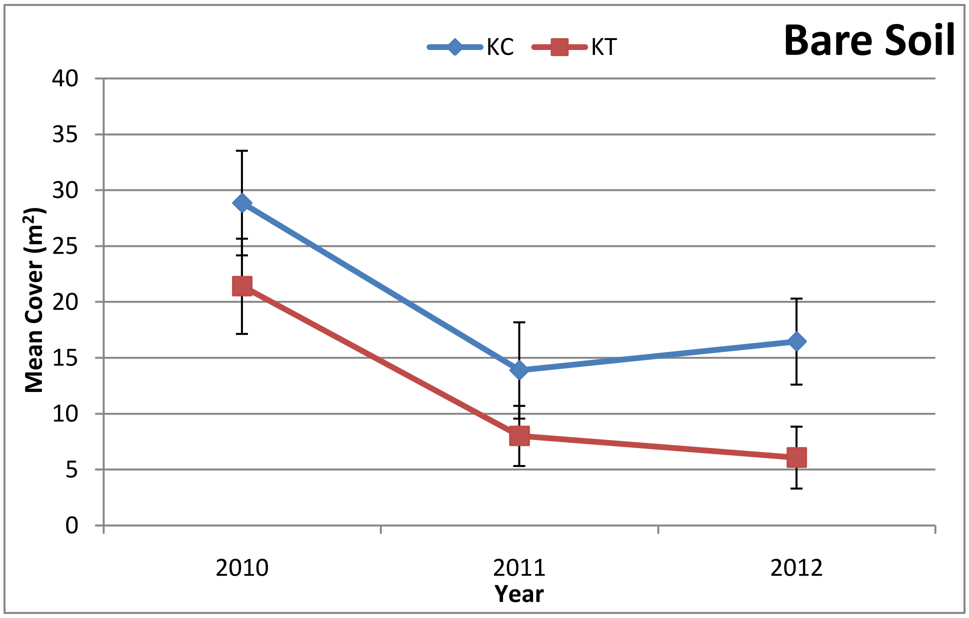
g. Grass, Vigil.



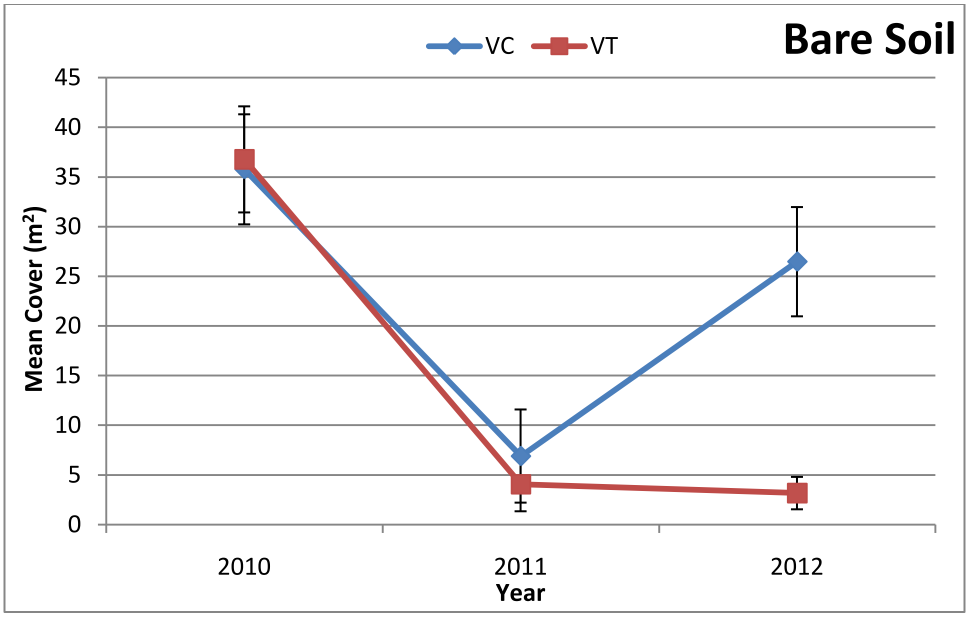
e. Grass, Wester.



i. Bare soil, Chilili.



j. Bare soil, Kelly.



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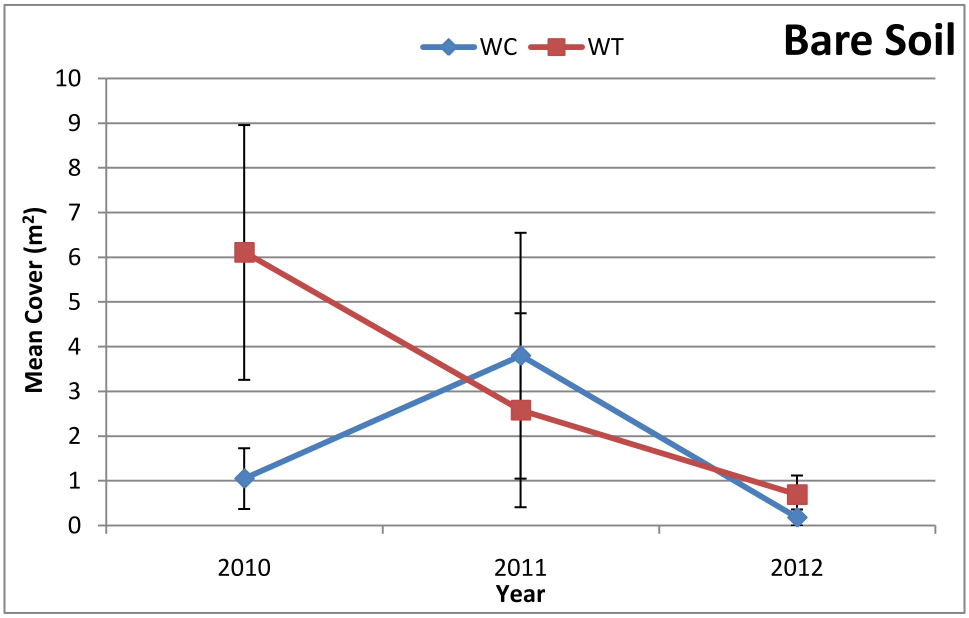
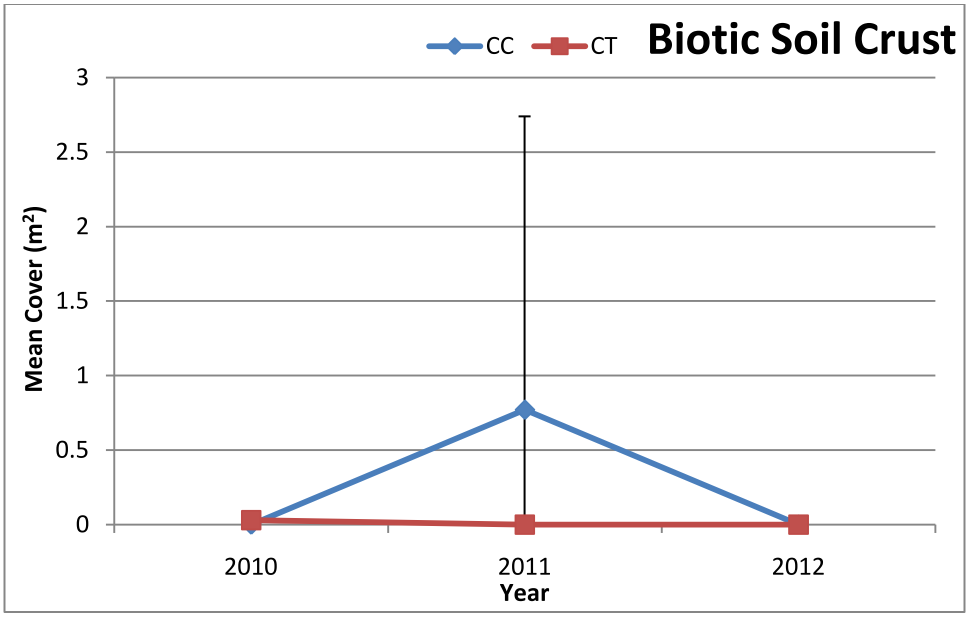
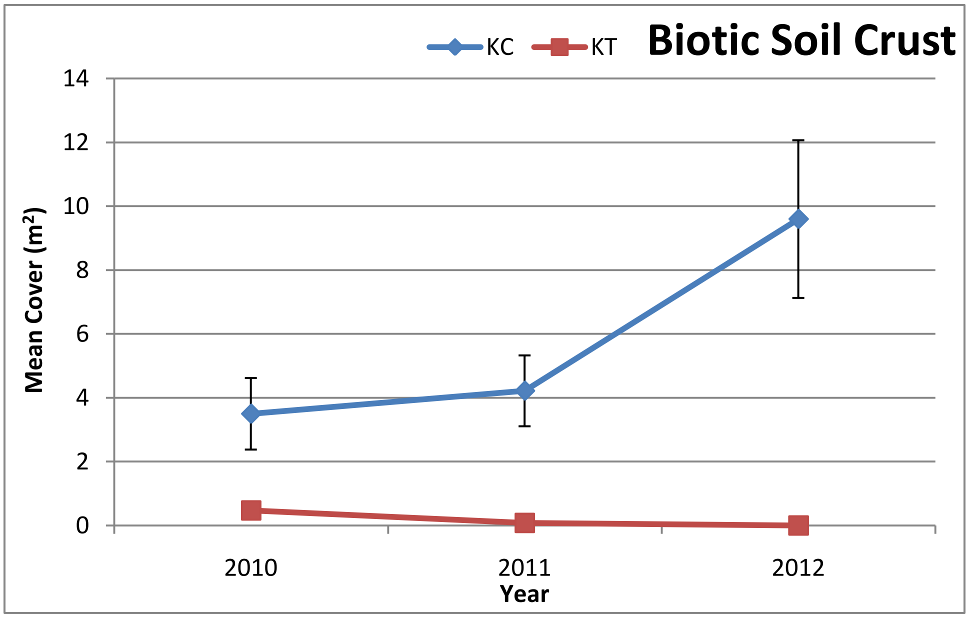


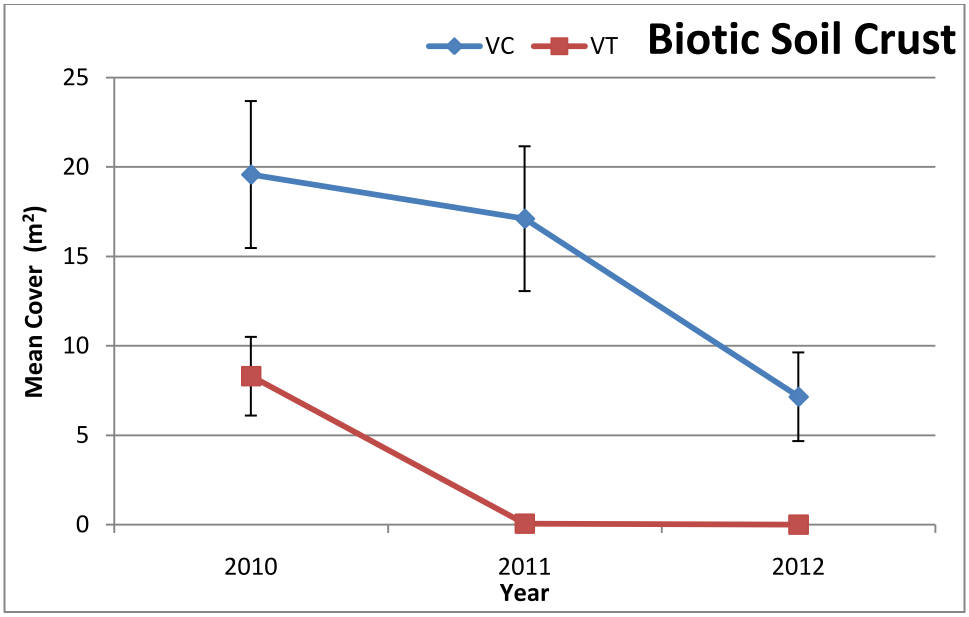
l. Bare soil, Wester.



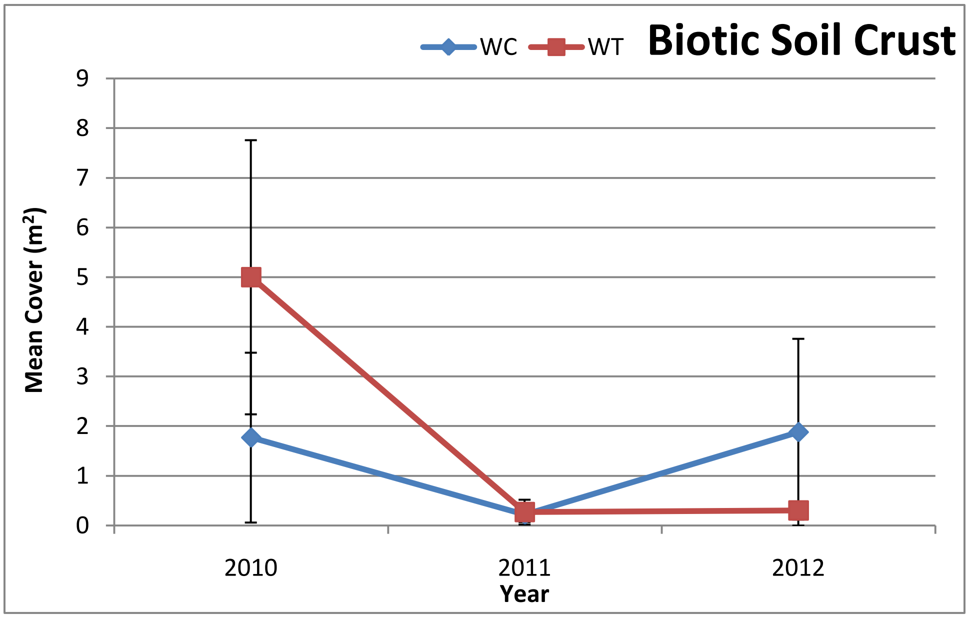
m. Biotic soil crust, Chilili.



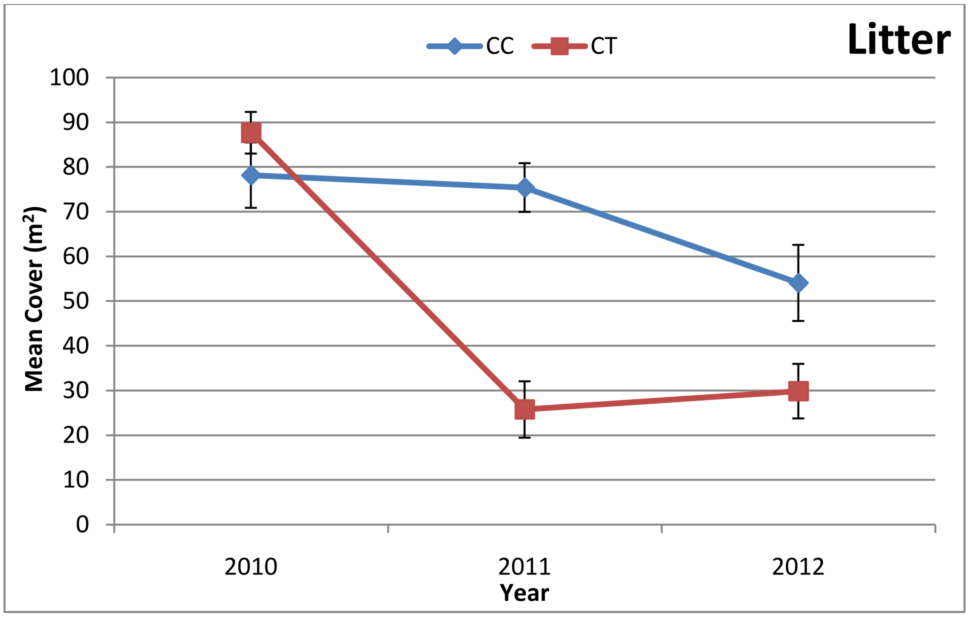
n. Biotic soil crust, Kelly.



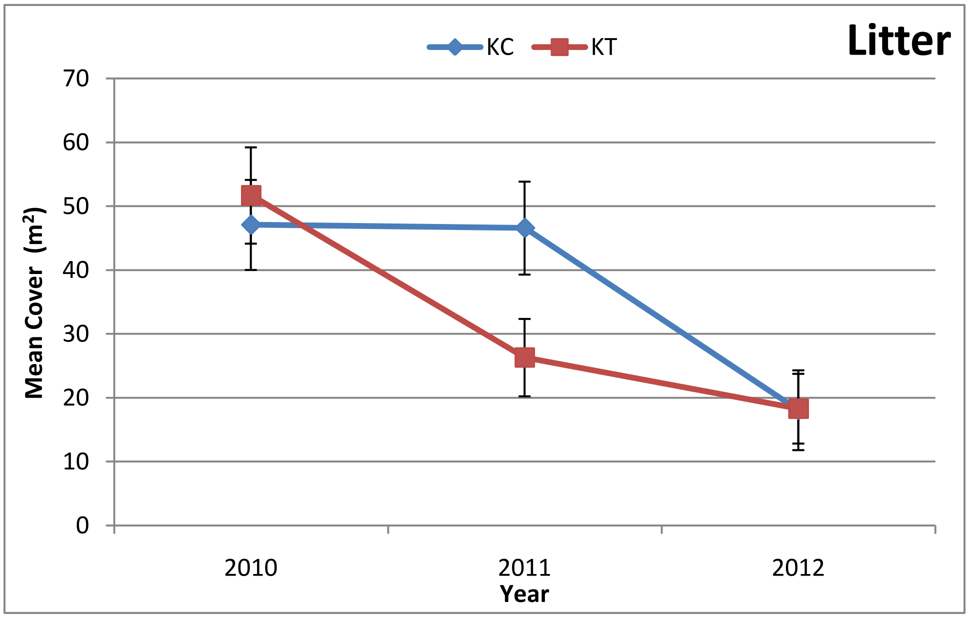
o. Biotic soil crust, Vigil.



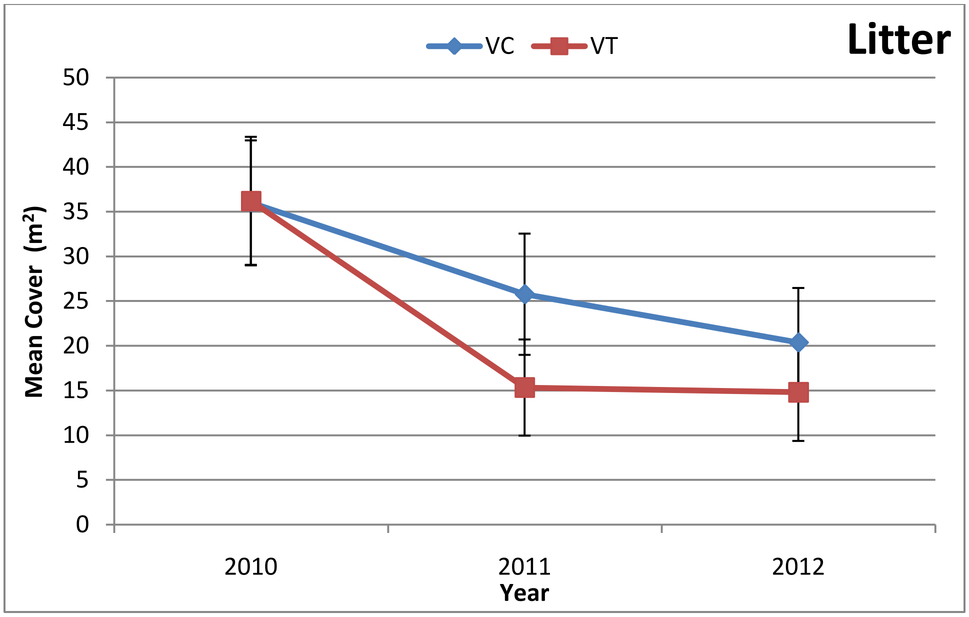
p. Biotic soil crust, Wester.



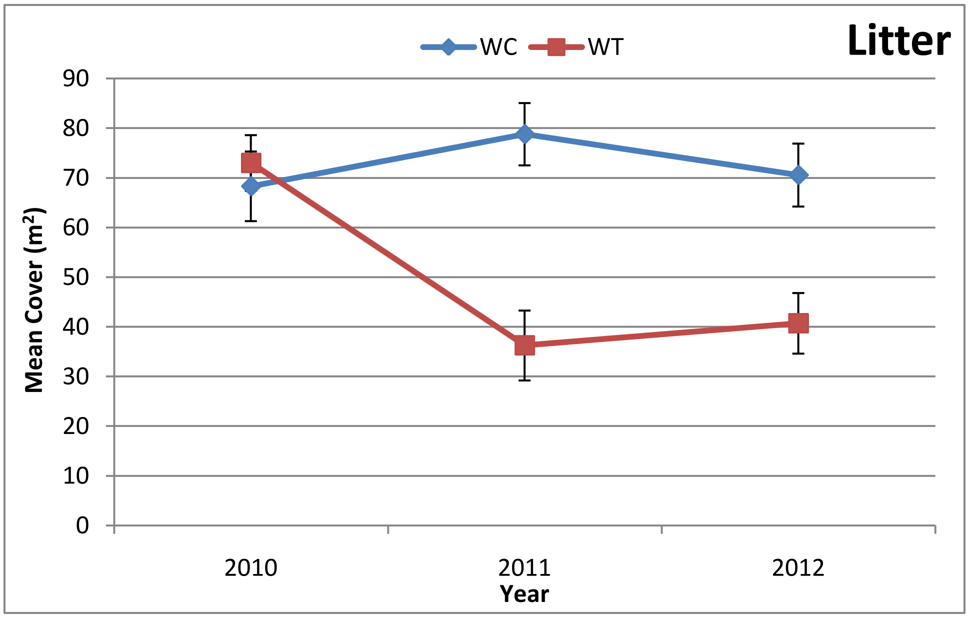
q. Leaf litter, Chilili.



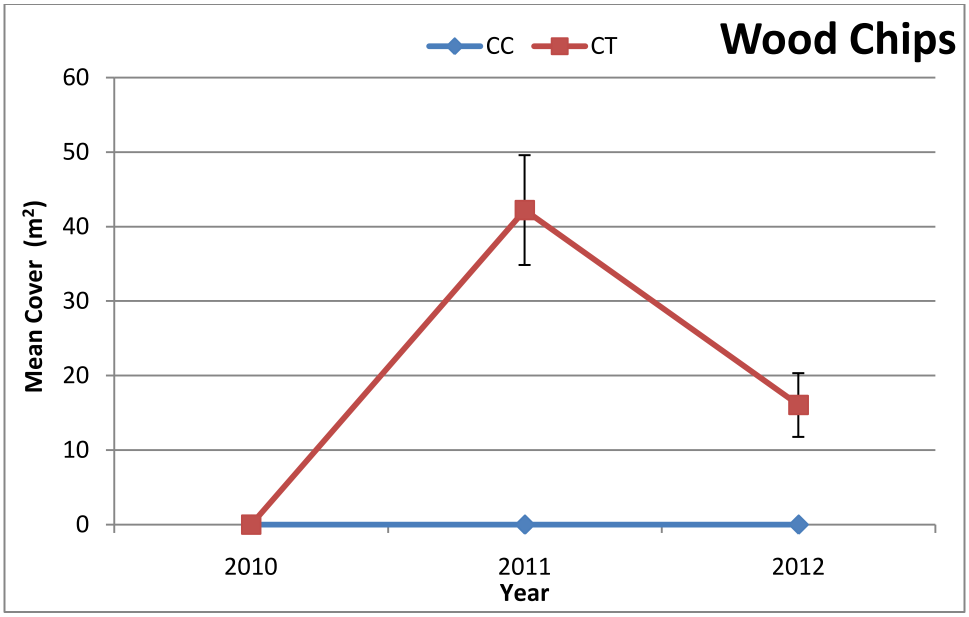
r. Leaf litter, Kelly.



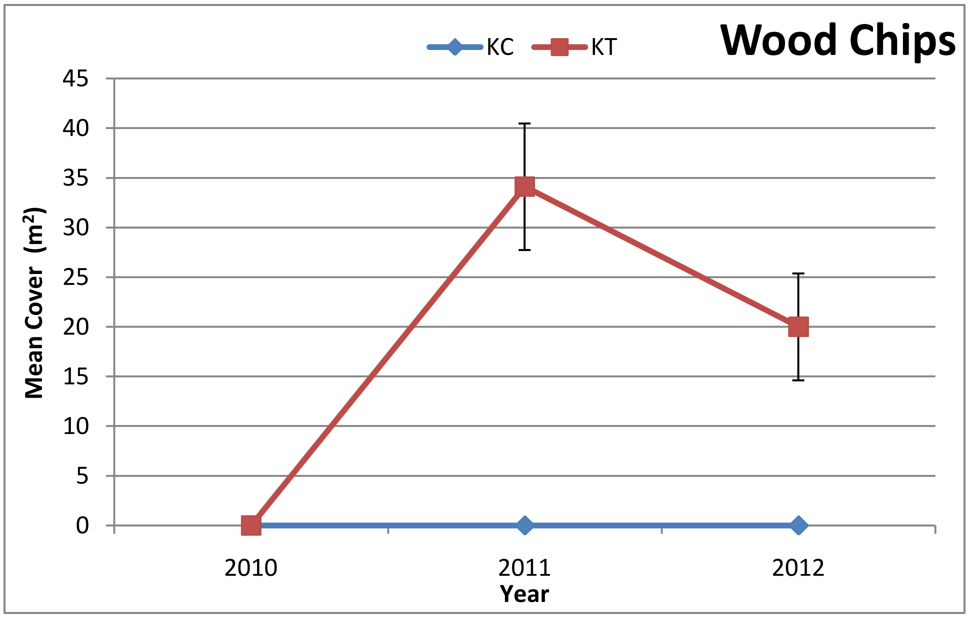
s. Leaf litter, Vigil.



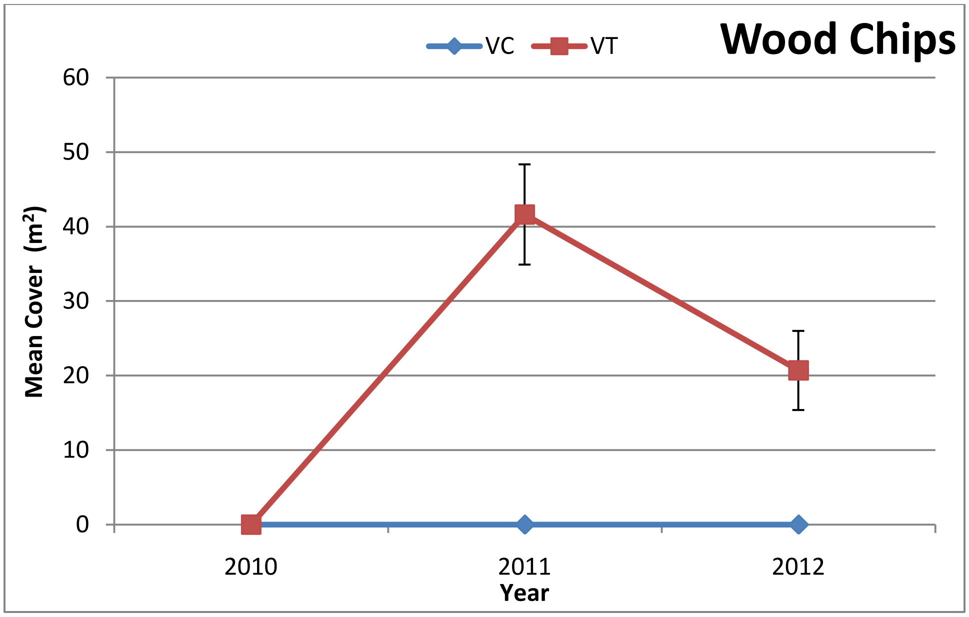
t. Leaf litter, Wester.



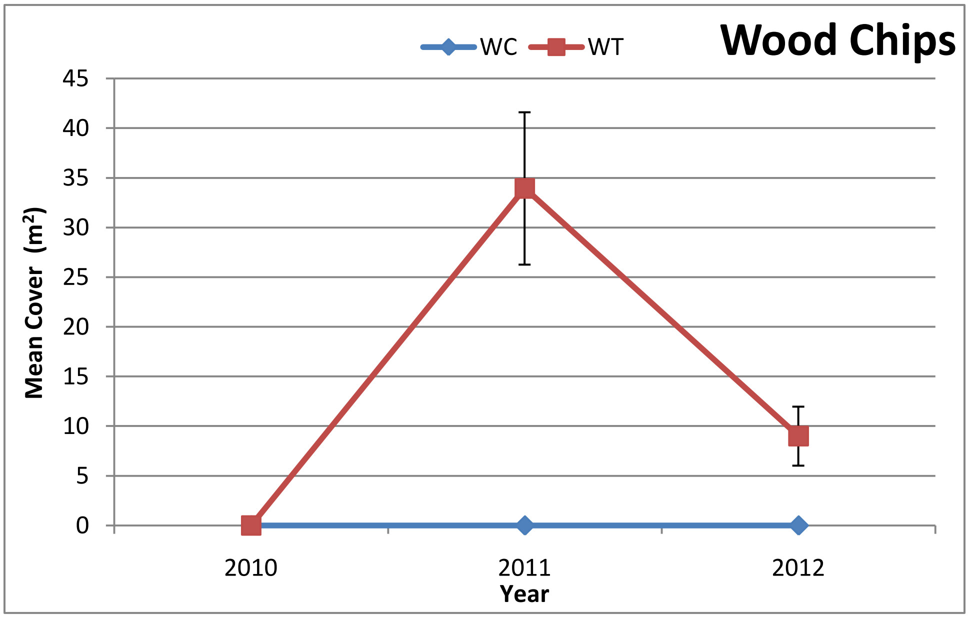
u. Wood chips, Chilili.



v. Wood chips, Kelly.



w. Wood chips, Vigil.



x. Wood chips, Wester.

Figure 2.67. These graphs illustrate the mean values cover type found across all vegetation quadrats among all of the study sites and paired study plots in fall 2010, 2011, and 2012. Thinning treatments occurred on the treatment plots between 2010 and 2011. Note that the vertical axis scales vary among these graphs in order to best present each cover type. Error bars represent +/- one standard error of the mean.

Table 2.12. Test Results for paired t-tests of No Difference between Mean Values of Vegetation and Ground Cover Types Measured from Vegetation Quadrats on Each Study Plot Pair at the Four Study Sites in 2012

Site	Parameter	Treated Mean	Control Mean	P-value (significance)
Chilili	Forbs	0.15	0.13	0.84
	Grasses	3.83	2.97	0.64
	Bare soil	0.00	0.03	0.28
	Cryptobiotic crust	0.00	0.00	1.00
	Leaf litter	**29.86**	**54.07**	**0.001**
	Wood chips	**16.05**	**0.00**	**0.001**
Kelly	**Forbs**	**3.11**	**0.16**	**0.03**
	Grasses	9.49	5.73	0.31
	Bare soil	**6.08**	**16.46**	**0.03**
	Cryptobiotic crust	**0.00**	**9.60**	**0.0002**
	Leaf litter	18.30	18.06	0.98
	Wood chips	**20.00**	**0.00**	**0.0005**
Vigil	**Forbs**	**14.58**	**1.87**	**0.005**
	Grasses	**16.85**	**4.95**	**0.004**
	Bare soil	**3.17**	**26.47**	**<0.0001**
	Cryptobiotic crust	**0.00**	**7.15**	**0.0004**
	Leaf litter	14.80	20.38	
	Wood chips	**20.69**	**0.00**	**0.0003**
Wester	Forbs	0.29	0.41	0.65
	Grasses	7.79	4.12	0.07
	Bare soil	0.69	0.18	0.29
	Cryptobiotic crust	0.30	1.88	0.40
	Leaf litter	**40.72**	**70.57**	**0.001**
	Wood chips	**9.00**	**0.00**	**0.005**

All tests were with sample sizes of 36; p-values of less than 0.05 represent significant differences. Parameters in bold represent those with significant differences between paired plots. Refer to Figure 2.67for graphical illustrations of differences in mean values.

Forb canopy cover was significantly higher on the treated plots at both of the piñon/juniper sites in 2012, but not at either of the ponderosa pine sites (Figure 2.67, a–d). Forb cover at the Vigil site was considerably higher in 2012 than before thinning treatments in 2010 and after treatments in 2011, while forb cover on control plots remained relatively the same over the three-year period. Forb cover on the Kelly site treatment plot increased dramatically in 2011 following treatments and declined slightly in 2012, but remained significantly higher on the treated plot following treatments in 2011. The majority of forb species were summer annual plants that grew on disturbed soils and wood chips. All of the dominant species were native; no exotic invasive forb species were found. An example of the forb growth at the Vigil treatment plot in 2012 is provided in Figure 2.68.

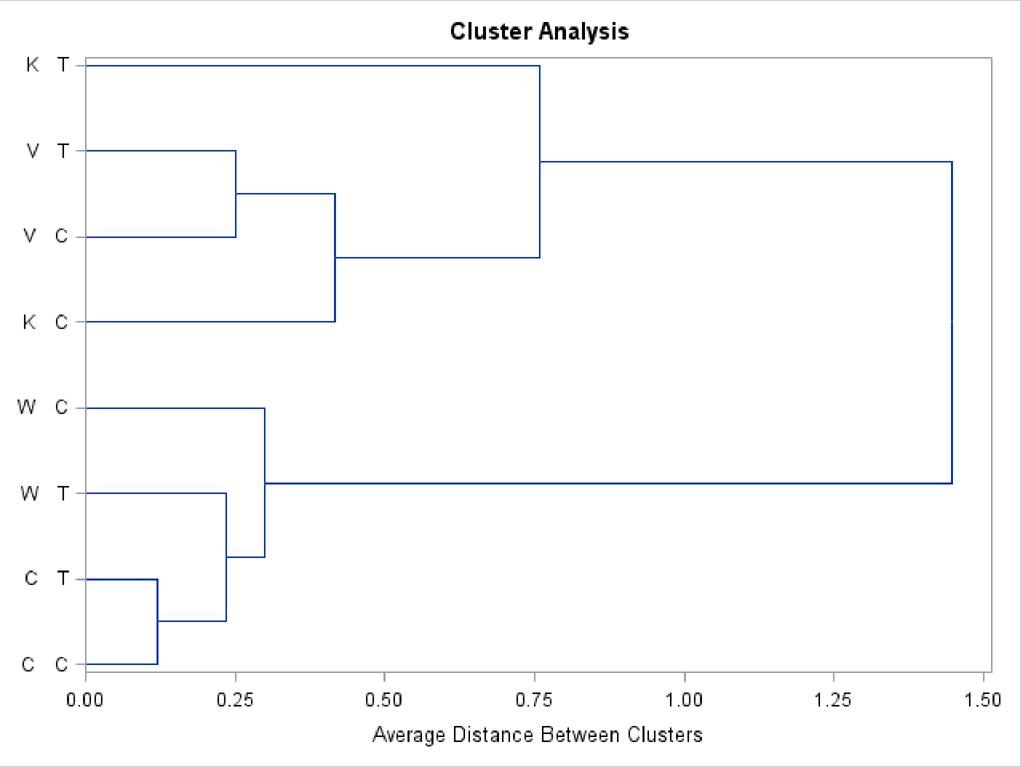
Figure 2.68. Forbs growing on disturbed soils and wood chips at the Vigil site, October 2012. Dominant species include ragleaf bahia with yellow flowers.

Grass cover was significantly higher only on the treated plot at the Vigil piñon/juniper site (see Table 2.12, Figure 2.67, e–h). Grass cover increased on the treated plot at the Vigil site from 2010 and 2011 on the treated plot, but remained similar on the control plot. Grass cover also was significantly higher on the treated plot at the Wester ponderosa site, but grass cover on the treatment plot there had always been significantly higher than the control plot, even before treatments in 2010. Therefore, grass cover at the Wester site did not respond differently on the treatment plot relative to tree thinning. Dominant grasses at the two piñon/juniper sites that responded positively to tree thinning were perennial species such as blue grama (*Bouteloua gracilis*) and James' galleta (*Pleuraphis jamesii*). Those grasses grew through the wood chips from existing individual plants that were in place prior to thinning treatments, unlike annual forbs that colonized the disturbed soils and wood chips. Blue grama growing through wood chips at the Vigil site is shown in Figure 2.69.

Figure 2.69. Perennial blue grama growing through wood chips at the Vigil piñon/juniper site treatment plot in 2012.

Bare soil was significantly higher on control plots than treated plots at the two piñon/juniper sites, but not at the two ponderosa pine sites in 2012, or in 2010 or 2011 (see Table 2.12, Figure 2.67, i–l). Bare soil is an inverse ground cover to leaf litter and wood chips, and the addition of wood chips in late 2010 resulted in less bare soil on treatment plots following thinning treatments at those two piñon/juniper sites. Considerable amounts of leaf litter were already present on the ground at the ponderosa pine sites, so additional wood chips did not change the amount of bare soil present as at the piñon/juniper sites where more bare soil was present to begin with. Cryptobiotic or biotic soil crust cover was significantly higher on the control plots than on the treatment plots at both of the piñon/juniper sites, but not at either ponderosa pine site in 2012 (see Table 2.12, Figure 2.67, m–p). However, biotic soil crust cover was significantly higher on those control plots prior to thinning treatments in 2010, so the difference is apparently not due to thinning treatment effects. Leaf litter cover was significantly higher on the control plots at both ponderosa pine sites in 2011 and 2012 following thinning treatments, but not in 2010 prior to treatments (see Table 2.12, Figure 2.67, q–t). This finding is apparently due to the addition of wood chips that covered the extensive leaf litter layers at those two ponderosa pine sites, while the two piñon/juniper sites had less leaf litter than bare soil, as stated above. Wood chips remained significantly higher on all treated plots in 2012, as in 2011 following thinning treatments (see Table 2.12, Figure 2.67, u–x). No wood chips existed prior to thinning treatments in 2010 and were applied only to the treated plots in late 2010. Wood chip cover on the treated plots declined by about 20% on all plots between 2011 and 2012, indicating some decomposition or redistribution, and/or increased herbaceous plant canopy cover over wood chips.

Measurements of herbaceous vegetation on the thirty-six 1-m² (10.8-square-foot) quadrats also provided information on the canopy cover of each plant species per quadrat. The similarity of plant species composition among all of the study plots over the five-year monitoring period was evaluated with the analytical method called cluster analysis (McCune and Grace 2002). Cluster analysis is useful for evaluating sets of species abundance when many species are involved. Cluster analysis compares sets of species/abundance data and determines how similar those sets are, then graphically represents their similarities as dendrograms or tree diagrams. The closer terminal branches are in those diagrams, the more similar those sets of species are in terms of composition and relative abundance. Cluster analysis dendrograms for all sites and plots for the spring and fall sampling periods for the years 2010, 2011, and 2012 are presented in Figure 2.70, a–c. Cluster analysis shows that in 2010 (see Figure 2.70, a), prior to tree thinning treatments, the ponderosa pine sites (Chilili and Wester) grouped together, the piñon/juniper sites (Kelly and Vigil) grouped together, and the paired plots at each ponderosa site were more similar to each other than to the other site. The Vigil paired plots also grouped together, but the Kelly plots were not as similar to each other as the Kelly control plot was to the Vigil plots, based on plant species compositions. There were no groupings of treatment versus control plots in 2010. In 2011 and again in 2012, those location-based groupings were less pronounced (see Figure 2.70, b–c), but still more important than similarities based on treatment versus control plots. The Kelly control plot and the Vigil treatment plot grouped together, distinct from all other plots. All other plots showed weak groupings at different levels of similarity, especially the ponderosa site (Chilili and Wester) plots, and no clear patterns were based on treatment versus control plots. These results indicate that the tree thinning treatments altered the location-based patterns found in 2010, but do not reveal particular treatment-based or plant-community–based groupings at this time, two years following treatments.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K T
V T
V C
K C
W C
W T
C T
C C
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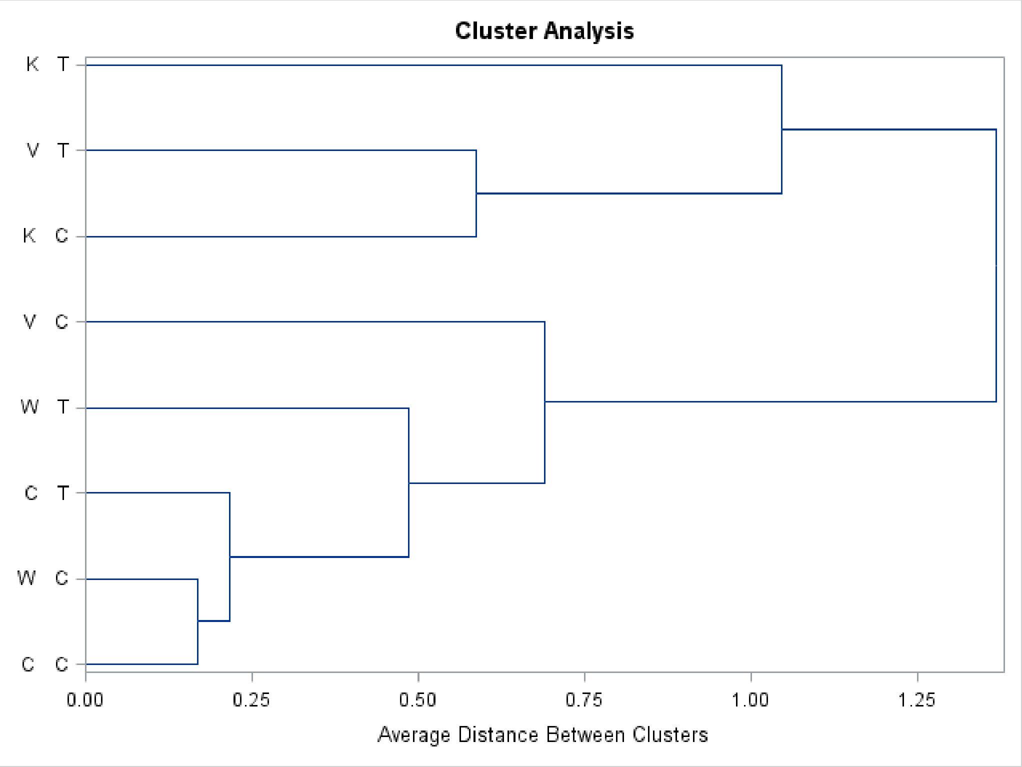
0.50
0.75
1.00
1.25
1.50
Average Distance Between Clusters

a. 2010.


Cluster Analysis
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V C
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C C
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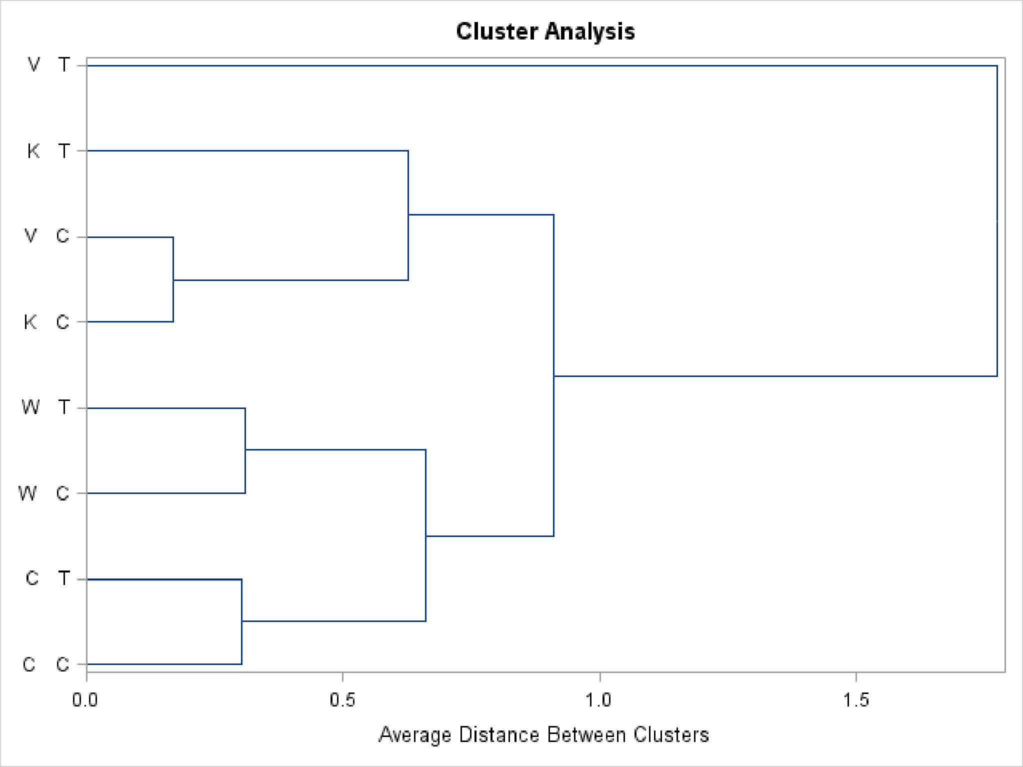
1.25
Average Distance Between Clusters

b. 2011.



c. 2012.

Figure 2.70. Cluster analysis results showing the similarity of monitoring sites and paired plots based on similarity of the herbaceous plant community species compositions: a. 2010, b. 2011, c. 2012.

Results of vegetation and ground cover monitoring showed that forest thinning did affect the physical structure of the woodland from reducing tree canopy and greatly affected the ground surface following the application of wood chips. Also, these findings show that at both piñon/juniper sites, herbaceous vegetation increased significantly on plots where trees were thinned, and that the patterns of location-based plant community similarities were altered by forest thinning treatments. Also, when measuring vegetation, we noticed that the vigorous growth of herbaceous plants, especially grasses, on the treated plots was being grazed heavily by domestic livestock (see wildlife camera results below). The removal of grass and forb canopies by livestock undoubtedly reduced canopy cover of those plants that were measured in October 2012 from all of the treatment plots. Therefore, actual herb canopy covers were likely higher on treatment plots than were measured, and the positive effects of tree thinning on those plots to herbaceous plants, especially grasses, were probably even greater than the data show. These findings are now two years following thinning treatments. As vegetation adjusts to the removal of some trees, and the effects of wood chips decomposing on the ground surface, more changes in vegetation and ground cover features are likely in years to come as a response to tree thinning.

2.7 WILDLIFE

Birds and small mammals are being monitored in order to determine if forest thinning affects native wildlife species. Both birds and small mammals were recorded from separate 50 × 50–m (164 × 164–foot) wildlife study plots that are immediately adjacent to each of the two vegetation and soils monitoring study plots at the four study sites. Birds and mammals were measured in late spring (May/June) and early fall (September/October) 2008, 2009, 2010, 2011, and 2012 for three consecutive days on each study plot.

2.7.1 BIRDS

The species composition and relative abundance of birds on all study plots were recorded by observing birds by point counts from one location at the center of each wildlife study plot. Each point count was conducted for 20 minutes at dawn for three consecutive mornings on each study plot in both spring and fall. Spring counts are intended to assess breeding bird use of the forest and woodland habitats, and fall counts are intended to assess migratory bird use of the same habitats. Many of the bird observations were based on hearing songs and calls and identifying those to species. Additionally, visual observations were often recorded.

Counts of individual birds in 2012 revealed that more birds were found on treated plots than on control plots in both the spring and in the fall (Figure 2.71). Bird counts were higher on control plots only at the Wester site in the spring, and the Vigil site in the fall. Numbers of bird species also tended to be higher on treated plots than control plots in both spring and fall, especially at the two piñon/juniper sites (Figure 2.72). During the 2012 spring surveys, more or equal numbers of species were found on control plots at the two ponderosa pine sites, while considerably more species were found on treated plots at the piñon/juniper sites. In the fall, the number of bird species was higher on treated plots at all sites except the Chilili ponderosa pine site.

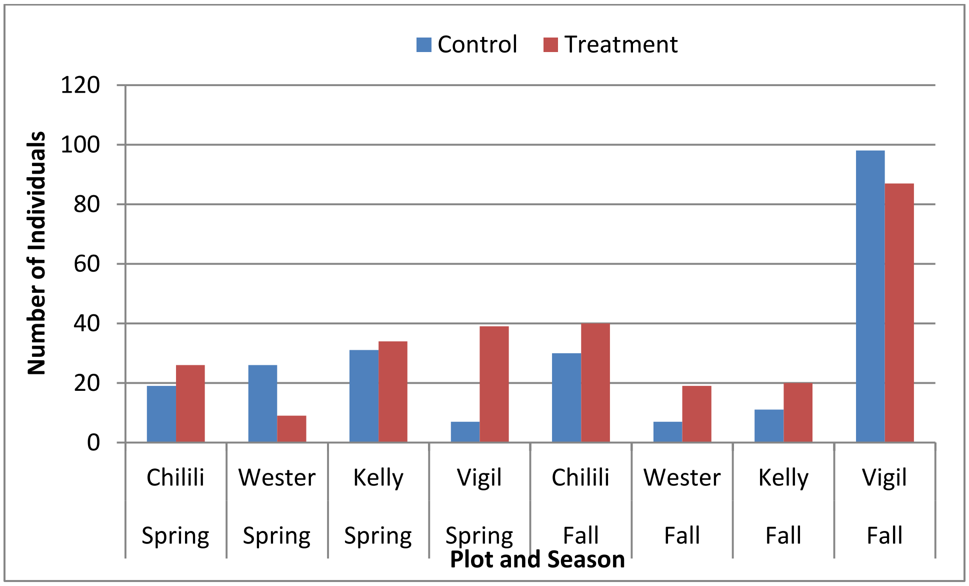


Figure 2.71. Numbers of individual birds recorded from thinning treatment and control plots across the four study sites in both spring and fall 2012.

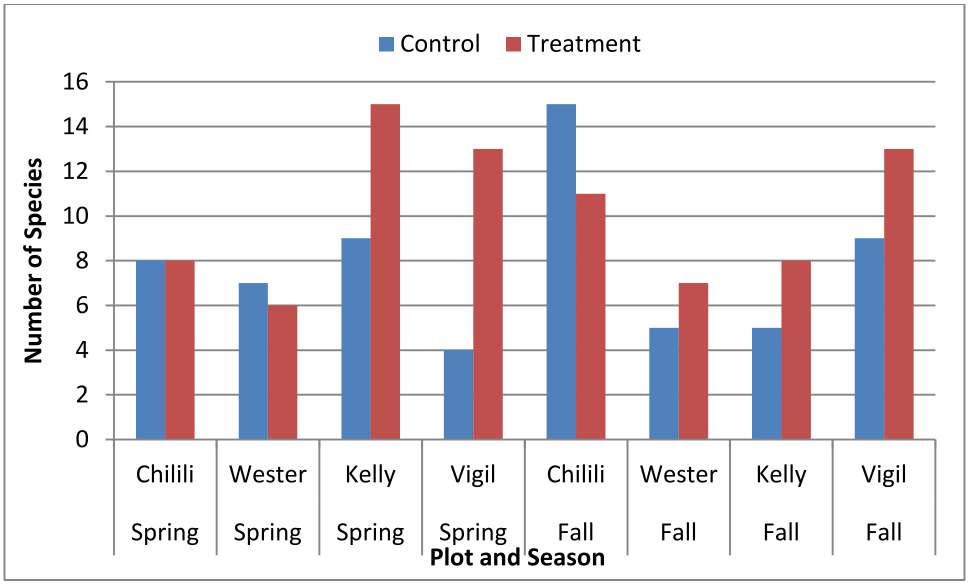
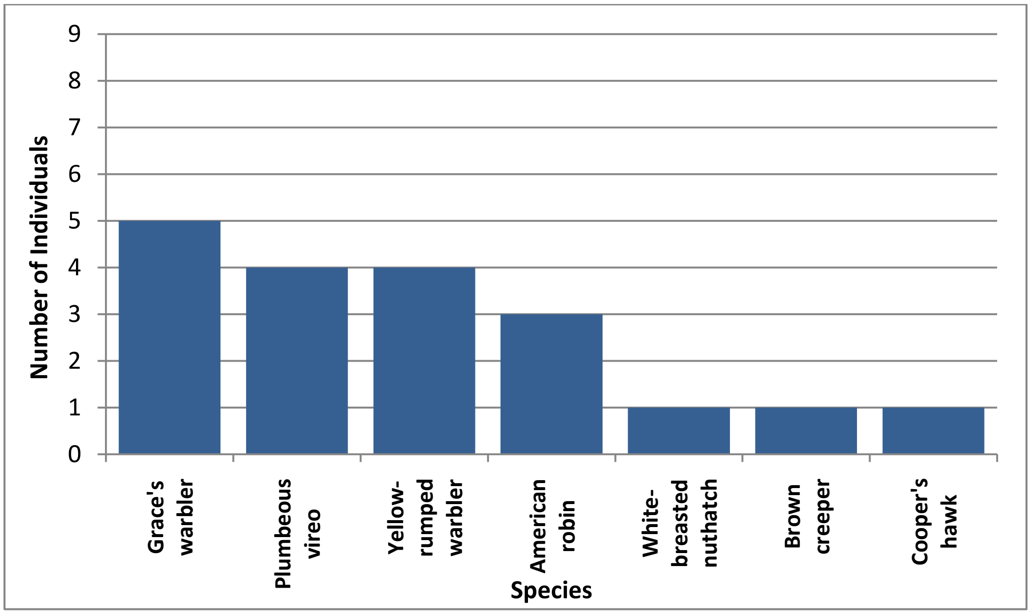
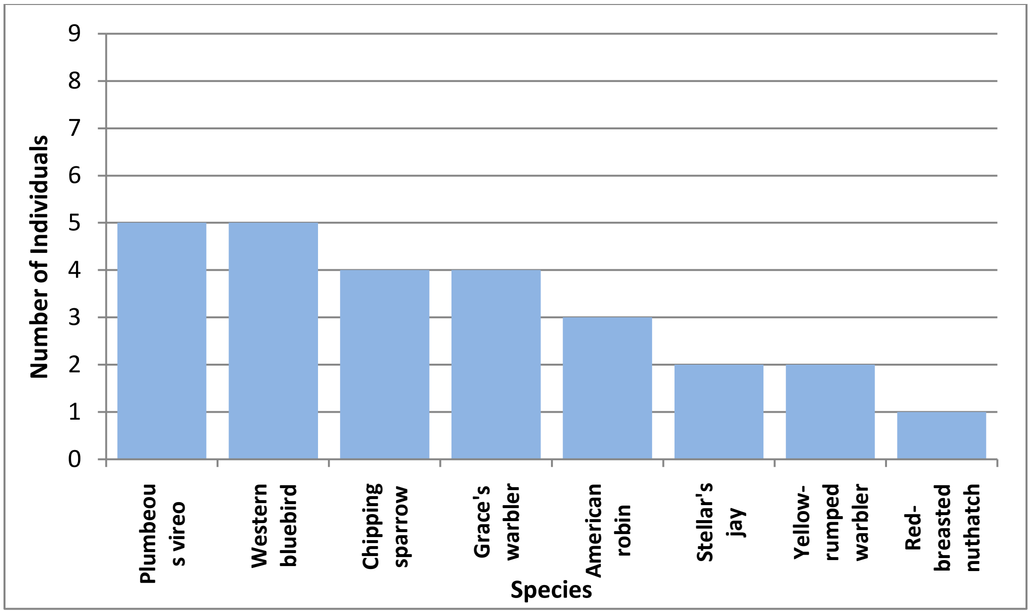


Figure 2.72. Numbers of bird species recorded from thinning treatment and control plots across the four study sites in both spring and fall 2012.

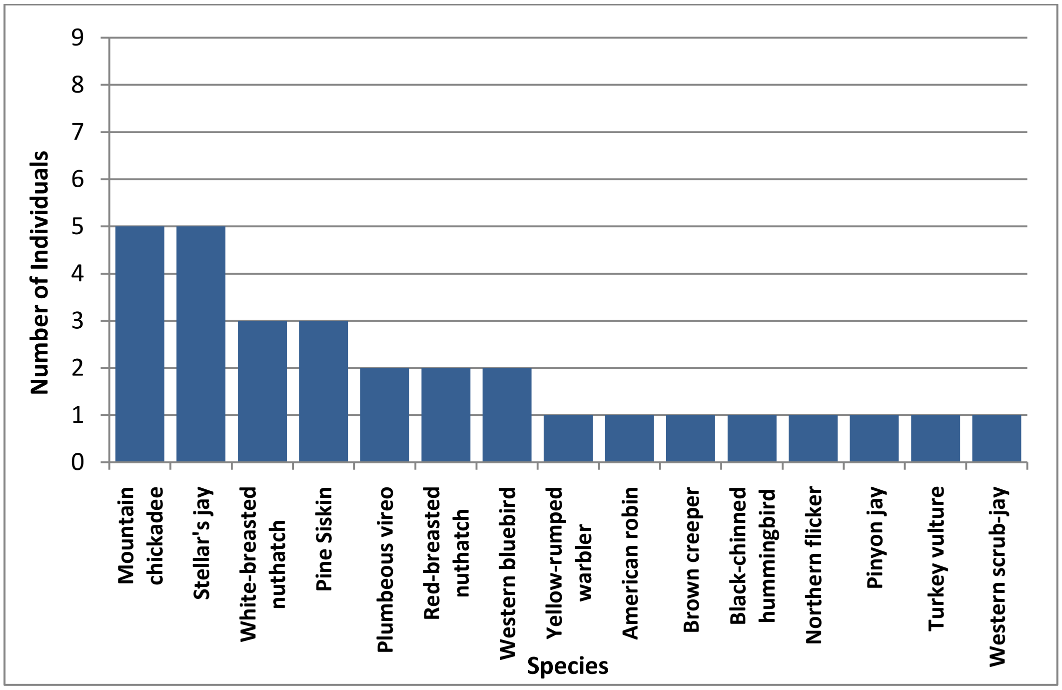
Figure 2.73 presents the species and numbers of individuals of those species summarized in Figure 2.71 and Figure 2.72. Examination of Figure 2.73 shows that in most cases, different species of birds dominate the spring and fall bird communities. Such findings should be expected, given that some of the species that breed at those sites in the spring migrate south in the fall and are replaced by species and individuals that migrated to the sites from locations further north and/or higher in elevation.



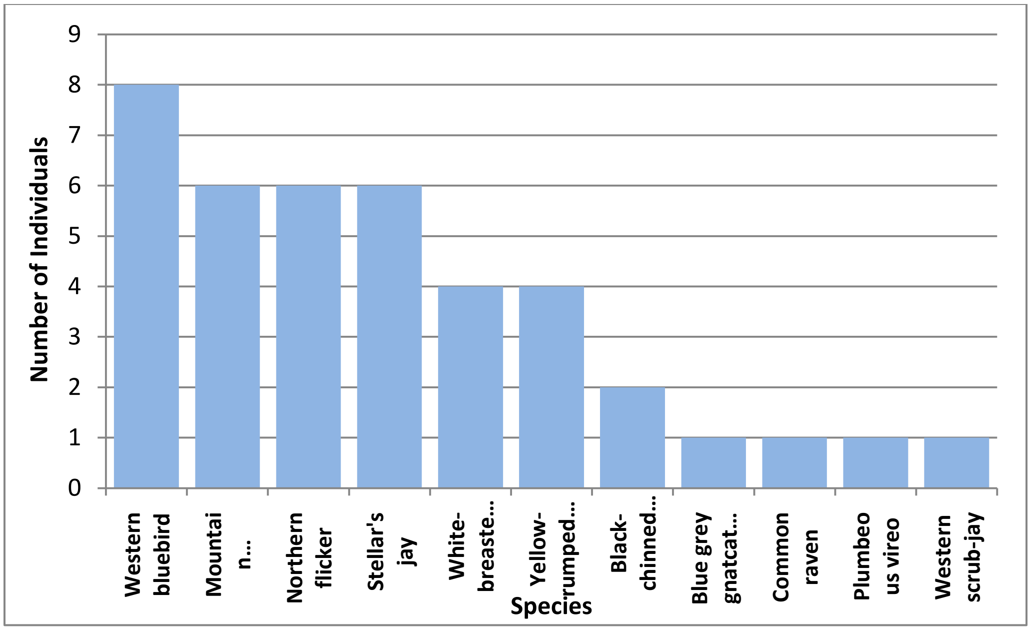
a. Chilili control plot, spring.



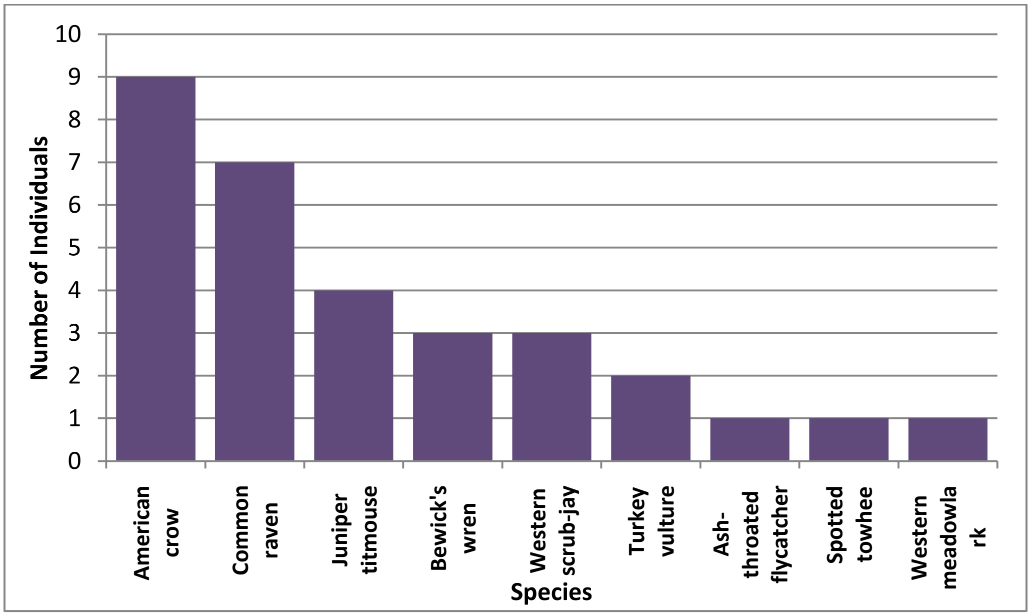
b. Chilili treatment plot, spring.



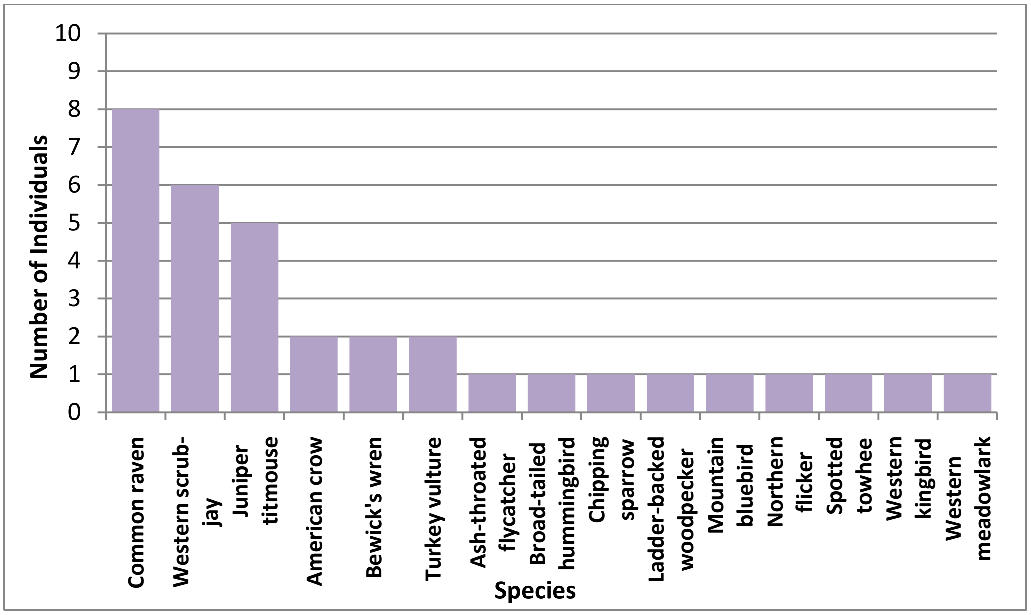
c. Chilili control plot, fall.



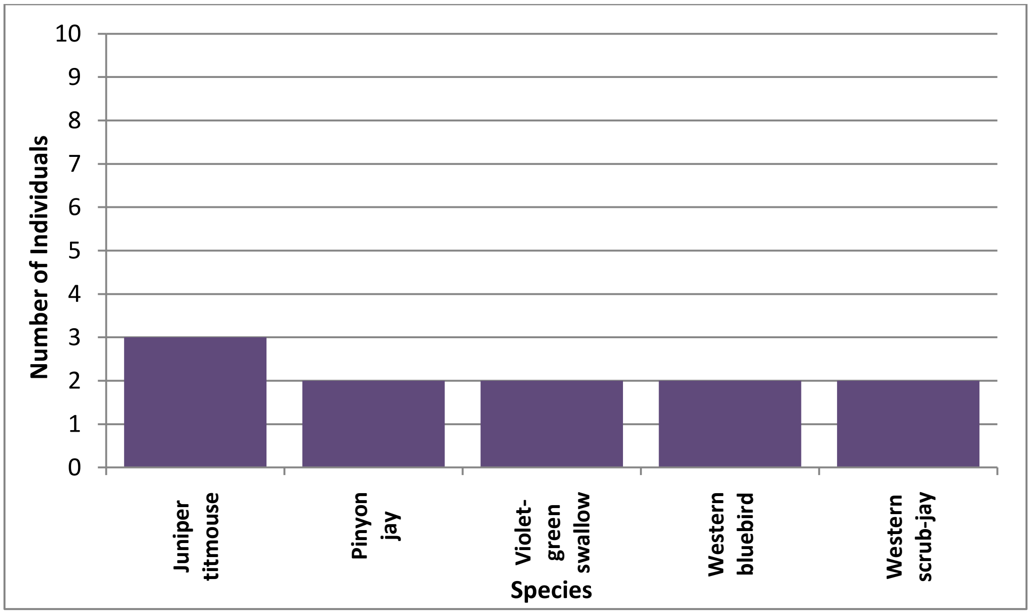
d. Chilili treatment plot, fall.



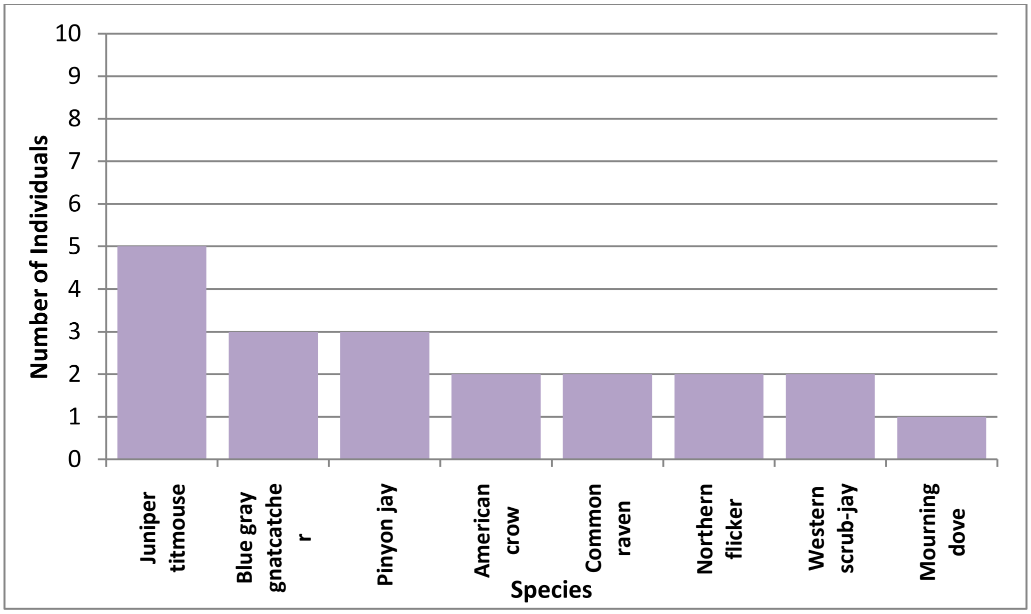
e. Kelly control plot, spring.



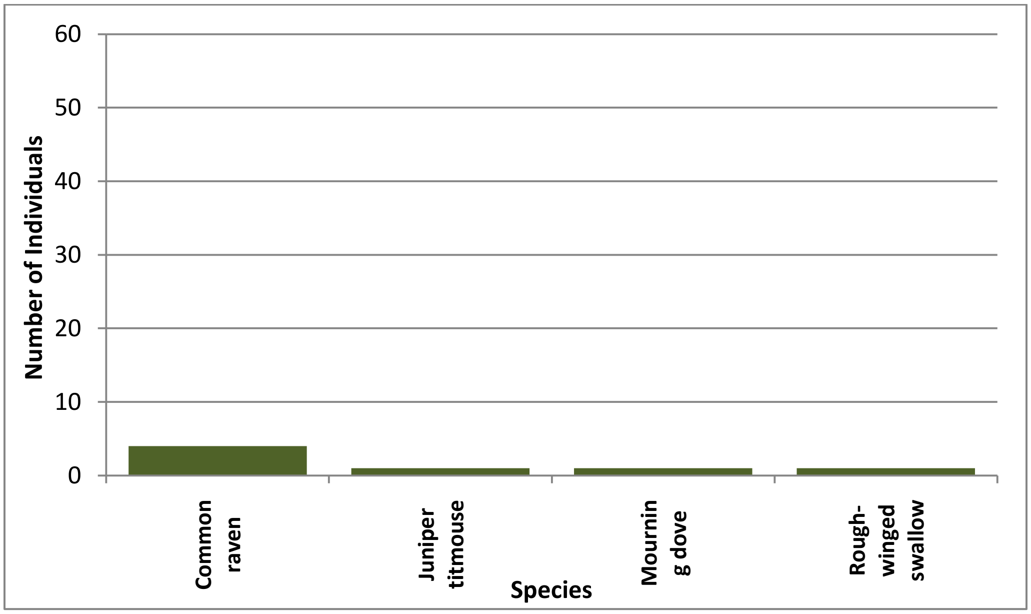
f. Kelly treatment plot, spring.



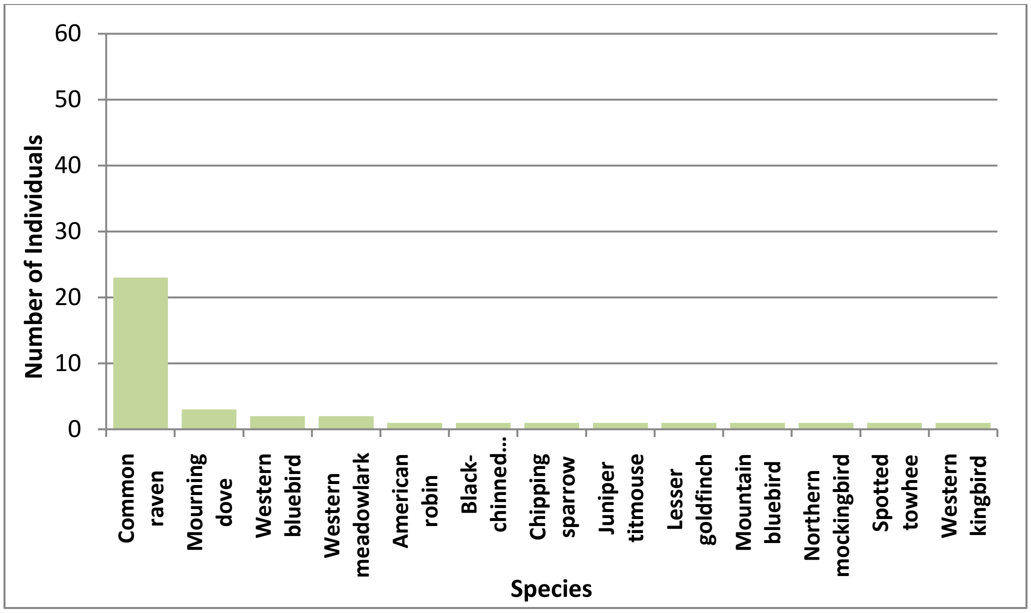
g. Kelly control plot, fall.



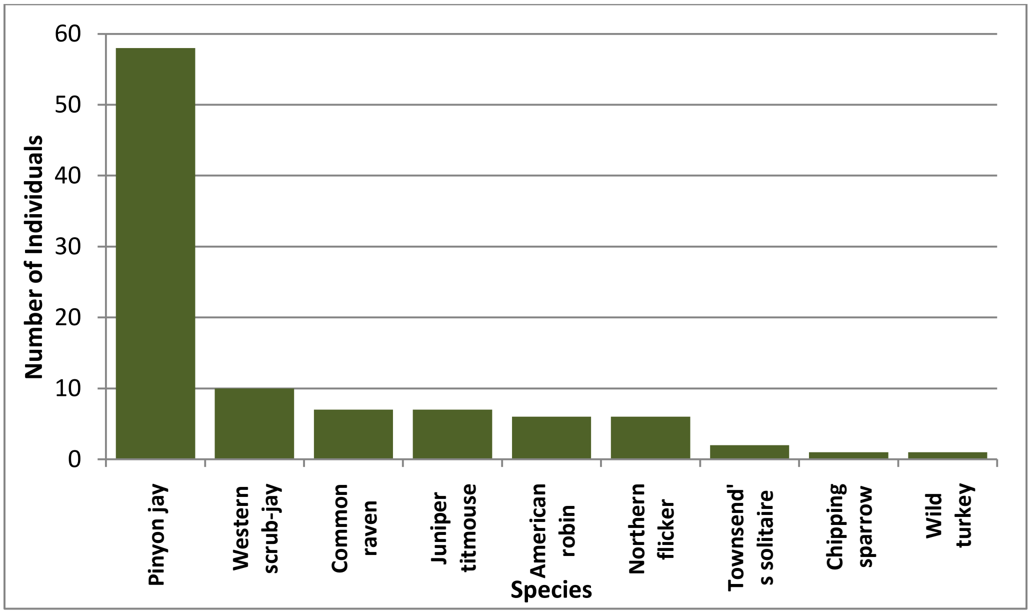
h. Kelly treatment plot, fall.



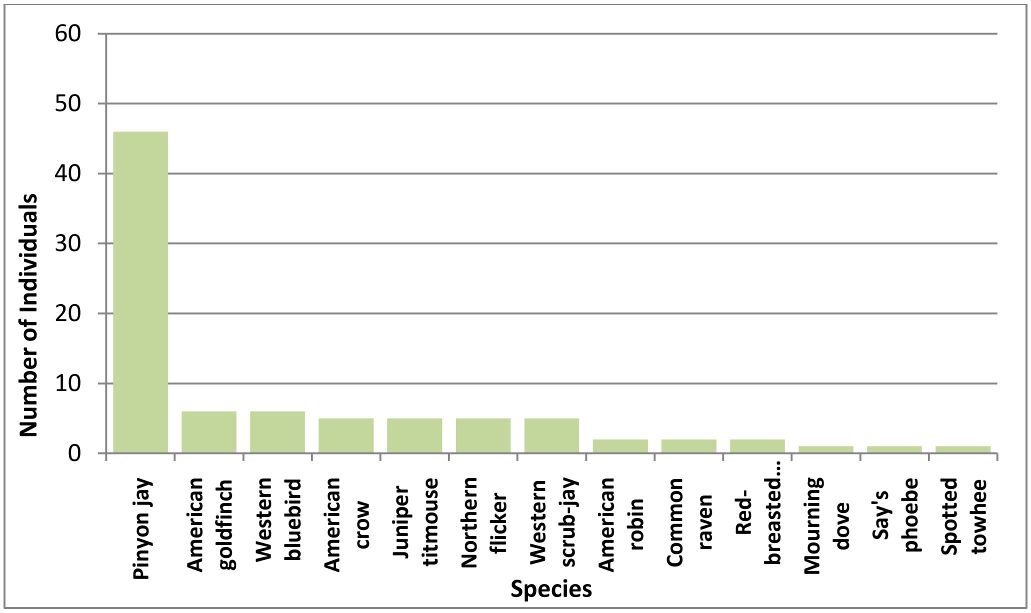
i. Vigil control plot, spring.



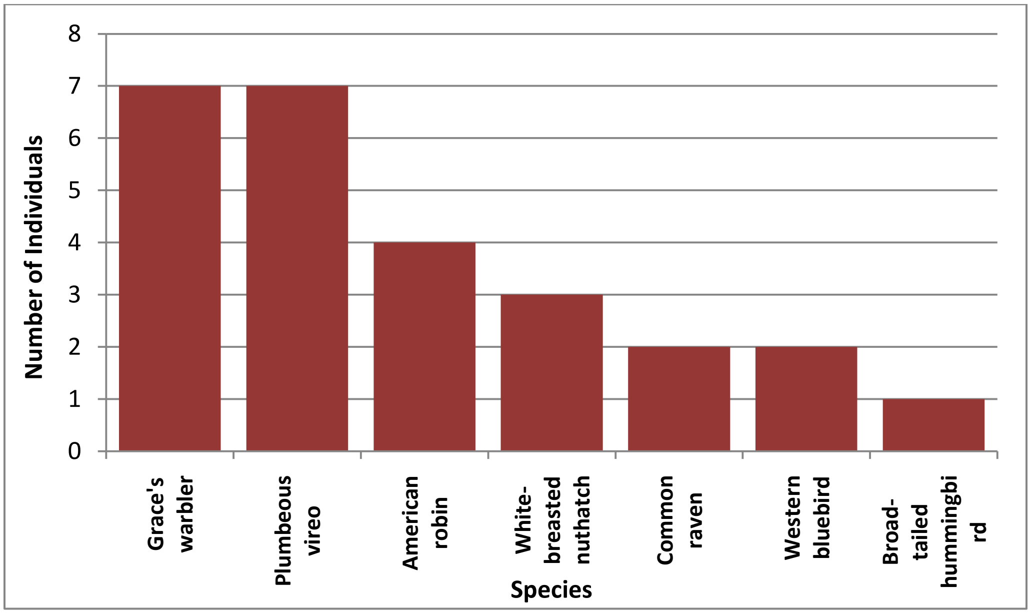
j. Vigil treatment plot, spring.



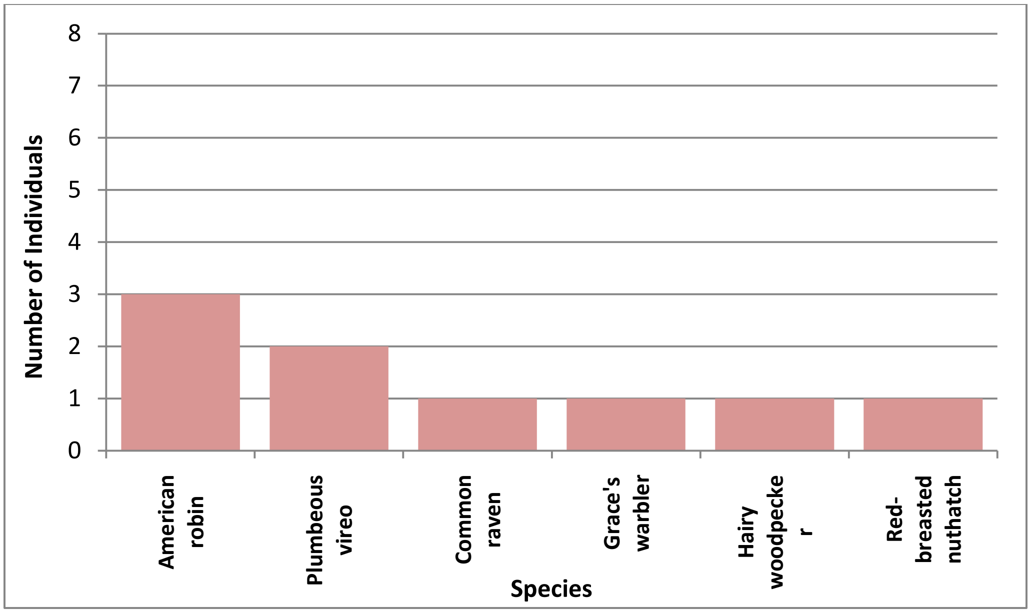
k. Vigil control plot, fall.



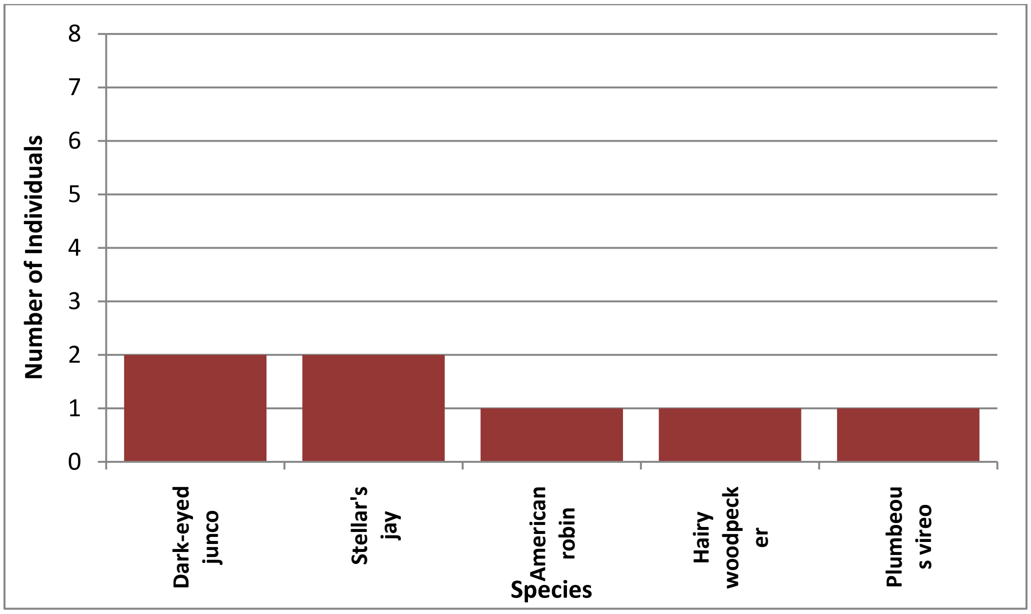
l. Vigil treatment plot, fall.



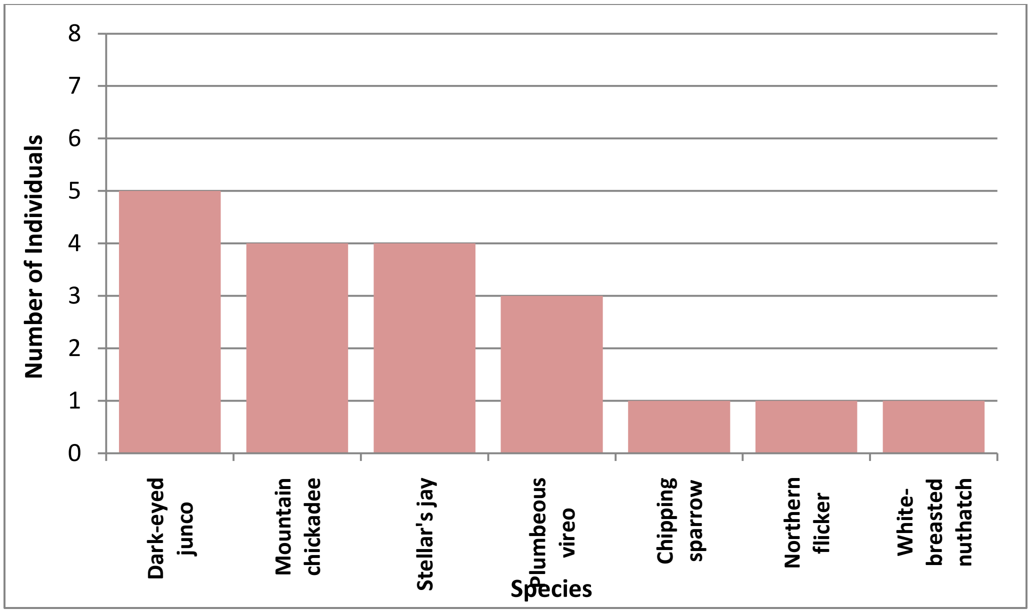
m. Wester control plot, spring.



n. Wester treatment plot, spring.



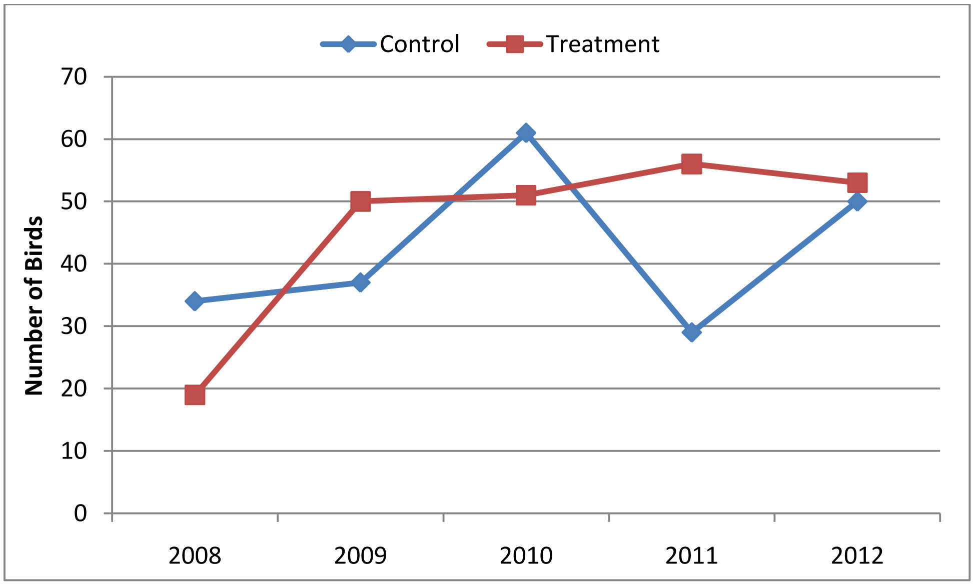
o. Wester control plot, fall.



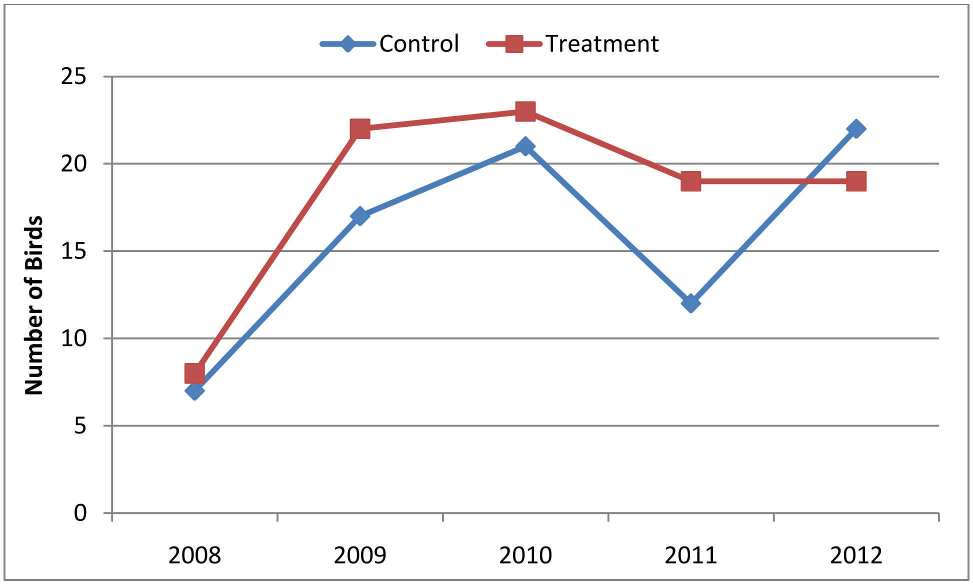
p. Wester treatment plot, fall.

Figure 2.73. Numbers of individual birds of each species recorded from all control and treatment study plots in 2012, both spring and fall.

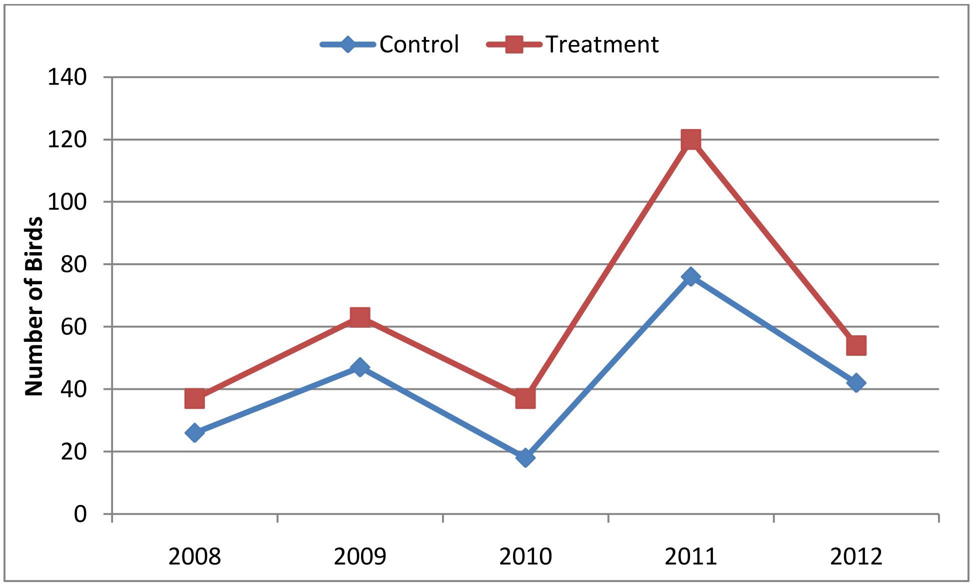
Figure 2.74 presents total numbers of birds from control and treatment plots, both spring and fall, from all four study sites, fall 2008 through fall 2012. In general, overall bird counts have increased over the years, and increases on treated versus control plots since thinning treatments in late 2010 have shown increases on treated plots at the two piñon/juniper sites, but not at the ponderosa pine sites.



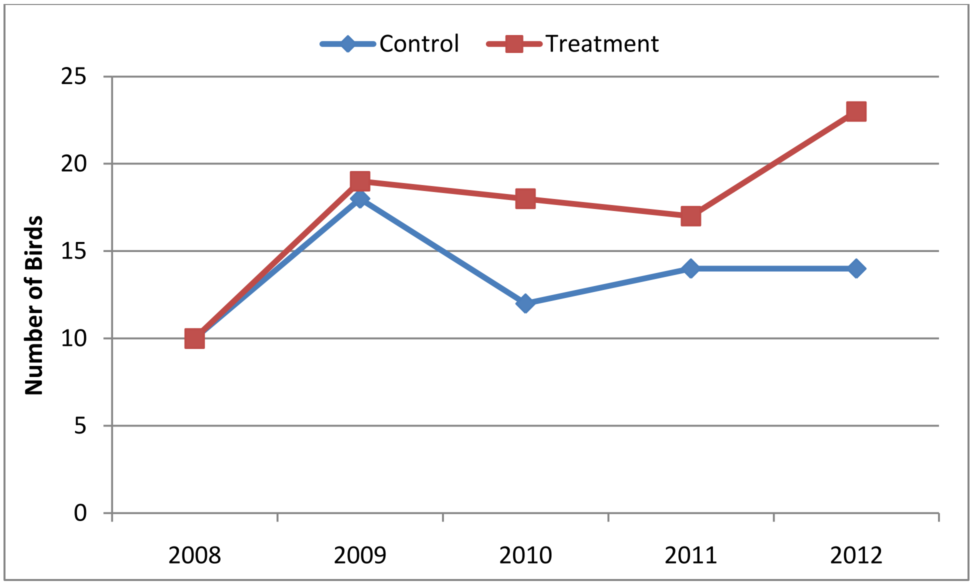
a. Chilili, spring.



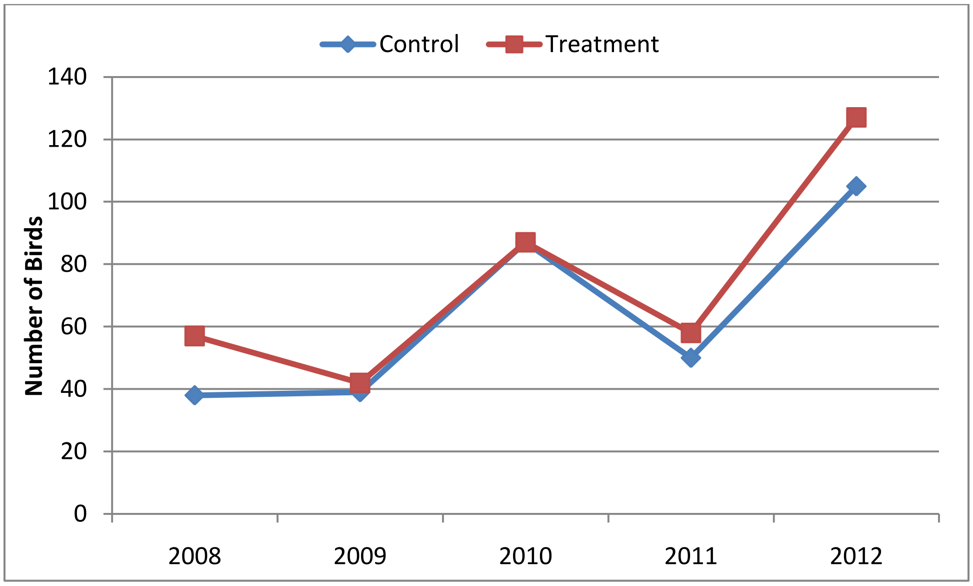
b. Chilili, fall.



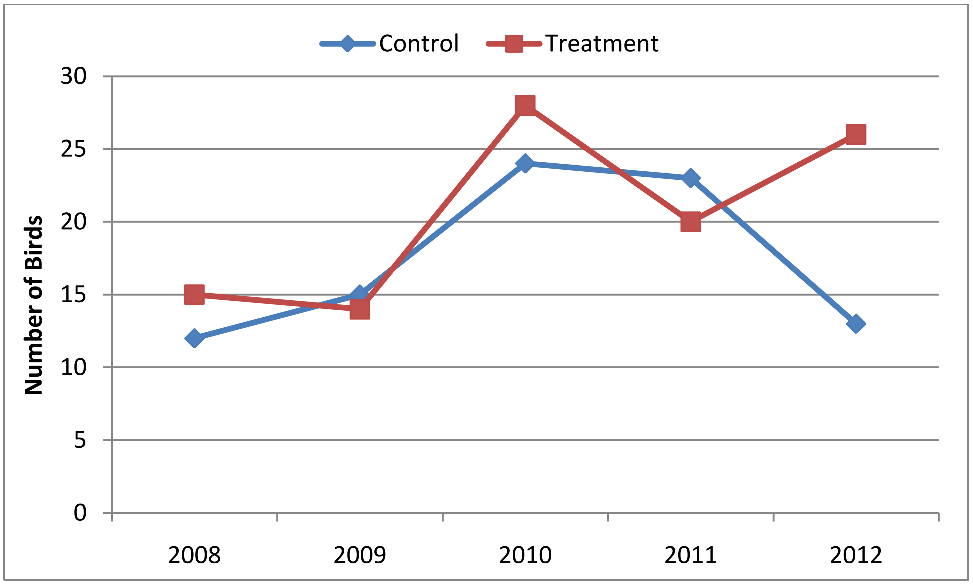
c. Kelly, spring.



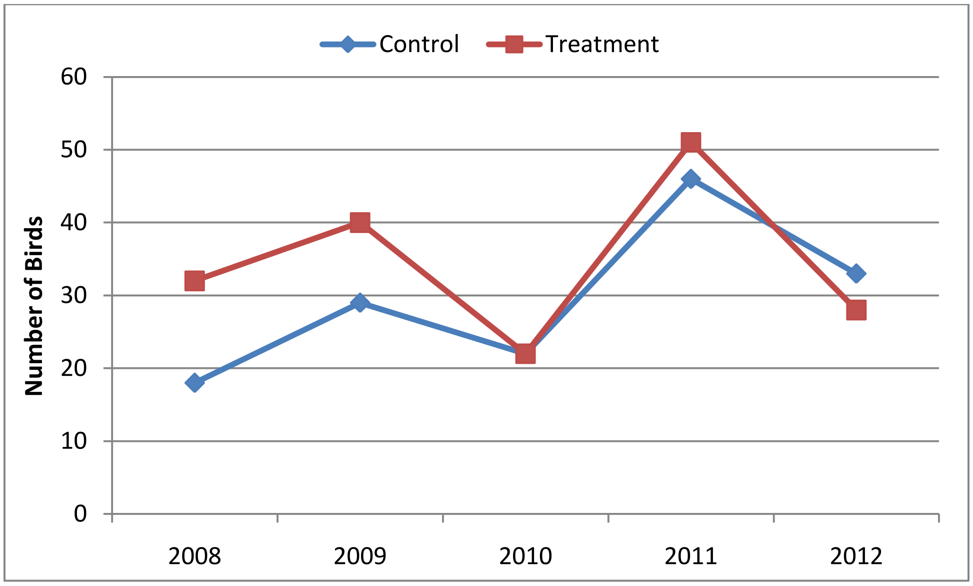
d. Kelly, fall.



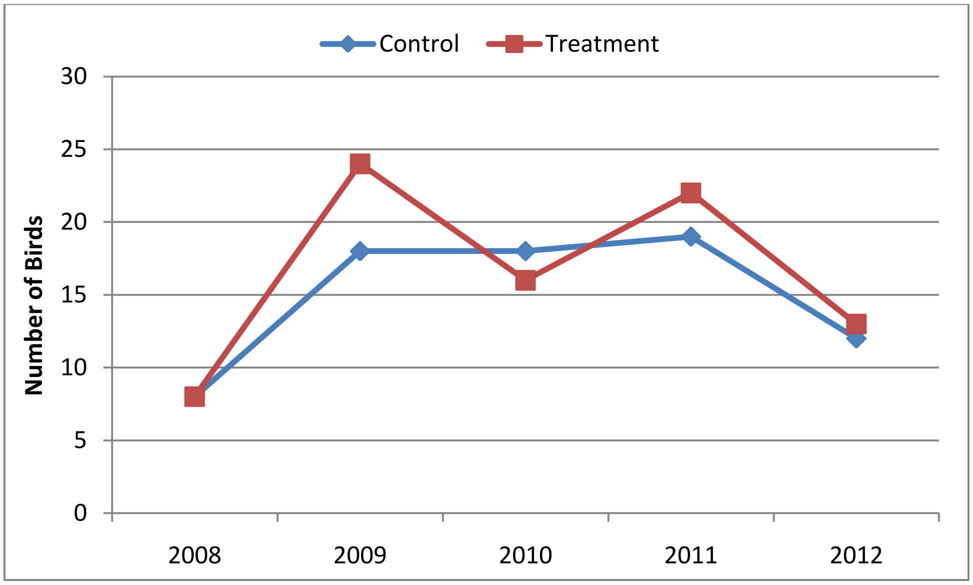
e. Vigil, spring.



f. Vigil, fall.



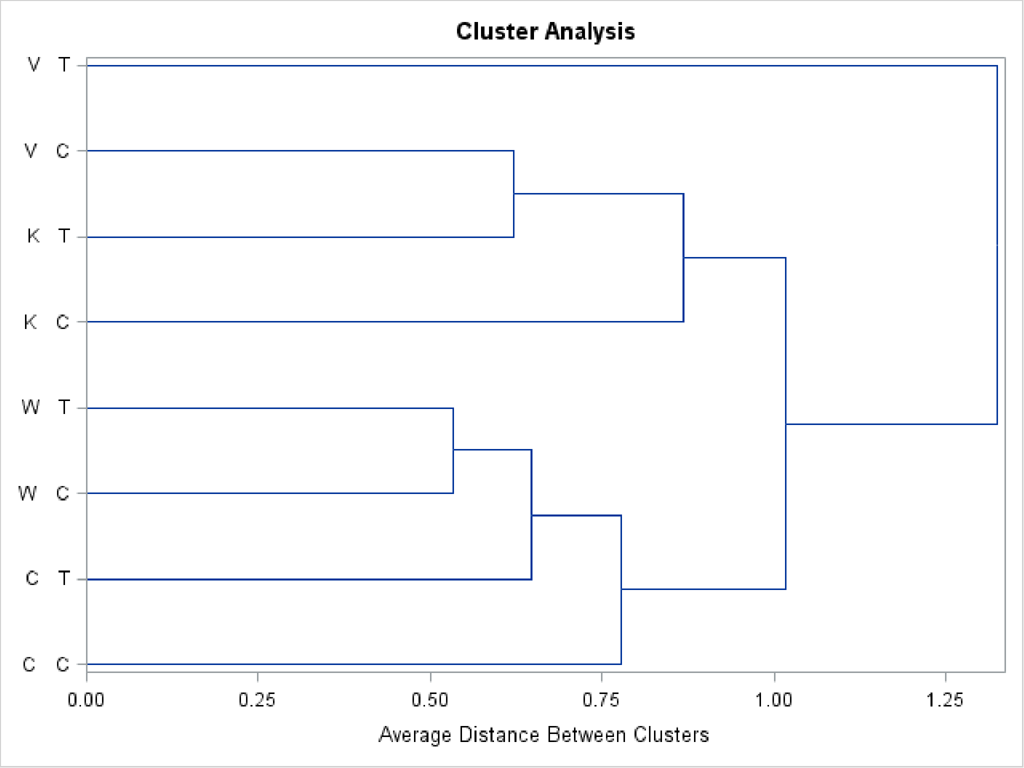
g. Wester, spring.



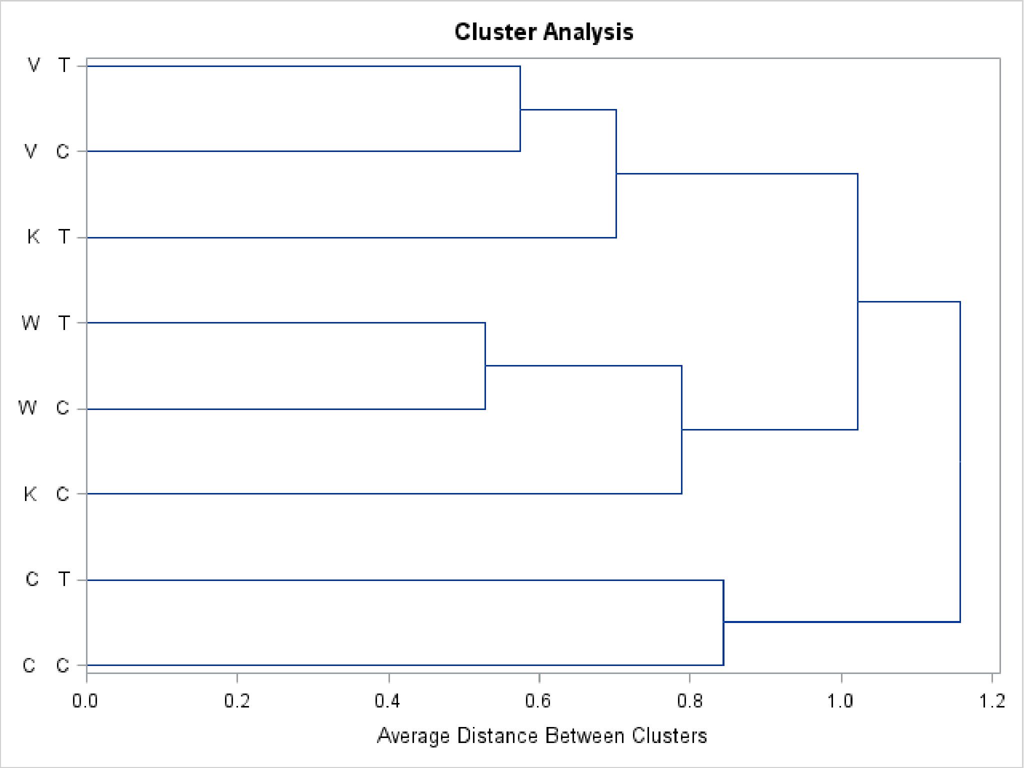
h. Wester, fall.

Figure 2.74. Total numbers of birds from both control and treatment plots at all four study sites, fall 2008–fall 2012.

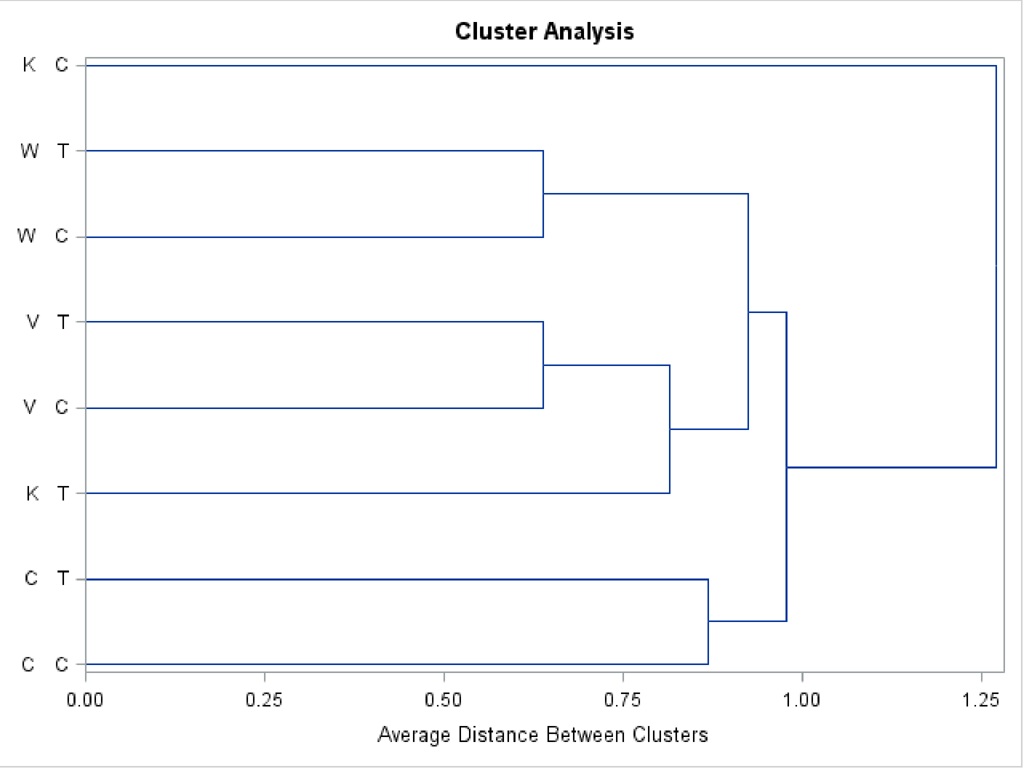
Cluster analysis dendrograms for all sites and plots for the spring and fall sampling periods for the years 2010, 2011, and 2012 are presented in Figure 2.75, a–j. Cluster analysis shows that over the five-year period, 2008 through 2012, bird communities were most similar to each other based on location. The ponderosa pine sites and plots within sites tended to group together, and the piñon/juniper sites and plots within sites tended to group together. This pattern was especially pronounced during the spring breeding period. As of fall 2012, the bird communities have not shown a response to forest thinning treatments, in which case plots would group together based on treatment status rather than location.



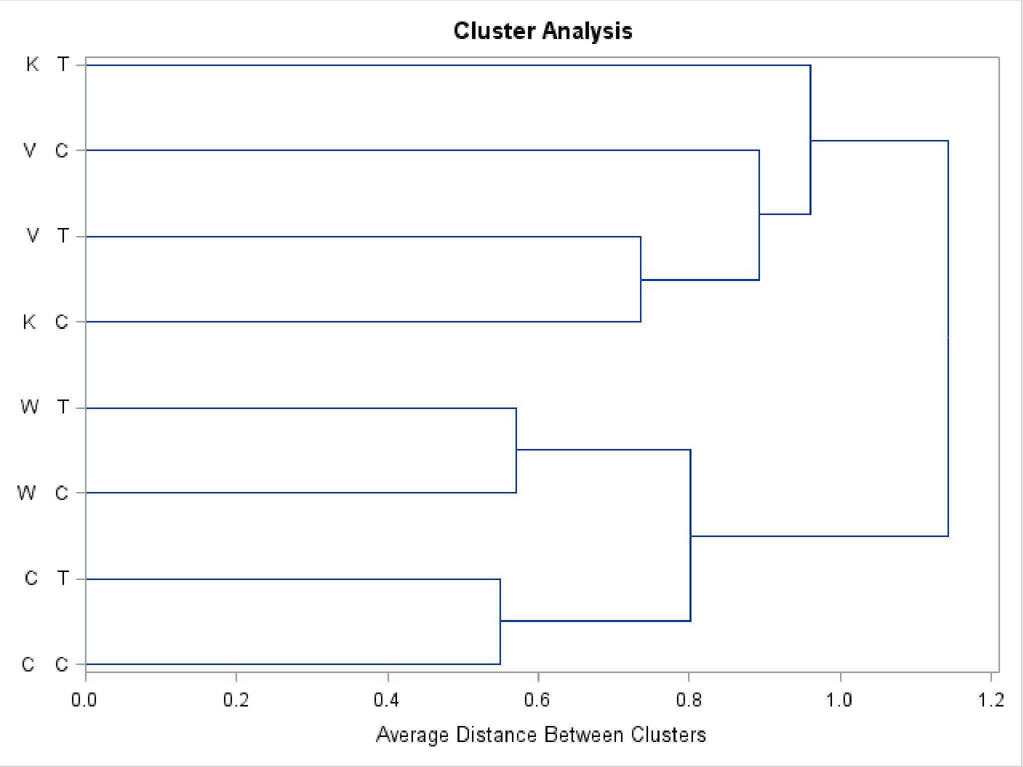
a. 2008, fall.



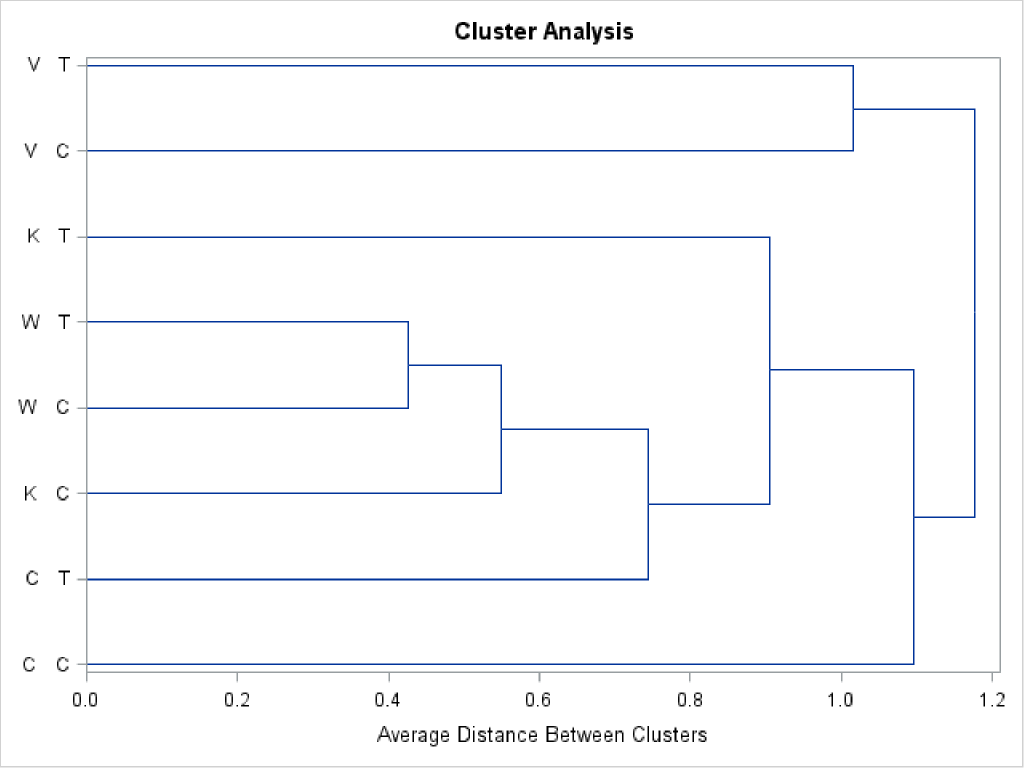
b. 2009, spring.



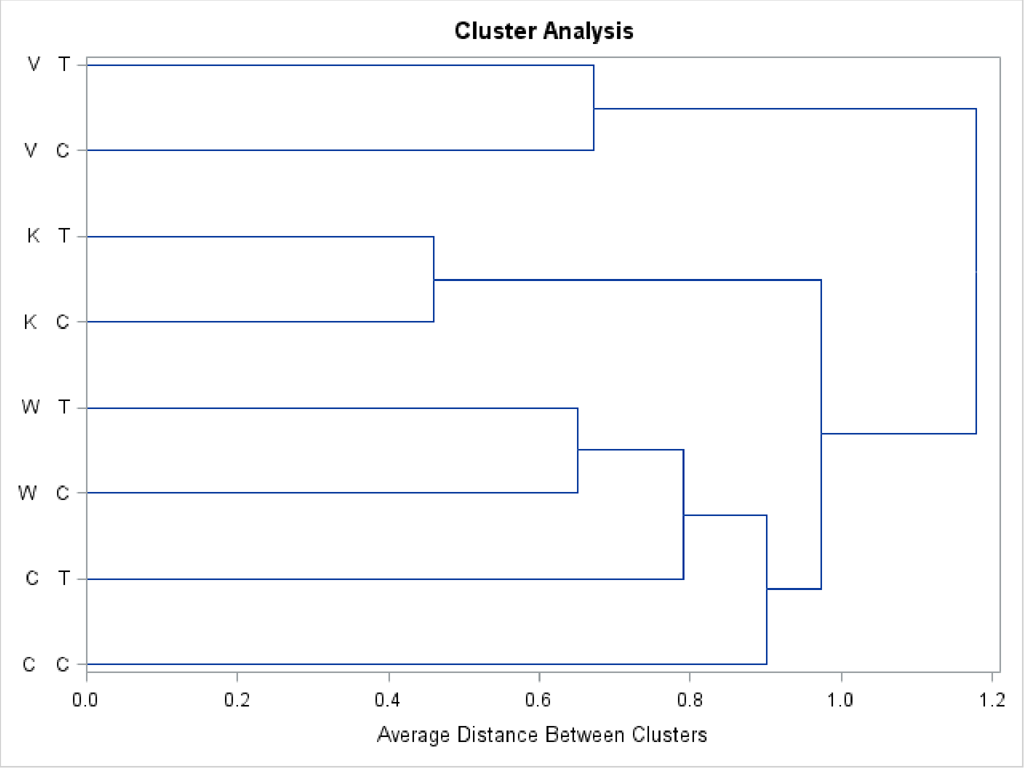
c. 2009, fall.



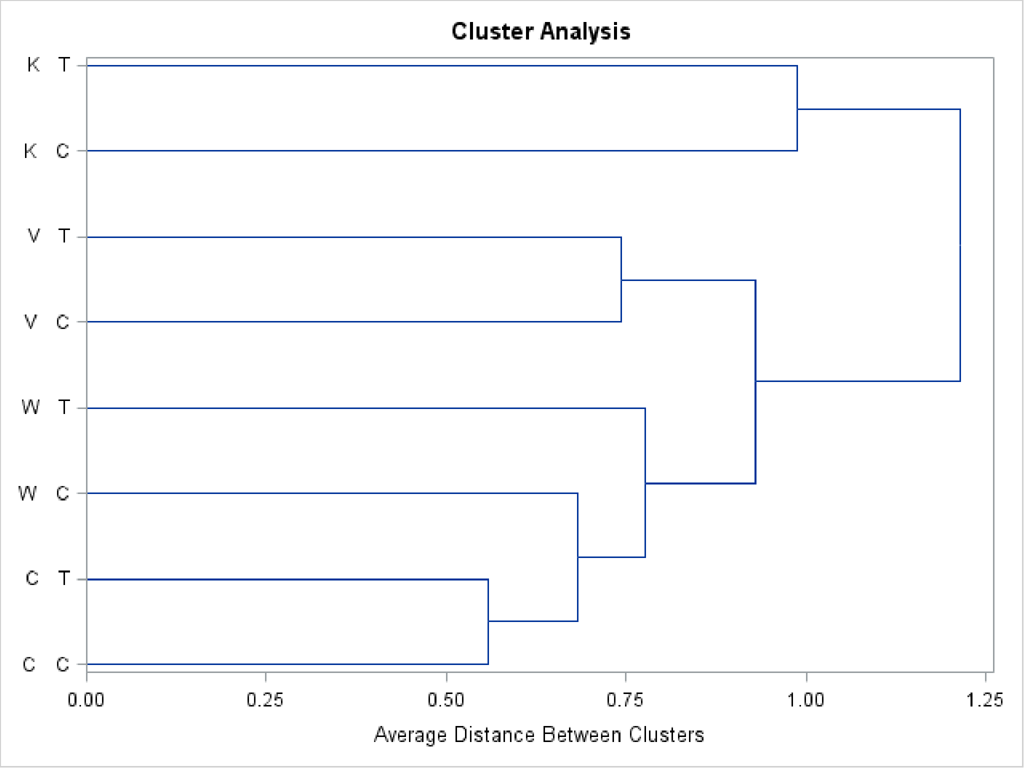
d. 2010, spring.



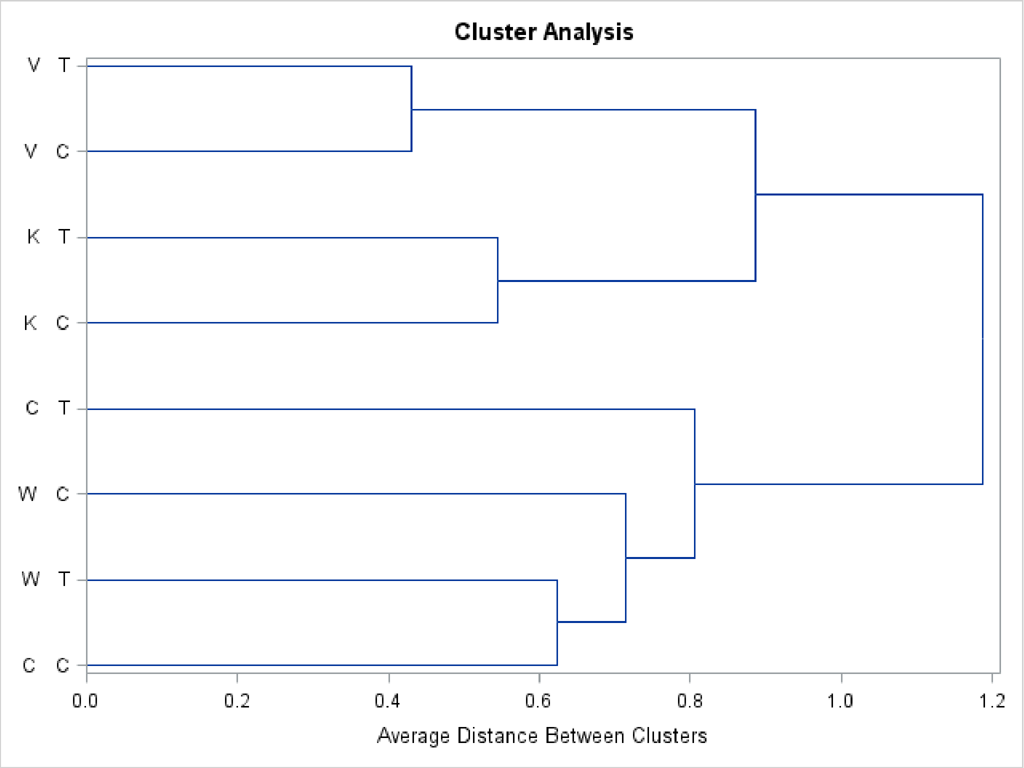
e. 2010, fall.



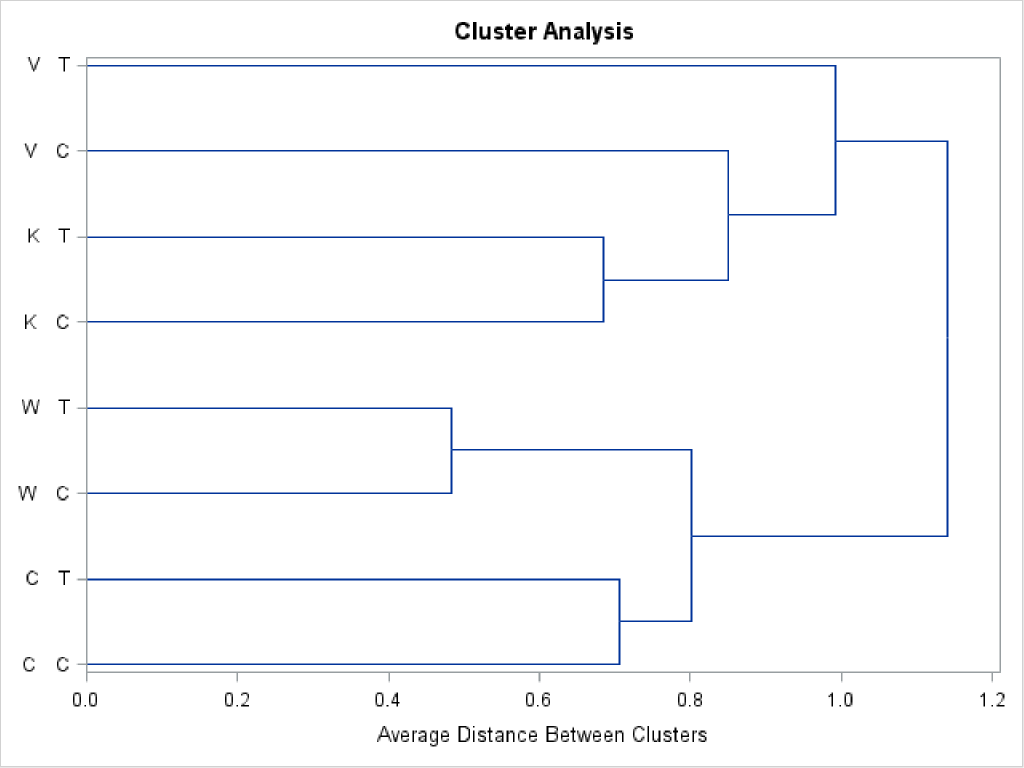
f. 2011, spring.



g. 2011, fall.



i. 2012, spring.



j. 2012, fall.

Figure 2.75. Cluster analysis dendrograms showing similarities of monitoring sites/plots based on bird species composition, spring and fall 2008-2010 prior to tree thinning treatments (a–e), spring and fall 2011 (f–g), and 2012 following thinning treatments (i–j).

2.7.2 SMALL MAMMALS

Small mammals (rodents) were sampled from a single six by six–trap grid (36 traps total) of live-capture rodent traps set at 10-m (33-foot) intervals on each of the wildlife monitoring plots for three consecutive nights in spring and fall, the same dates that birds were sampled in 2008, 2009, 2010, 2011, and 2012. Samples from spring and fall are useful to follow trends in adults and juveniles in order to assess breeding status and production over each year, but season species composition generally does not change as with birds.

Counts of individual rodents in 2012 revealed that more rodents were found on treated plots than on control plots in both the spring and in the fall at all sites except the Vigil piñon/juniper site (Figure 2.76). However, numbers of rodents increased considerably on the treatment plots in the fall compared to numbers on those same plots in the spring of 2012, indicating a disproportionate increase on treated plots in 2012. Numbers of rodent species also tended to be higher on treated plots than control plots in the fall, especially at the two piñon/juniper sites (Figure 2.77). Rodent numbers in general increased across all study sites except the Vigil site, indicating a general increase in rodent populations in 2012, given that summer is the principal breeding period.

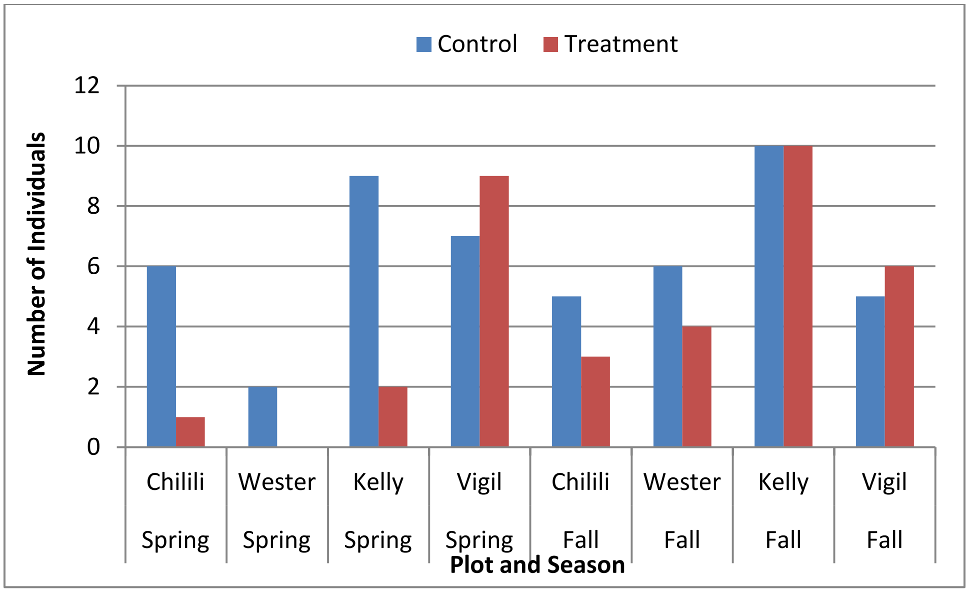


Figure 2.76. Numbers of individual rodents recorded from thinning treatment and control plots across the four study sites in both spring and fall, 2012.

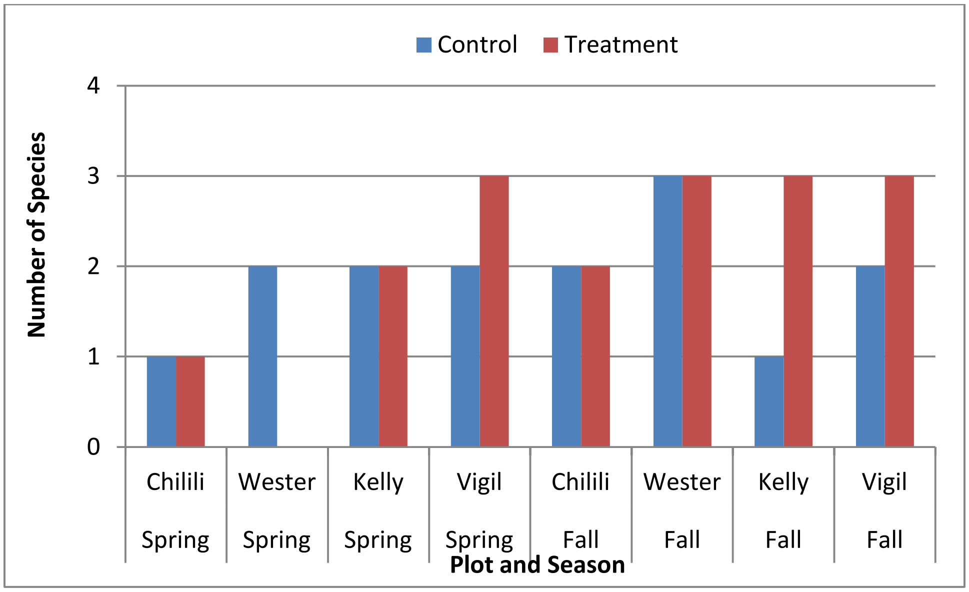
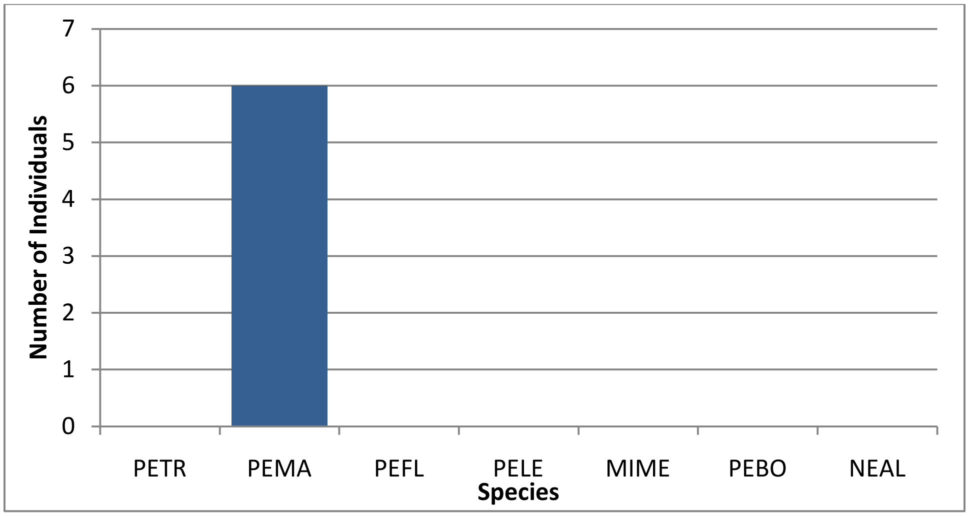
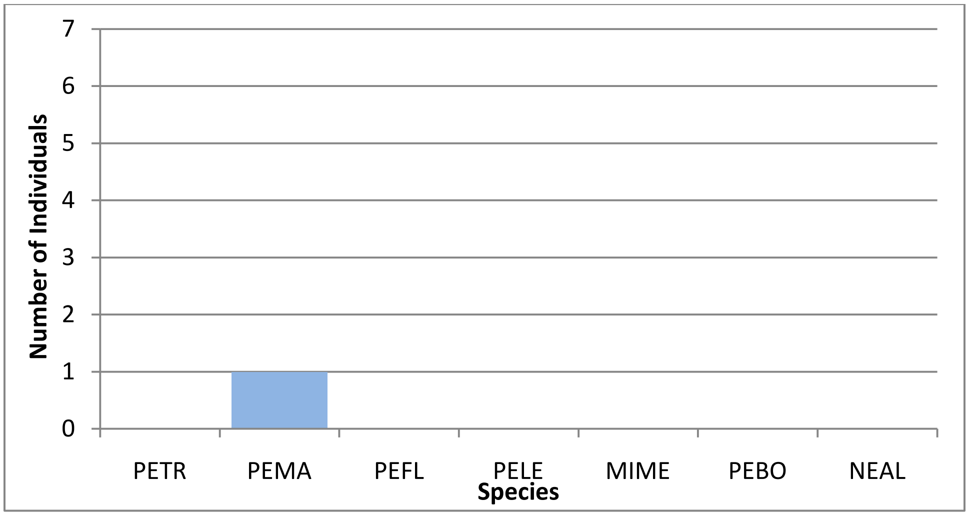


Figure 2.77. Numbers of rodent species recorded from thinning treatment and control plots across the four study sites in both spring and fall, 2012.

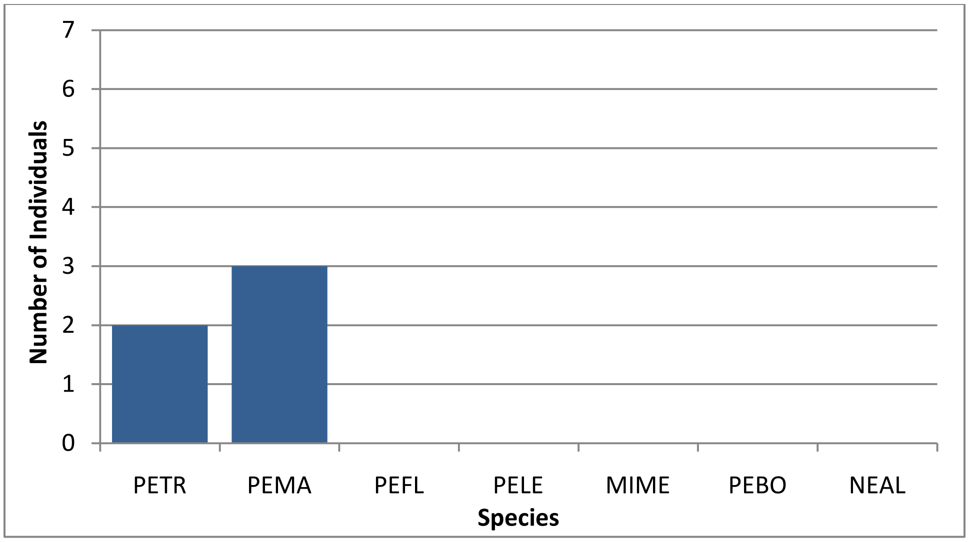
Figure 2.78 presents the species and numbers of individuals of those species summarized in Figure 2.76 and Figure 2.77. Examination of Figure 2.78 shows that the deer mouse (*Peromyscus maniculatus*) was the dominant species at the two ponderosa pine sites, and the pinyon mouse (*P. truei*) was the dominant rodent species at the two piñon/juniper sites. However, the deer mouse also was common at the Vigil site, especially in the spring. There were little differences in numbers of species present between paired control and treatment plots.



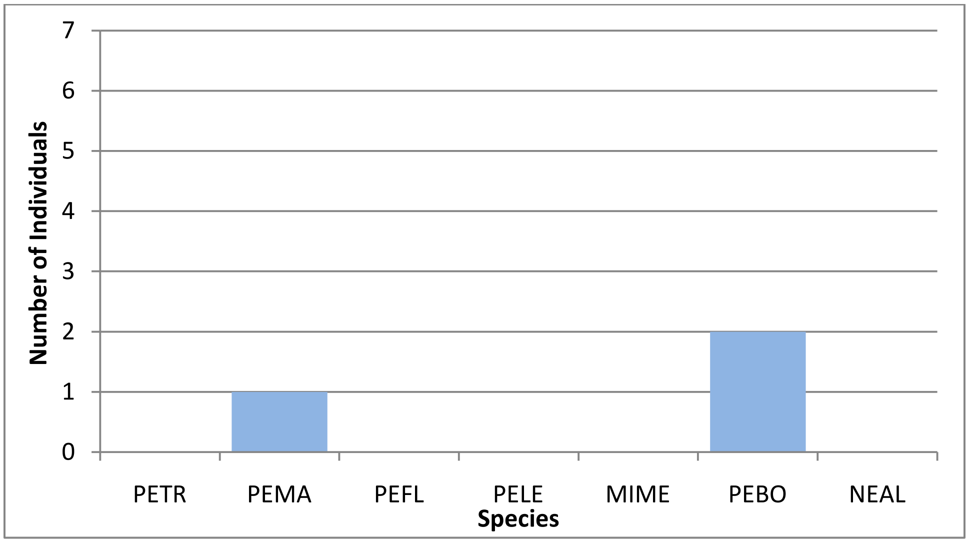
a. Chilili control plot, spring.



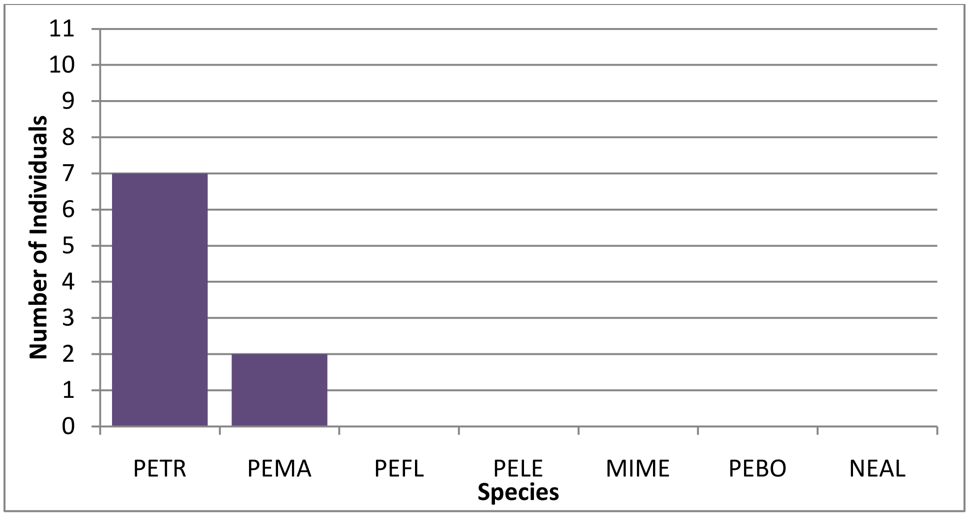
b. Chilili treatment plot, spring



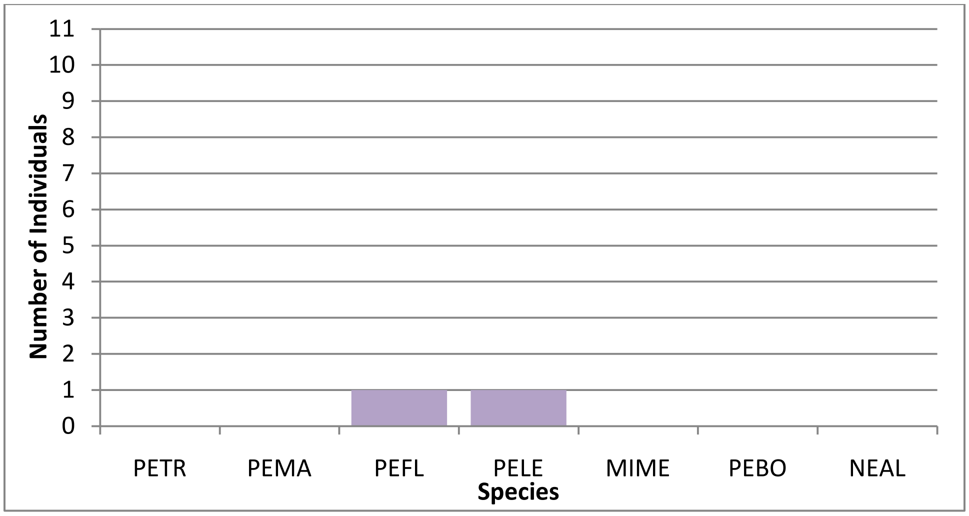
c. Chilili control plot, fall.



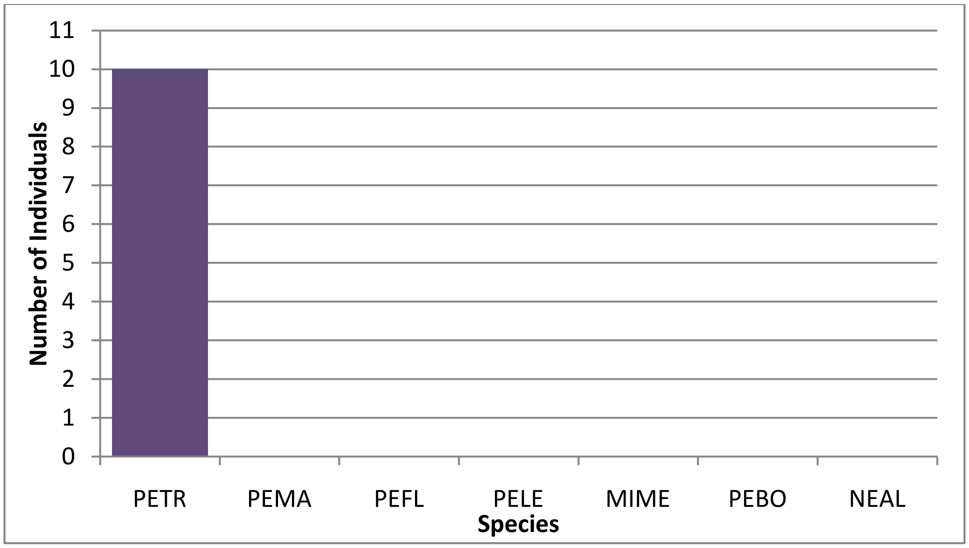
d. Chilili treatment plot, fall.



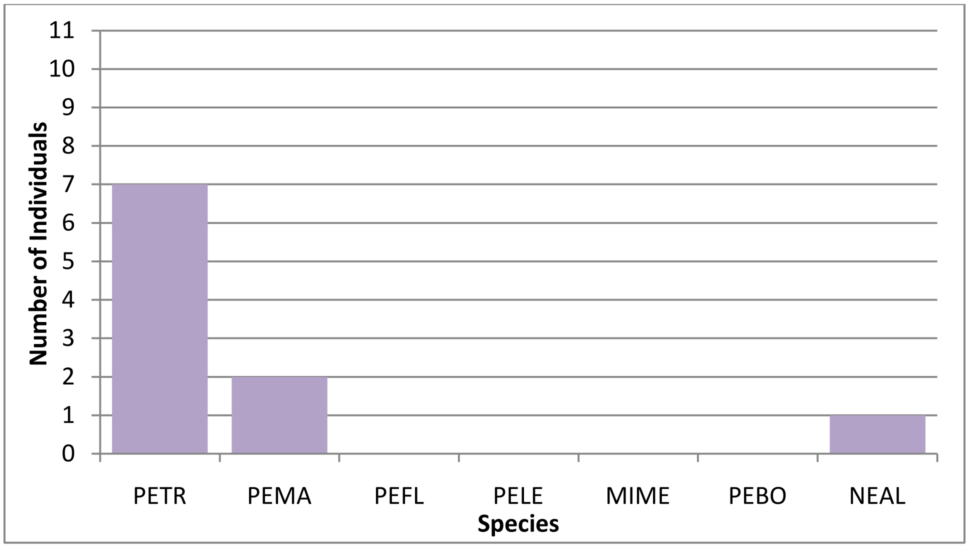
e. Kelly control plot, spring.



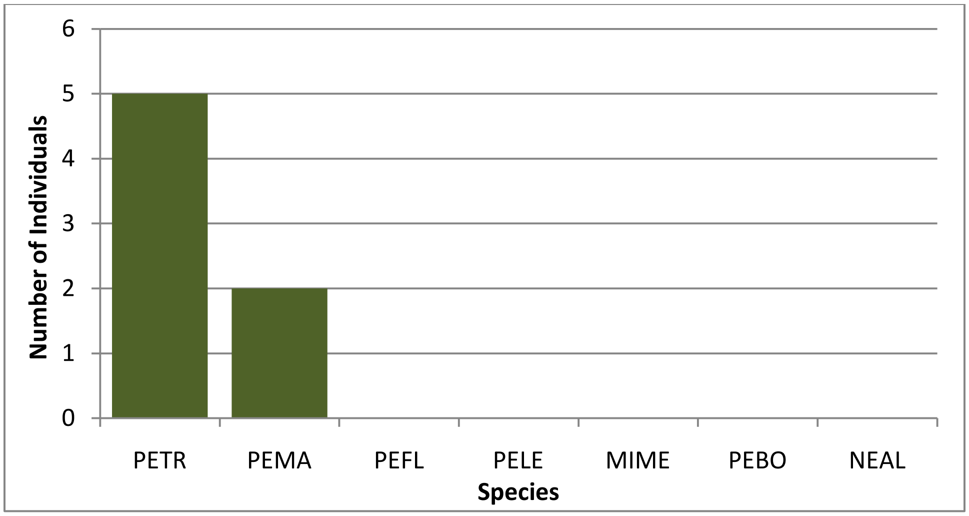
f. Kelly treatment plot, spring.



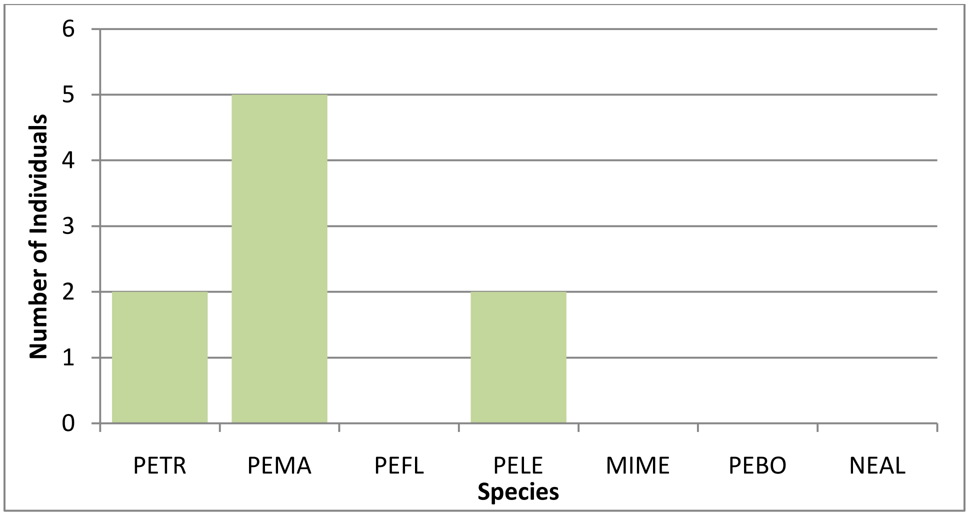
g. Kelly control plot, fall.



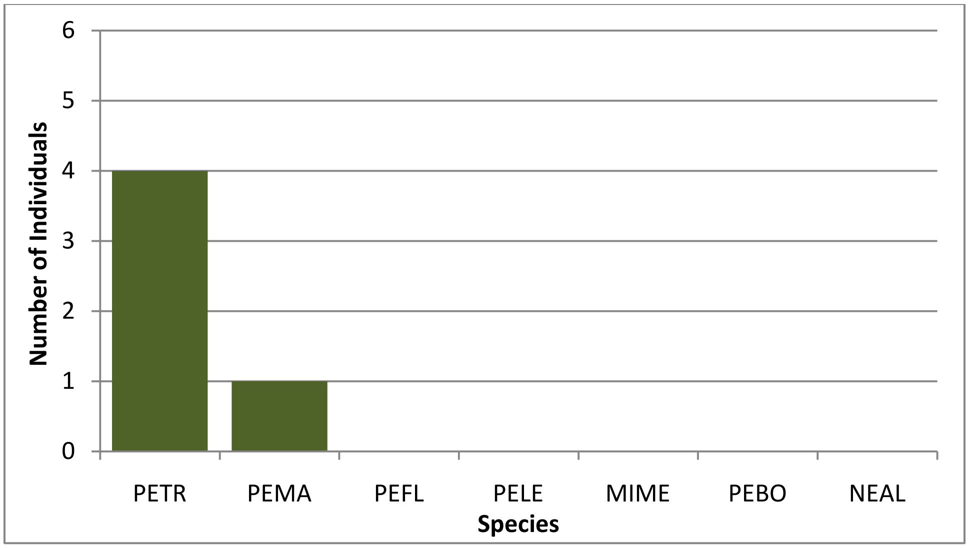
h. Kelly treatment plot, fall.



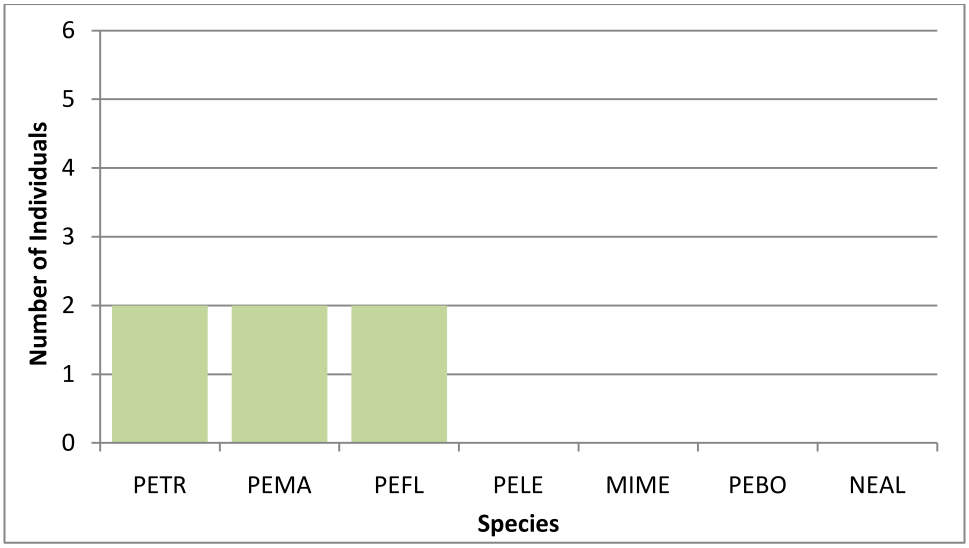
i. Vigil control plot, spring.



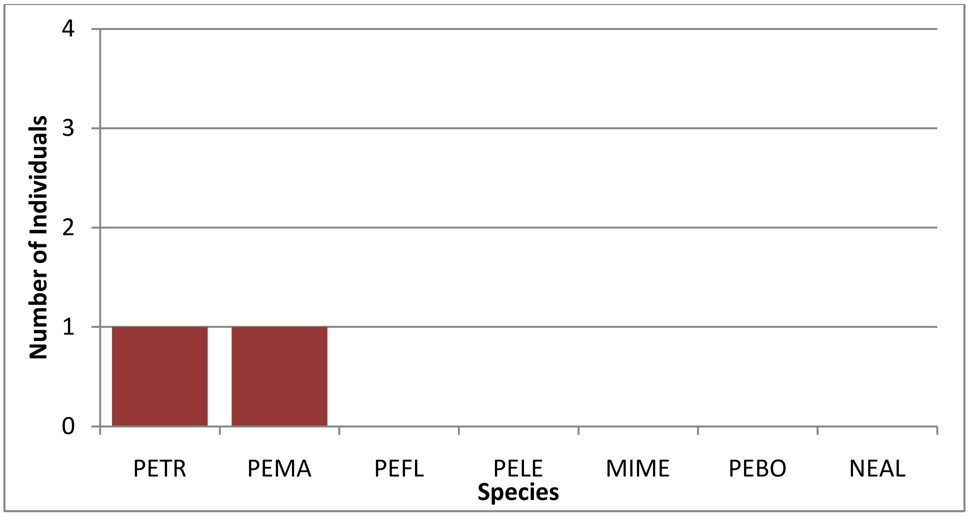
j. Vigil treatment plot, spring.



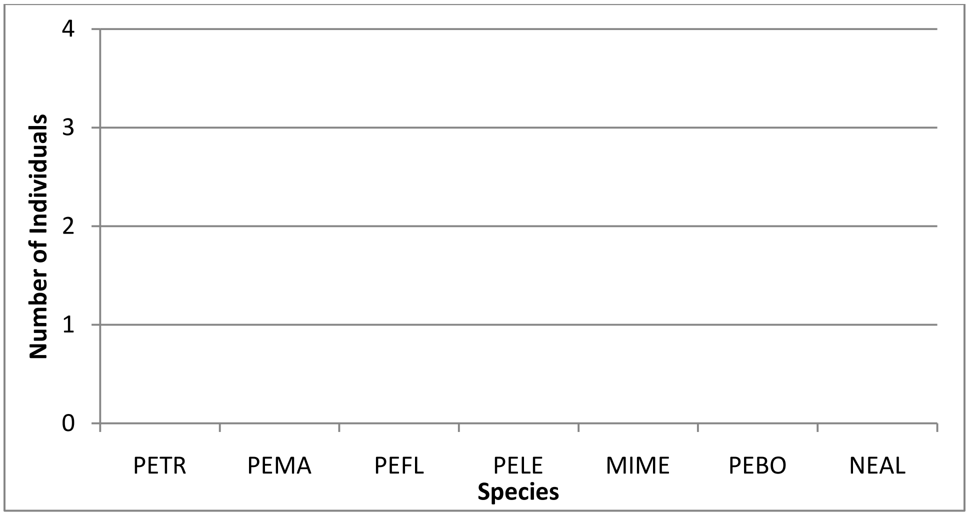
k. Vigil control plot, fall.



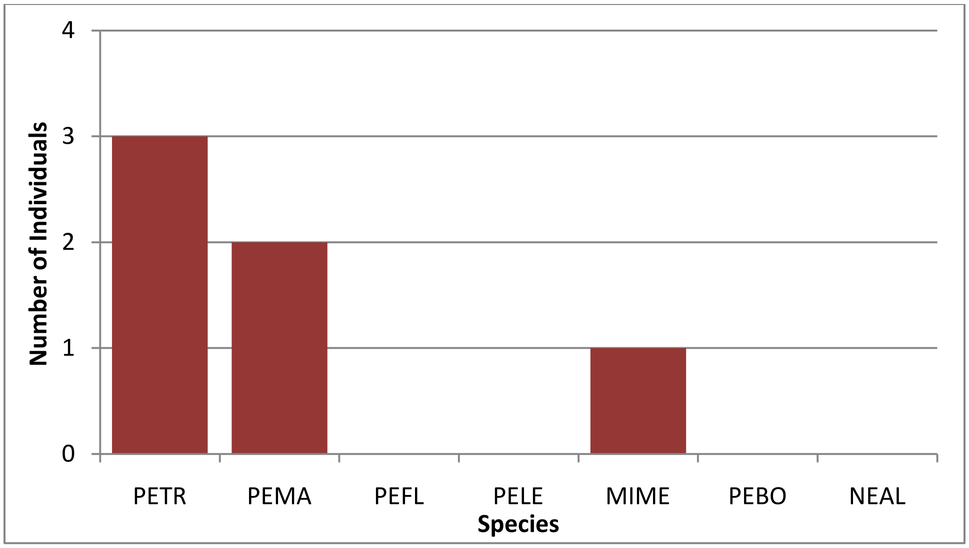
l. Vigil treatment plot, fall.



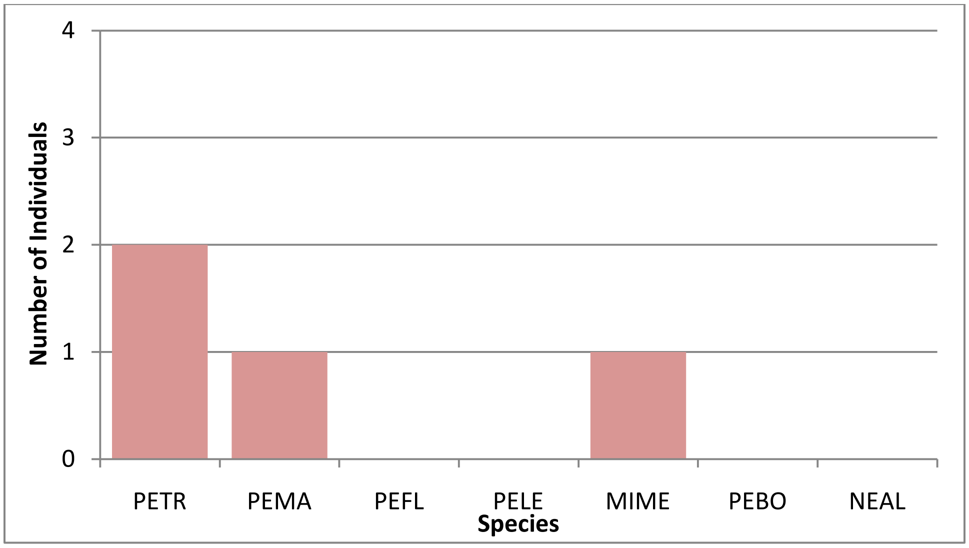
m. Wester control plot, spring.



n. Wester treatment plot, spring.



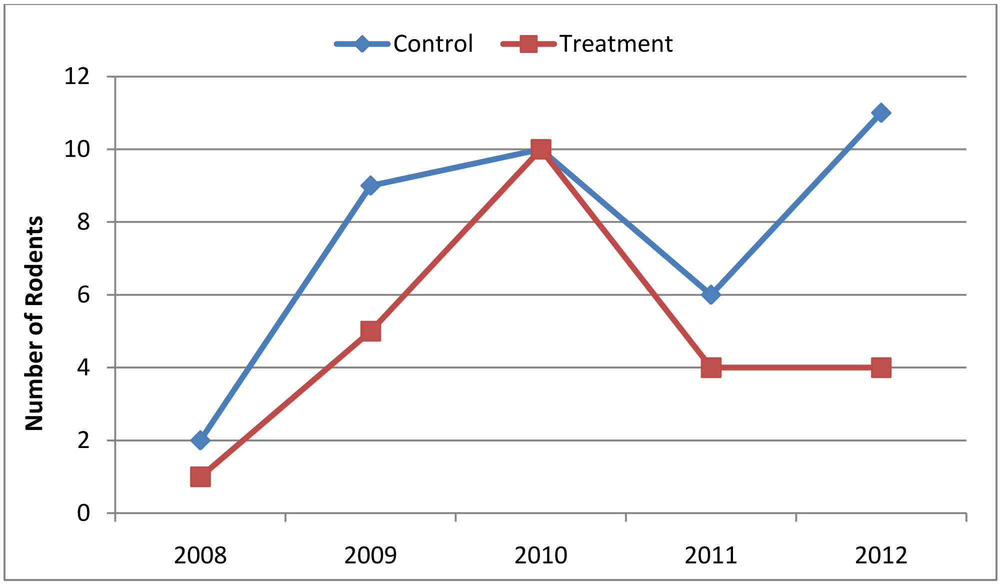
o. Wester control plot, fall.



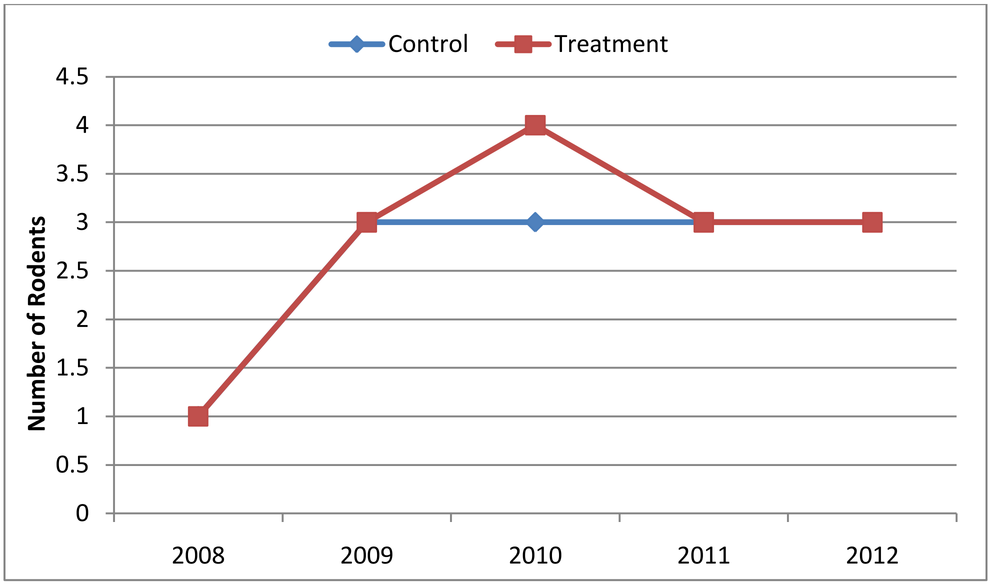
p. Wester treatment plot, fall.

Figure 2.78. Numbers of individual rodents of each species recorded from all control and treatment study plots in 2012, both spring and fall. Rodent species codes correspond to the following names: PETR = *Peromyscus truei* (pinyon mouse), PEMA = *Peromyscus maniculatus* (deer mouse), PEFL = *Perognathus flavus* (silky pocket mouse), PELE = *Peromyscus leucopus* (white-footed mouse), MIME = *Microtus mexicanus* (Mexican vole), PEBO = *Peromyscus boylii* (brush mouse), NEAL = *Neotoma albigula* (white-throated wood rat).

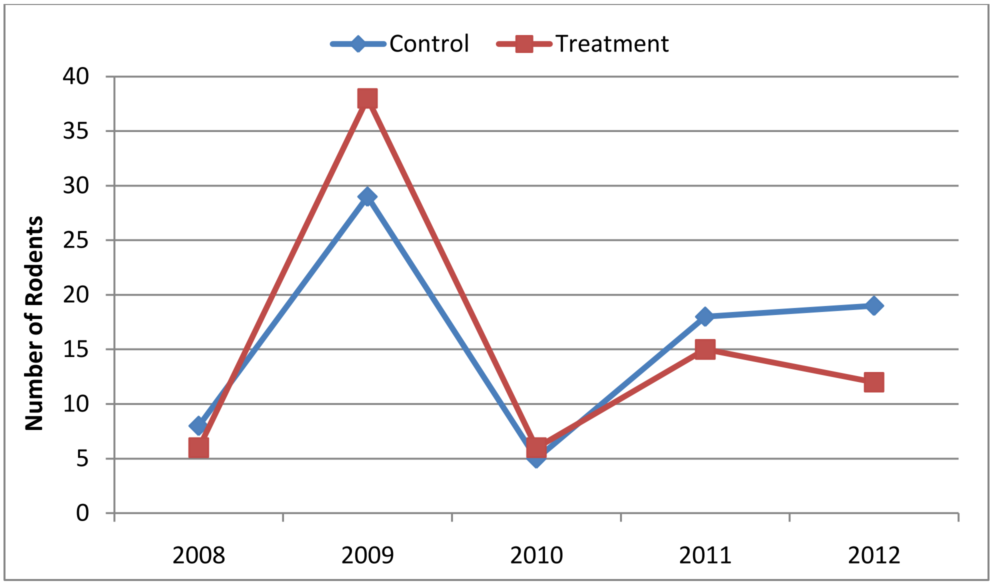
Figure 2.79, a–h, presents total numbers of rodents from control and treatment plots, both spring and fall, from all four study sites, fall 2008 through fall 2012. In general, overall rodent counts peaked in 2009, declined in 2010, and have been increasing slightly in 2011 and 2012, but were declining between spring and fall in 2012. Rodent numbers have increased on control versus treated plots at both ponderosa pine sites since tree thinning treatments in late 2010, indicating that deer mice densities have declined on treated plots at those two sites, especially the Wester site. Rodent numbers at the two piñon/juniper sites do not show any general consistent trends between treatment and control plots since thinning treatments were imposed. Numbers of rodent species were not high enough to perform cluster analysis of rodent communities across the sites as was done for birds above.



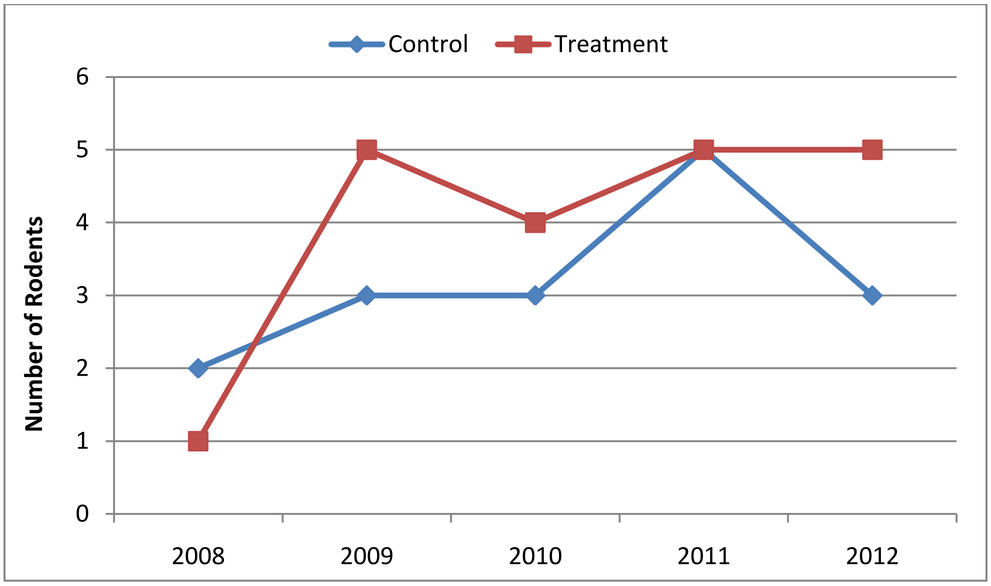
a. Chilili spring.



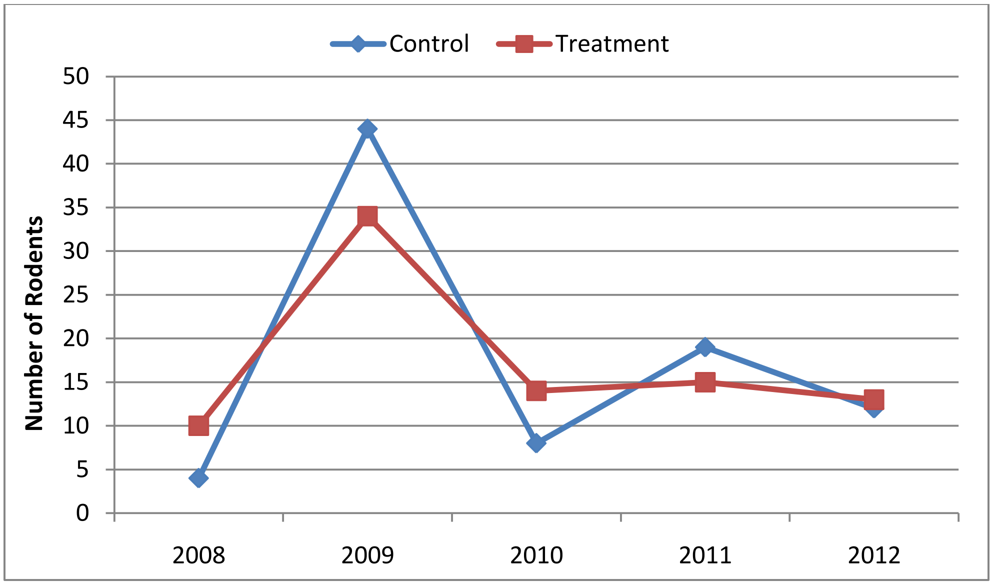
b. Chilili fall.



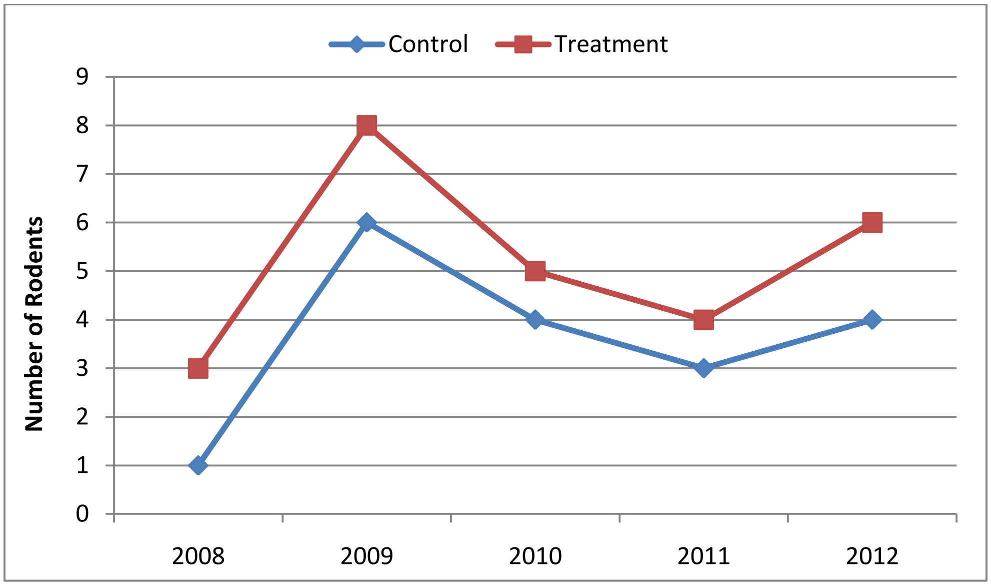
c. Kelly spring.



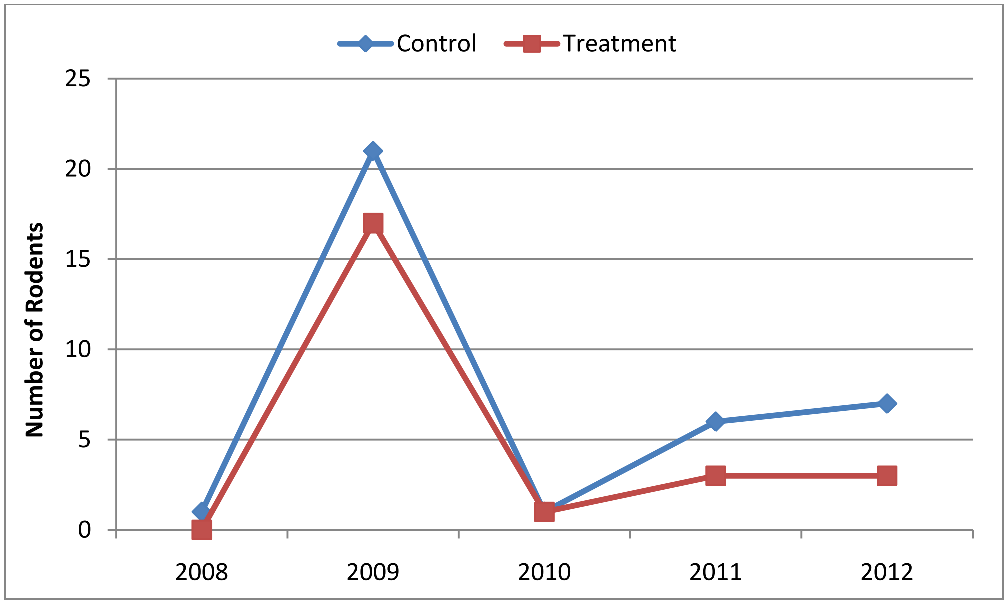
d. Kelly fall.



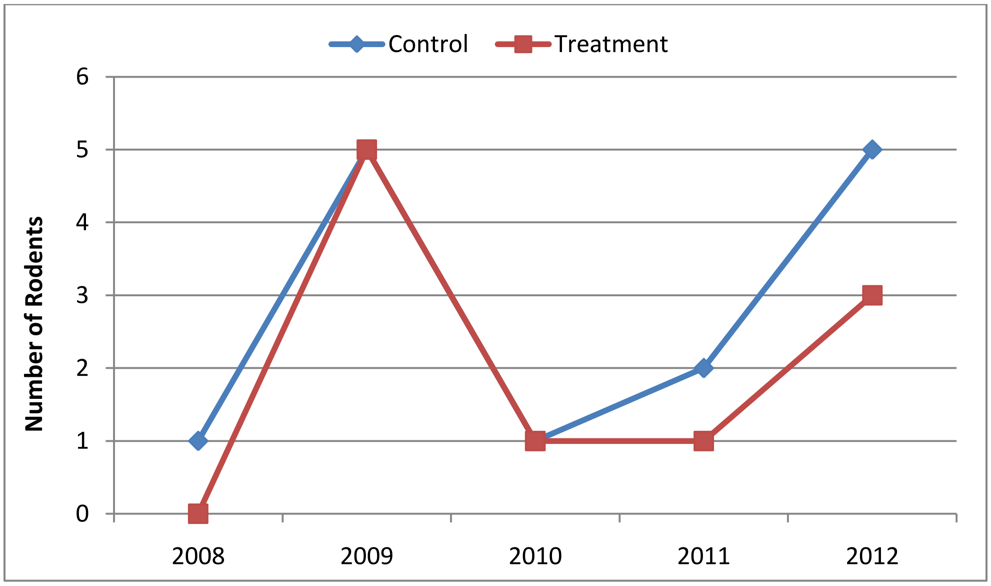
e. Vigil spring.



f. Vigil fall.



g. Wester spring.



h. Wester fall.

Figure 2.79. Total numbers of rodents from both control and treatment plots at all four study sites, fall 2008–fall 2012.

2.7.3 WILDLIFE CAMERAS

Wildlife cameras (Figure 2.80) were established on the forest thinning paired control and treatment monitoring plots in February 2012 in order to evaluate how medium and large wildlife species are using the control versus treated study plots. The cameras were all Leaf River IR5 infrared cameras that had a detection sensor up to 21 m (70 feet). One camera was placed on each of the eight control and treatment study plots among the four sites, Chilili, Kelly, Vigil, and Wester. The wildlife cameras were erected near the center of each wildlife monitoring plot, approximately 1.2 m (4 feet) from the ground and oriented toward open areas free of trees up to 20 m (66 feet) away from each camera. The cameras operate during day and night using a movement sensor infrared flash. Camera photograph cards were offloaded each month.

Figure 2.80. Automatic wildlife camera.

Figure 2.81 and Figure 2.82 present summaries of numbers of different types of animals recorded from wildlife cameras during 2012. Figure 2.81 presents all types of animals summed over all treatment and control plots from all sites. Note that one of the cameras at the Vigil piñon/juniper site malfunctioned, so data from that site are not included. These findings show that in general, native wildlife species such as mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and wild turkey (*Meleagris gallopavo*) are more frequent on control than treatment plots, while domestic livestock, both cattle and horses, were more frequent on treatment plots than control plots. Figure 2.82 shows that domestic livestock were especially abundant at the Kelly piñon/juniper site and were about equally abundant on both the control and treatment plots at the Wester ponderosa pine site. These findings indicate that native wildlife species may prefer the more dense stands of trees remaining on the control plots than the more open habitats created on the treatment plots. In contrast, domestic livestock appear to prefer the more open treated plots where trees were removed. The physical structure of tree stands may be important, but also the increased growth of herbaceous vegetation on treated piñon/juniper plots may also be more attractive to domestic livestock.

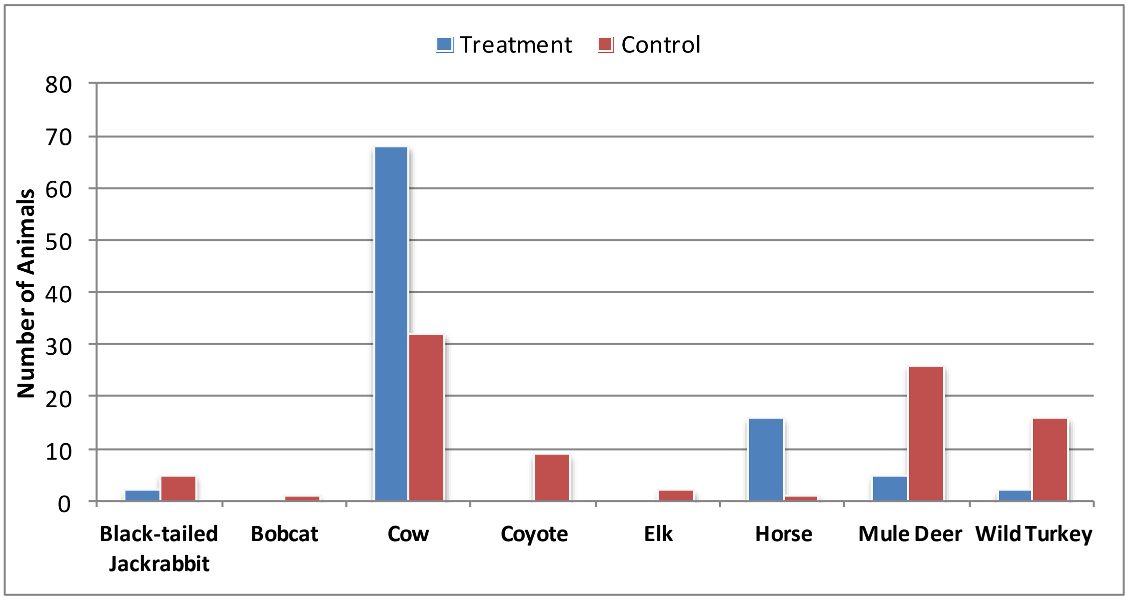


Figure 2.81. Summary of total photographs of different animals recorded from wildlife cameras during 2012.

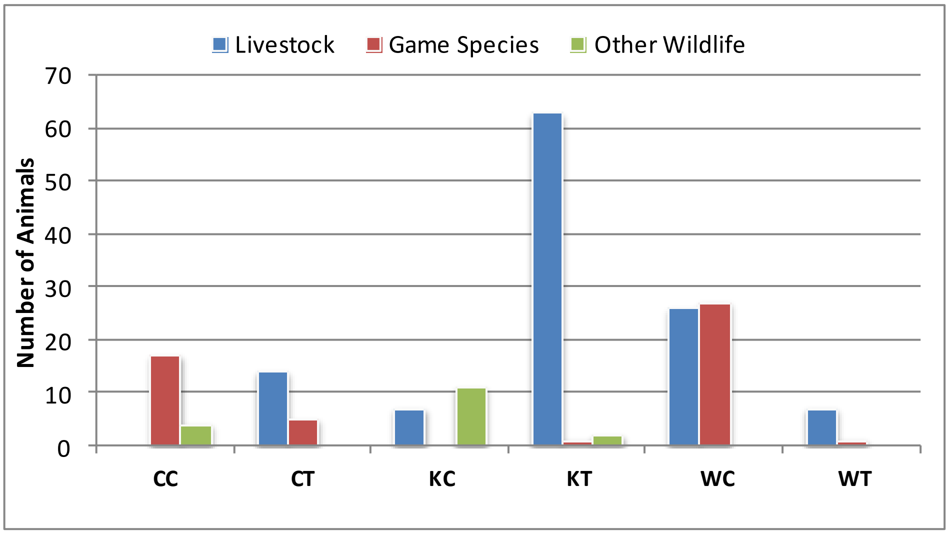


Figure 2.82. **Summary of types of animals recorded from control and treatment plots at each study site during 2012. Note that one camera at the Vigil site malfunctioned several times, so those incomplete data are not presented.**

3.0 EPHEMERAL WATERSHED STREAM MONITORING

Background information on the stream piezometers can be found in the 2009 Annual Report. In addition to the paired watershed flumes, piezometers were installed on three nearby streams in order to gauge surface flows on a larger scale (Figure 3.1). The 2012 monitoring season saw very few flows; however, a large flow did occur at the Vigil site and destroyed the stream piezometer (Figure 3.2). Due to the damage caused to the stream piezometer from the flood, the stage was not able to be recorded; however, it was estimated that the peak flow reached nearly 1.5 m (5 feet) (Figure 3.3). A new gauge made of galvanized steel was installed to replace the damaged gauge on a subsequent site visit. The other gauges at the Chilili and Kelly site did not record any flows during the 2012 monitoring season, but seem to be in good working order.

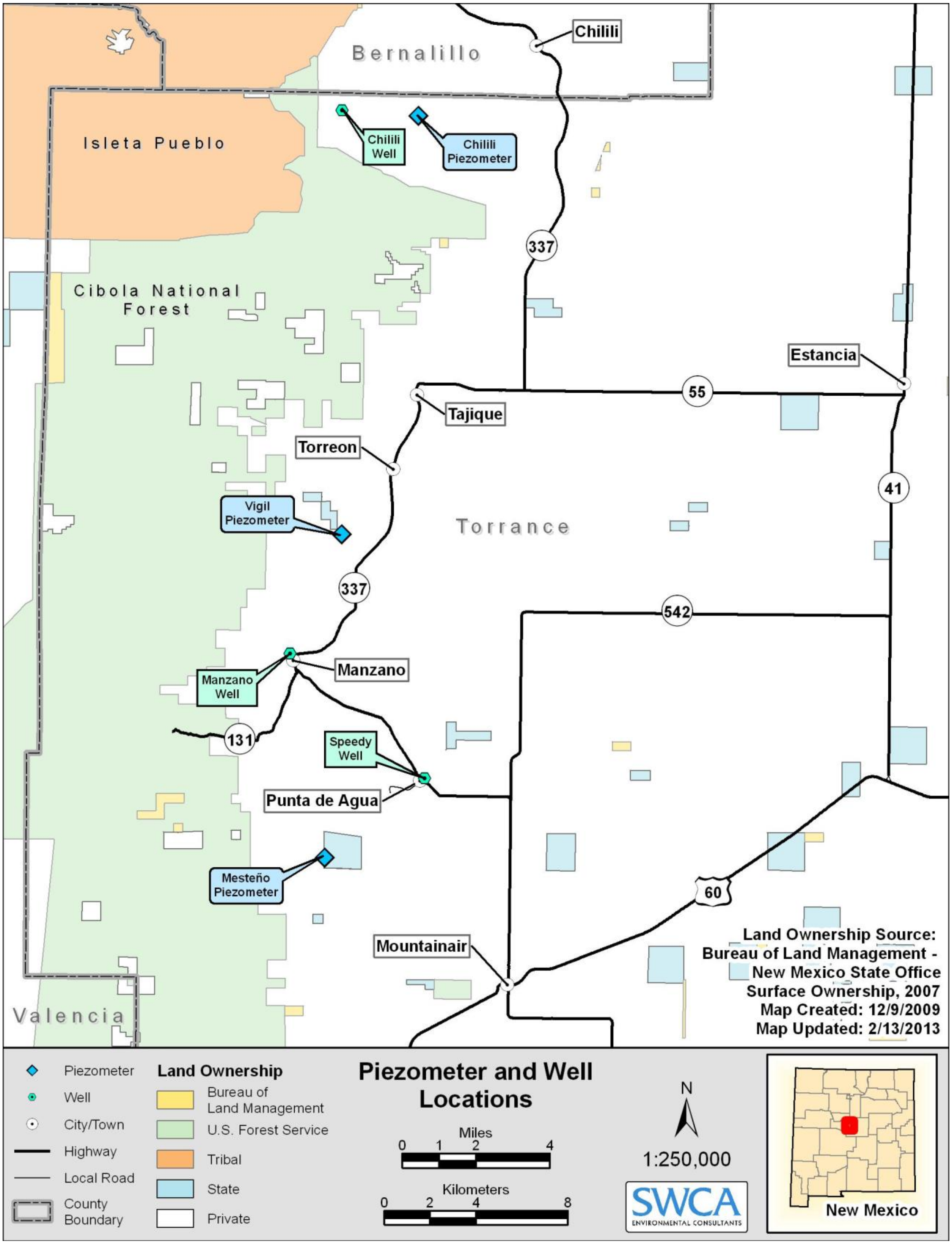


Figure 3.1. Location of the piezometers and wells within the Estancia Basin.

Figure 3.2. The Vigil piezometer in the fall of 2012 after a storm event destroyed the gauge.

Figure 3.3. View of the Vigil piezometer facing downstream showing the high water mark (1.5 meters) as a red line above the piezometer.

3.1 GROUNDWATER WELL MONITORING

The monitoring study is evaluating infiltration rates in the Estancia Basin by using deep pressure sensors to monitor the level of groundwater in relation to stream flow events. By monitoring the groundwater levels in private wells located close to stream monitoring locations, changes in recharge can be observed, and potentially the impact of thinning and burned areas can be compared to these groundwater levels to asses any changes.

Ideally, this project will evaluate infiltration rates in the control areas versus burned areas and relate this information to nearby groundwater levels. This could be accomplished by monitoring private wells located close to stream monitoring locations. Sandia National Laboratory and the U.S. Geological Survey are currently initiating well monitoring programs. Both entities have been receptive to sharing data when they become available, though neither knows if data would be available near the project's piezometer locations in the immediate future. The monitoring will use deep pressure sensors to monitor the level of groundwater in relation to stream flow events. If these data are available, they will be compared to the collected data from this project.

SWCA installed three well monitoring devices during early to mid June 2009. These well monitoring locations are at Chilili, Manzano, and Punta de Agua (see Figure 3.1). Each monitoring well is equipped with Solinst Levelogger Junior pressure transducers that were programmed to record values hourly. The Chilili site is approximately 30 m (98 feet) from the western flume. The well is approximately 15 m (50 feet) deep, and depth to groundwater when installed is approximately 8 feet (25 feet). The Manzano well is shallow, approximately 8 m (25 feet) deep, and periodically goes dry. The municipal well is nearby and likely contributes to the drawdown in this area. SWCA is looking for an alternative well, but until it is found this well will continue to be monitored. The Punta de Agua well is in "downtown" Punta. The well is approximately 37 m (120 feet) deep, and depth to groundwater is approximately 28 m (91 feet) when installed. SWCA will off-load data quarterly at each well location.

Figure 3.4 through Figure 3.6 display the well data from each of the three locations monitored in the Estancia Basin. During 2012 all wells showed a general decline throughout the year. The well at Punta de Agua showed a steady decline through the course of the year, while the well at Chilili showed a response to the snowmelt as can be seen by the peak in late April 2012. This draw down can likely be attributed to increased pumping for domestic and agricultural use at the Punta site and a lack of a good snowpack and early season precipitation at the Chilili site. The Chilili well did show a small rise in during the month of October, which was the result of several large late season monsoonal storms. The well at Manzano remained dry for the course of the 2011 season.

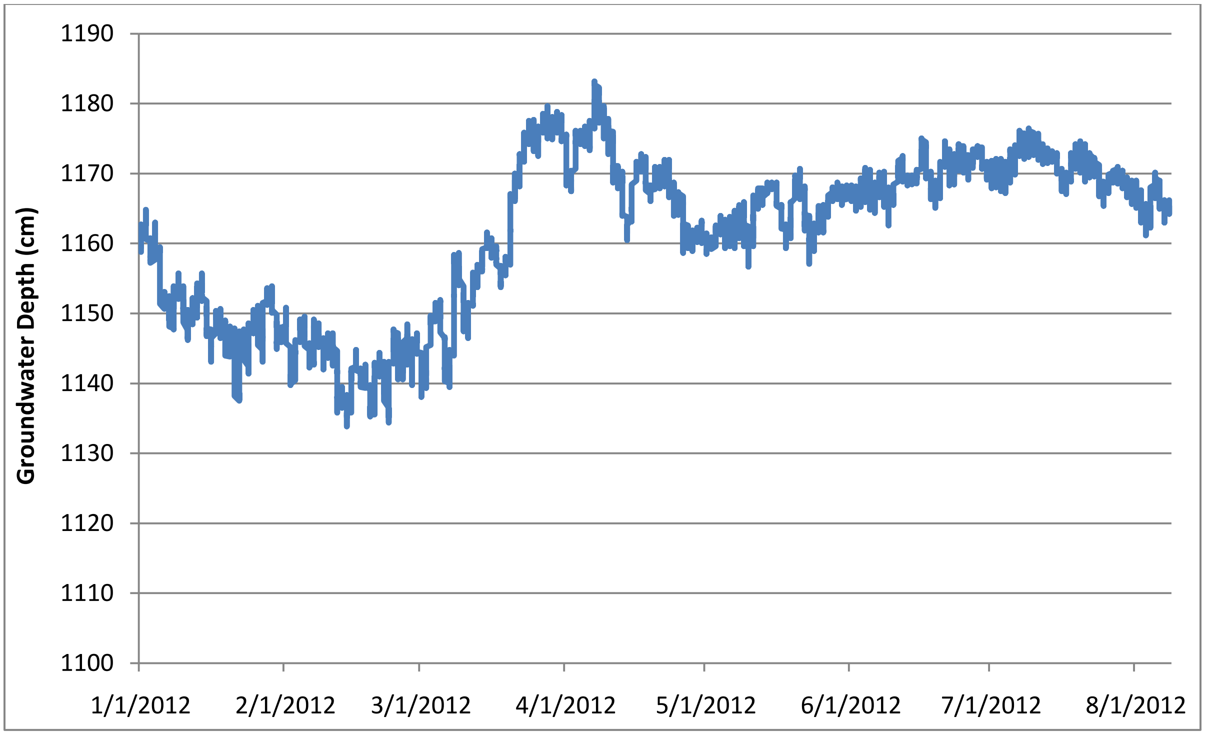


Figure 3.4. Well data from the Chilili site showing the peak from the snowmelt followed by a steady decline, which represents the drought conditions that the region faced in 2012.

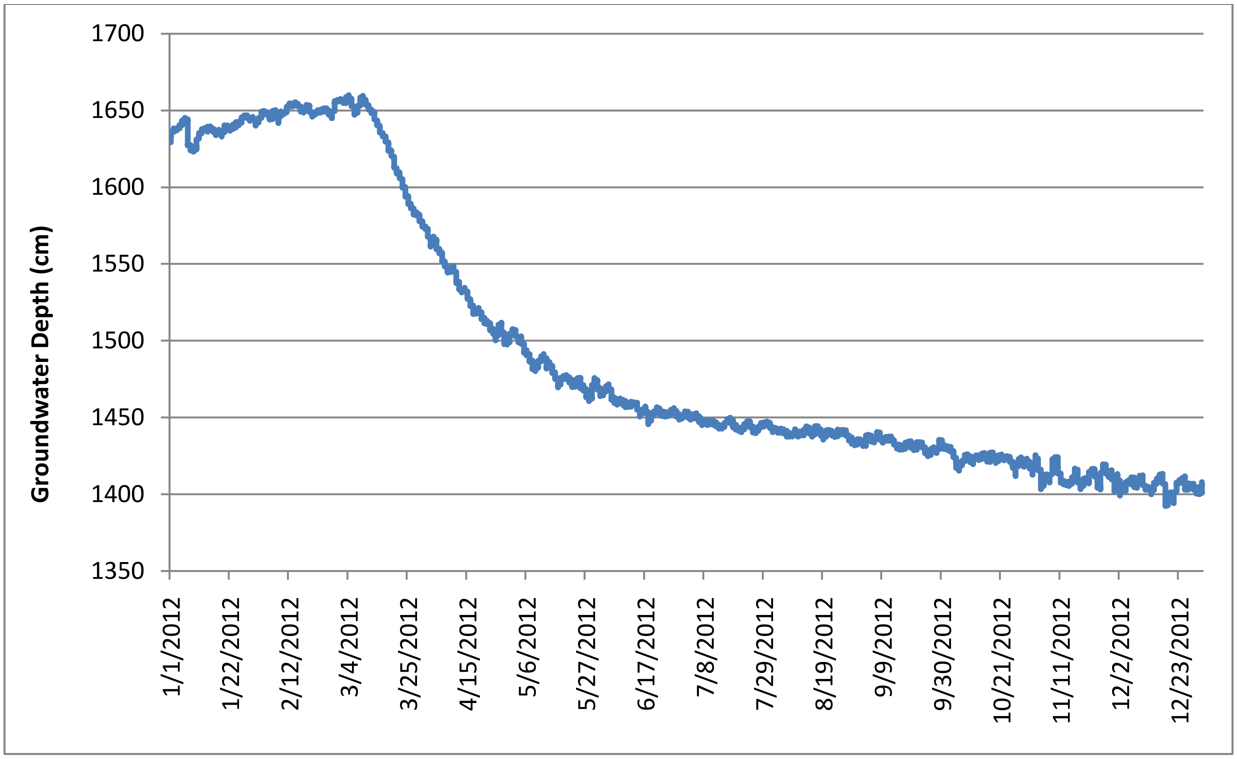


Figure 3.5. **Well data from the Punta de Agua site showing steady rise of the groundwater over the summer months.**

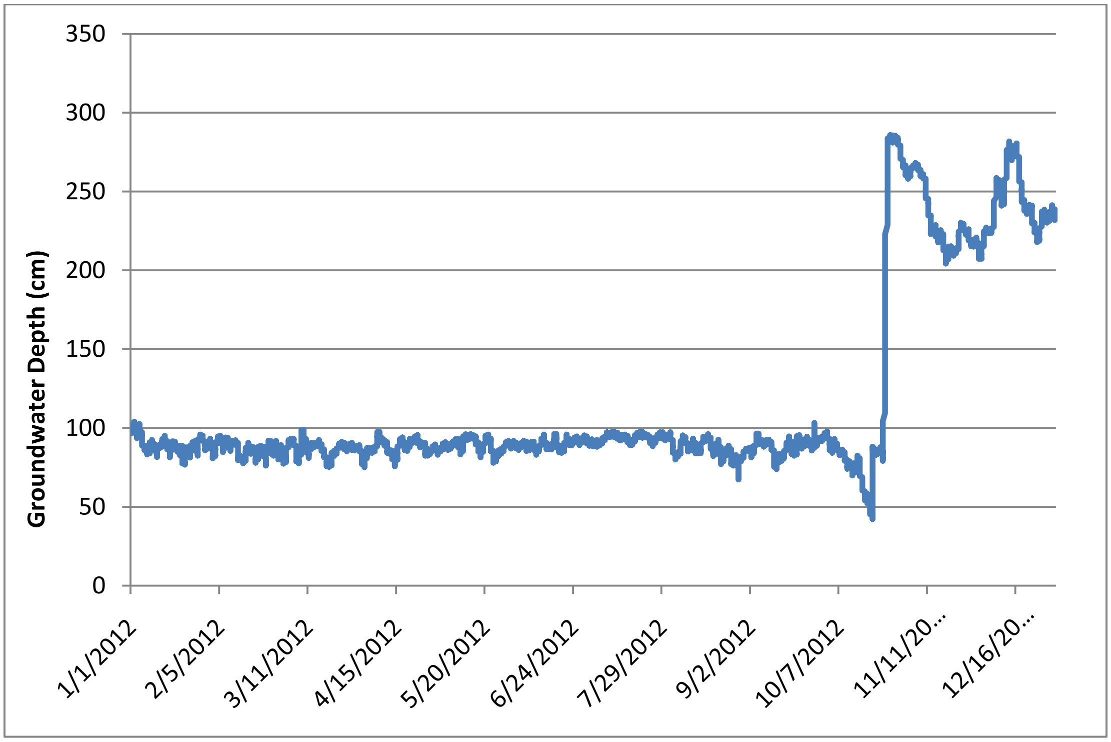


Figure 3.6. **Well data from the Manzano site showing the fluctuations in groundwater over the summer months.**

4.0 SOUTH MOUNTAIN WEATHER STATION

The SMWS was installed by EnviroLogic to provide meteorological, soil moisture, and temperature data as part of the Estancia Basin Watershed Health and Restoration Program overseen by the Steering Committee. EnviroLogic installed the SMWS in September 2006 to initiate site-specific monitoring of rainfall and soil water content at various soil depths. For details on site selection and monitoring protocols, please refer to the 2008 Monitoring Plan (SWCA 2008). The SMWS is within the Edgewood Soil and Water Conservation District on the private property near South Mountain, Santa Fe County, New Mexico, approximately 19 km (12 miles) north of the town of Edgewood (Figure 4.1). The intent of EnviroLogic was to assess water infiltration through soil depths, relate that to meteorological variables, and then compare two measured locations to determine the effects of forest thinning projects on groundwater recharge.

The SMWS measures precipitation, wind speed and direction, air temperature, humidity, and solar radiation. Soil moisture and temperature probes are situated at various depths at two locations with distinct vegetation structure types: one site within a piñon/juniper stand and one site in an adjacent open area consisting of short grasses. EnviroLogic referred to these locations as “Tree” and “Meadow,” respectively. The Tree site is situated approximately 30 m (98 feet) northeast of the SMWS within a grouping of oneseed juniper and piñon pine trees. The Meadow site is situated approximately 11 m (36 feet) northwest of the SMWS, in vegetation dominated by blue grama and broom snakeweed (*Gutierrezia sarothrae*).

SWCA is now responsible for the management of the SMWS and the maintenance, summation, and distribution of the data collected at this station. The following sections summarize the data collected since SWCA assumed responsibility for SMWS in April 2008. SWCA prepared a report, “South Mountain Weather Station: History, Data Summaries, and Continued Operation,” summarizing the data collected from 2006 and 2007 by EnviroLogic, and submitted that report to the Steering Committee. This report is available at the Restoration Institute’s website (http://www.nmfwri.org/).

During the 2012 monitoring season, New Mexico, particularly Torrance and Bernalillo Counties, experienced a severe drought (see Figure 2.7). The affects of the drought can clearly be seen in the result summaries below. The soil moisture measurement at both the Meadow and Tree sites showed long periods of drying, with only the near surface sensors showing variation (Figure 4.2–Figure 4.8). There were also no storms in 2012 that were able to produce deep seepage, which would register with the sensors in the deep bore holes. In fact, over the course of the monitoring period the deep soil moisture sensors at both the Meadow and Tree sites have remained constant with no variation. The effects of the drought can also be seen when looking at Figure 4.8, which displays the monthly averages of relative temperature and relative humidity. This graph shows high temperatures in June and July with low average relative humidity. This combination of high temperatures and low relative humidity is prime fire weather conditions and, therefore, likely a key factor for the occurrence of several large catastrophic wildfires in both New Mexico and Arizona (Los Conchas, Pacheco, and Wallow wildfires).

The data displayed below in Figure 4.2 through Figure 4.8 are summarized as monthly averages of relevant meteorological data. Also Figure 4.9 through Figure 4.11 summarizes the relevant meteorological data on an annual basis from 2009 through 2012. These graphs display any trends that may be occurring within the project area. Figure 4.9 shows the annual precipitation and average ambient air temperature on the same graph and it can clearly be seen that the pattern displayed is the same trend seen at the Watchdog weather stations. Figure 4.10 and Figure 4.11 show the soil moisture changes over the past for years at both the meadow and tree sites.

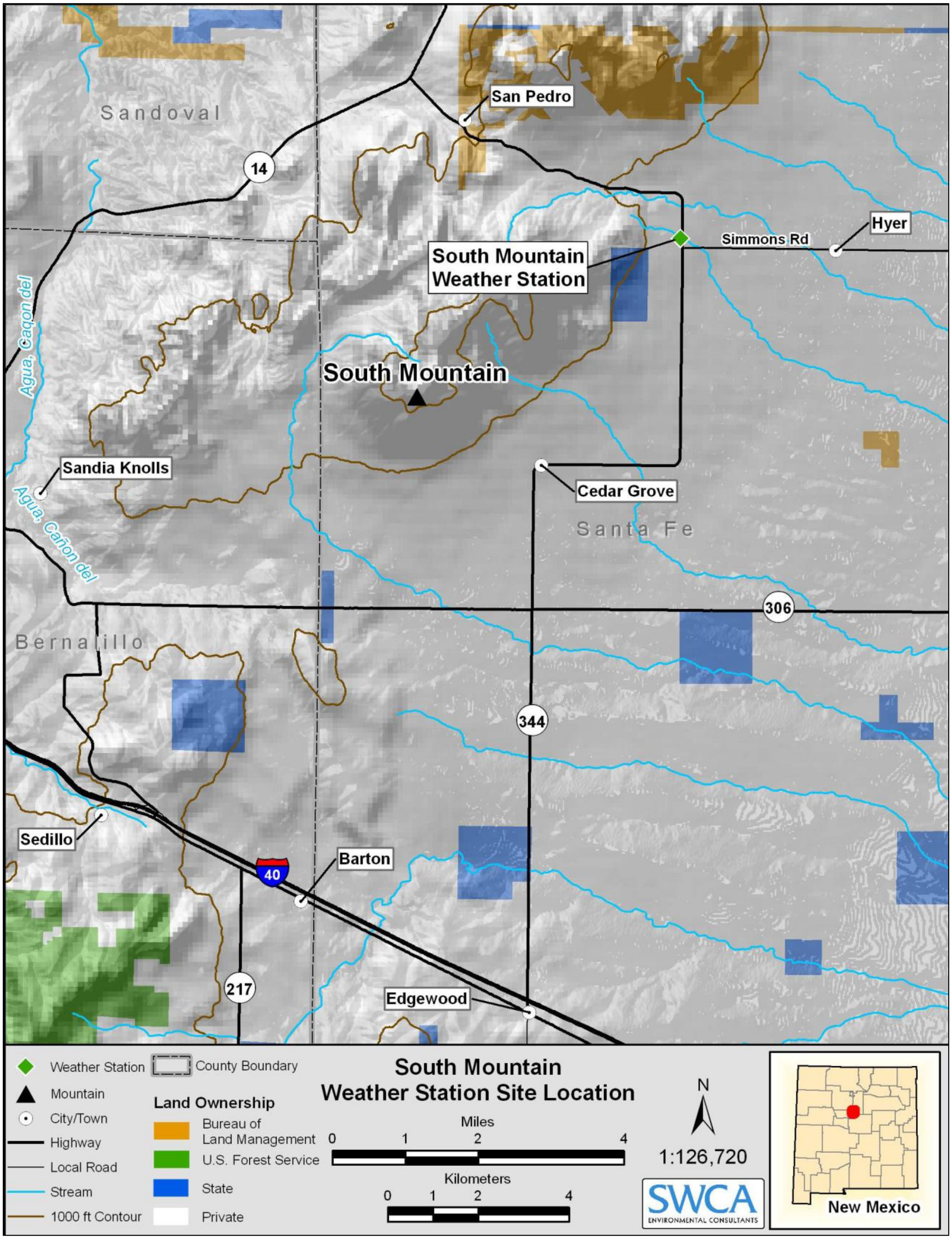


Figure 4.1. Location of the South Mountain Weather Station.

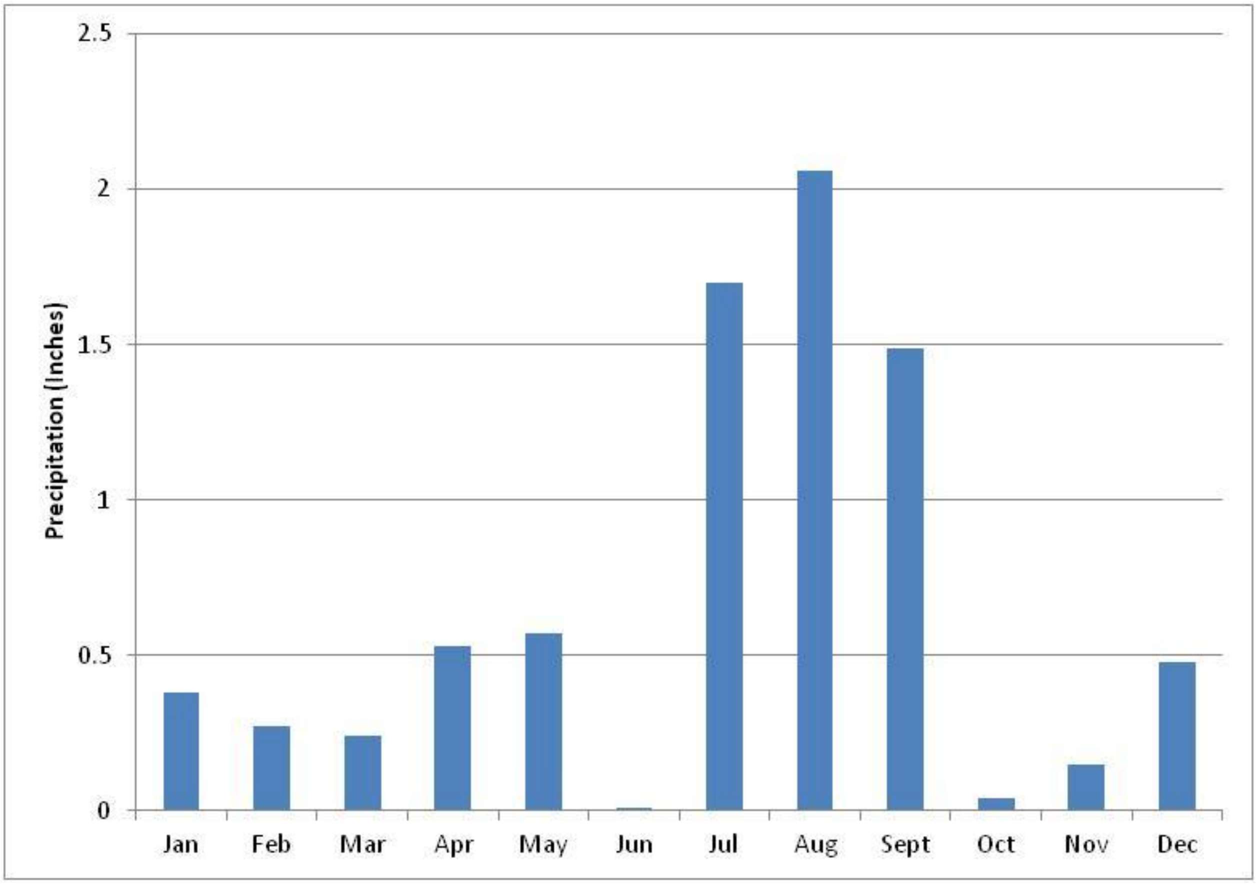


Figure 4.2. Graph showing monthly total rainfall over the course of 2012.

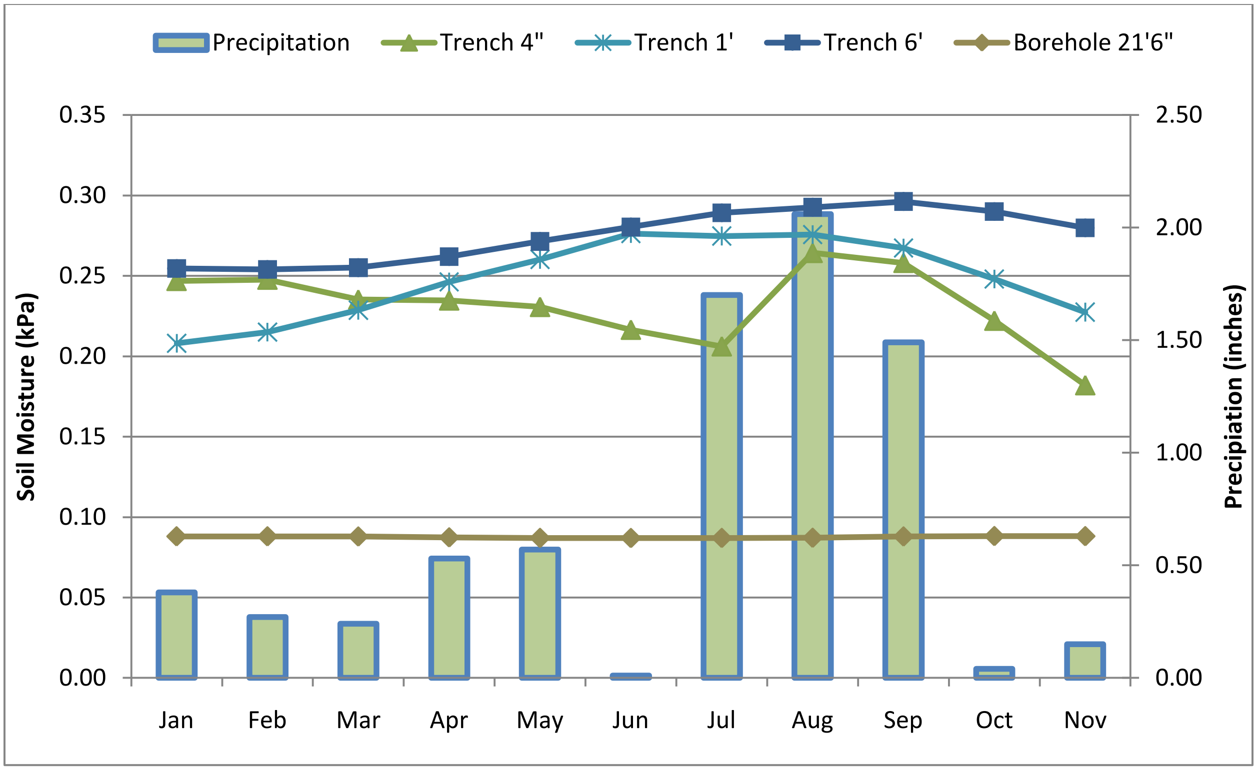


Figure 4.3. **Tree site monthly average soil moisture and total precipitation for 2012.**

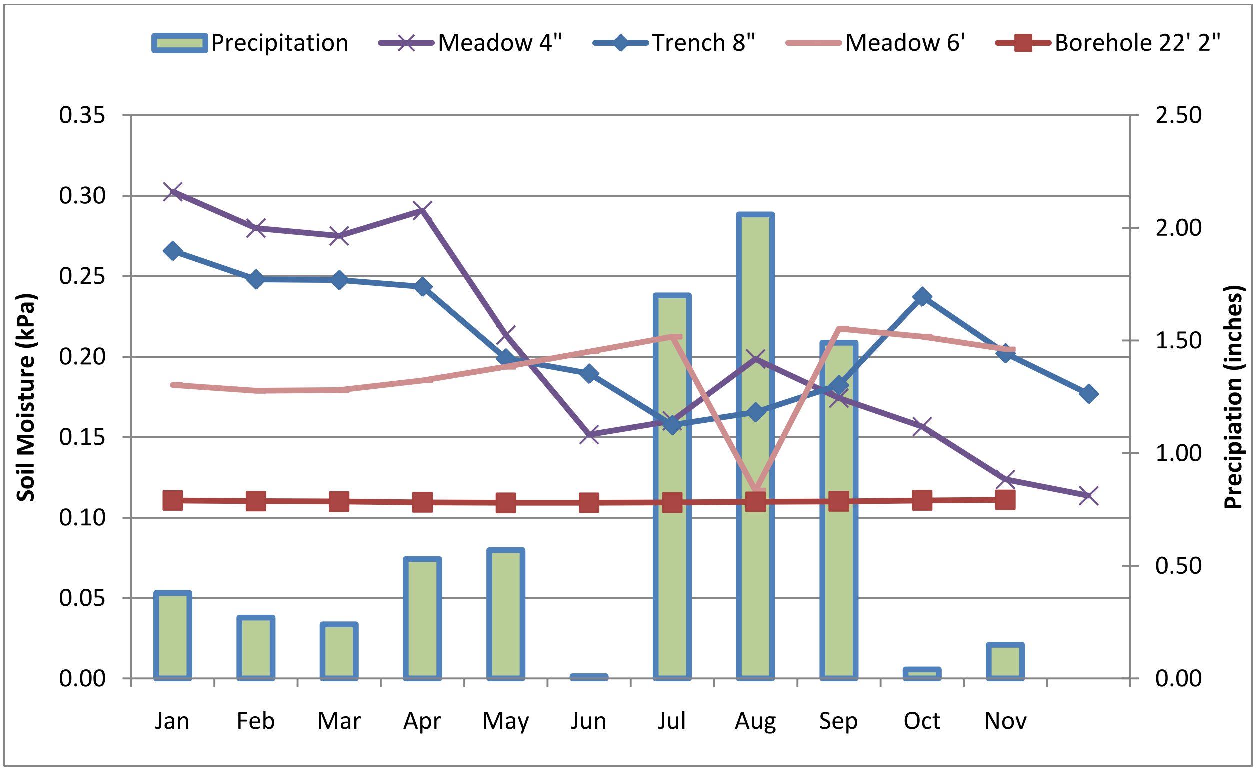


Figure 4.4. **Meadow site average monthly soil moisture and total precipitation for 2012.**

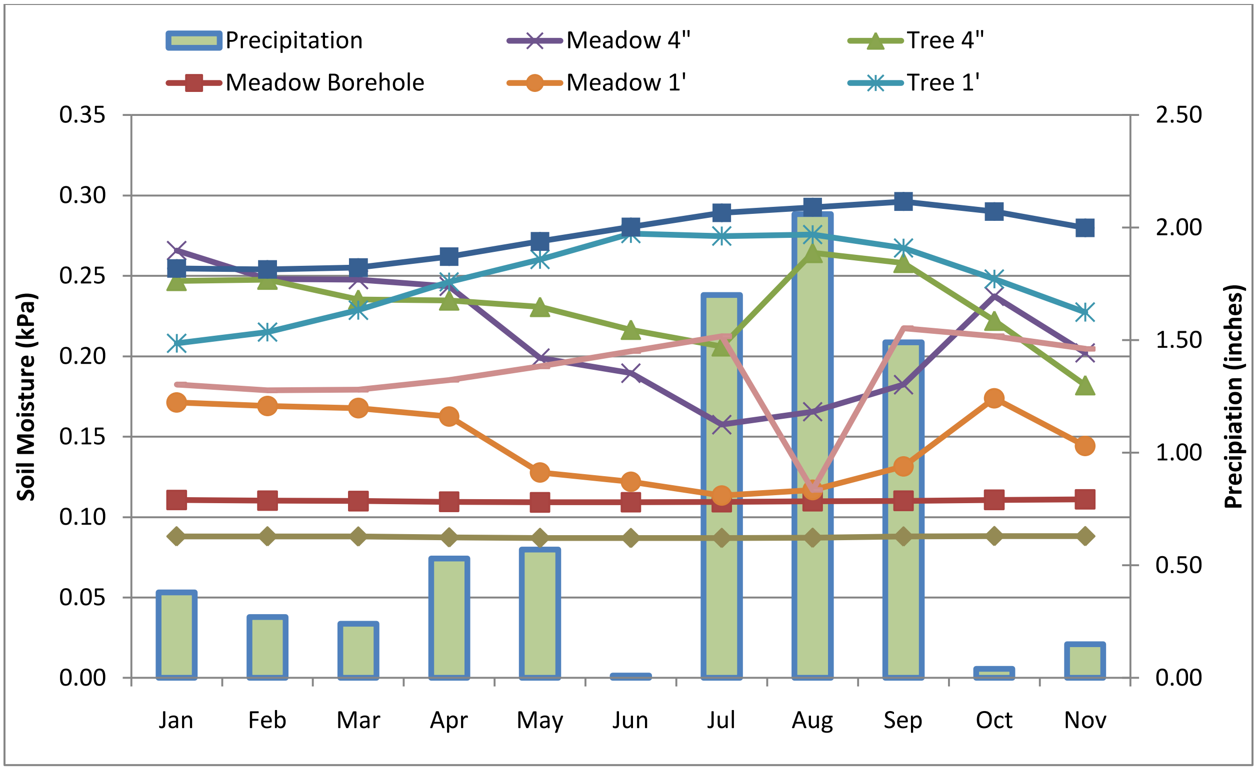


Figure 4.5. **Tree and Meadow site average monthly soil moisture and total precipitation for 2012.**

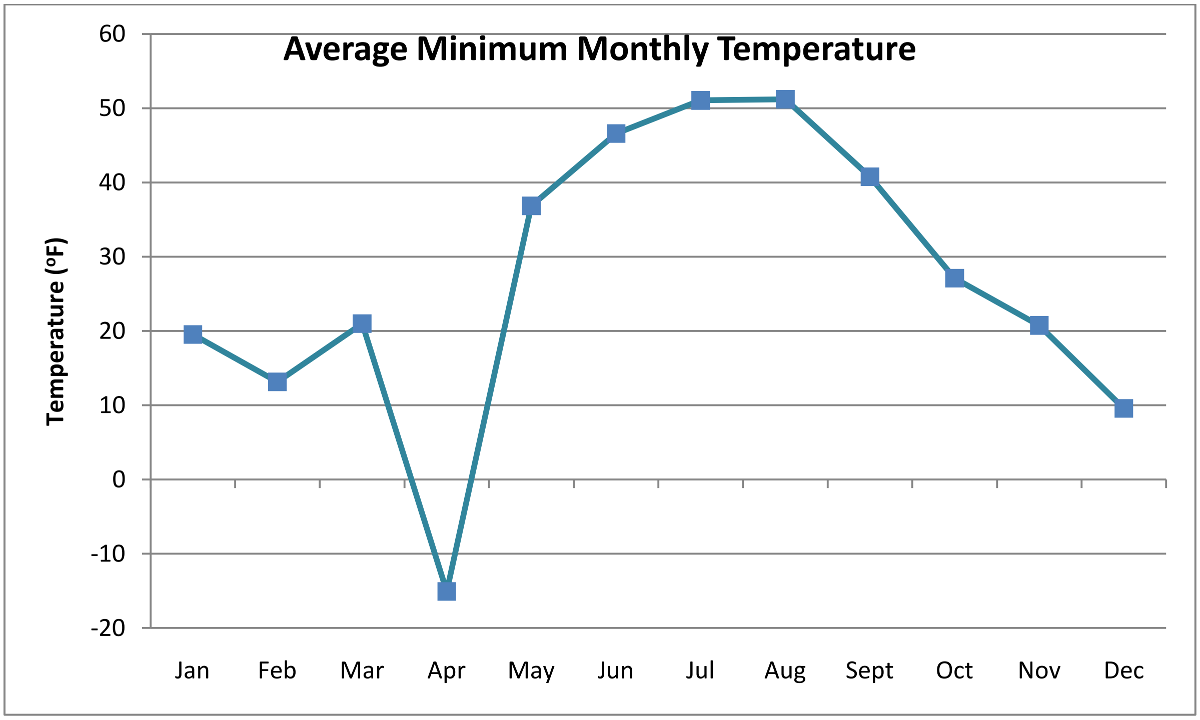


Figure 4.6. **Minimum monthly temperature experienced at the SMWS during 2012.**

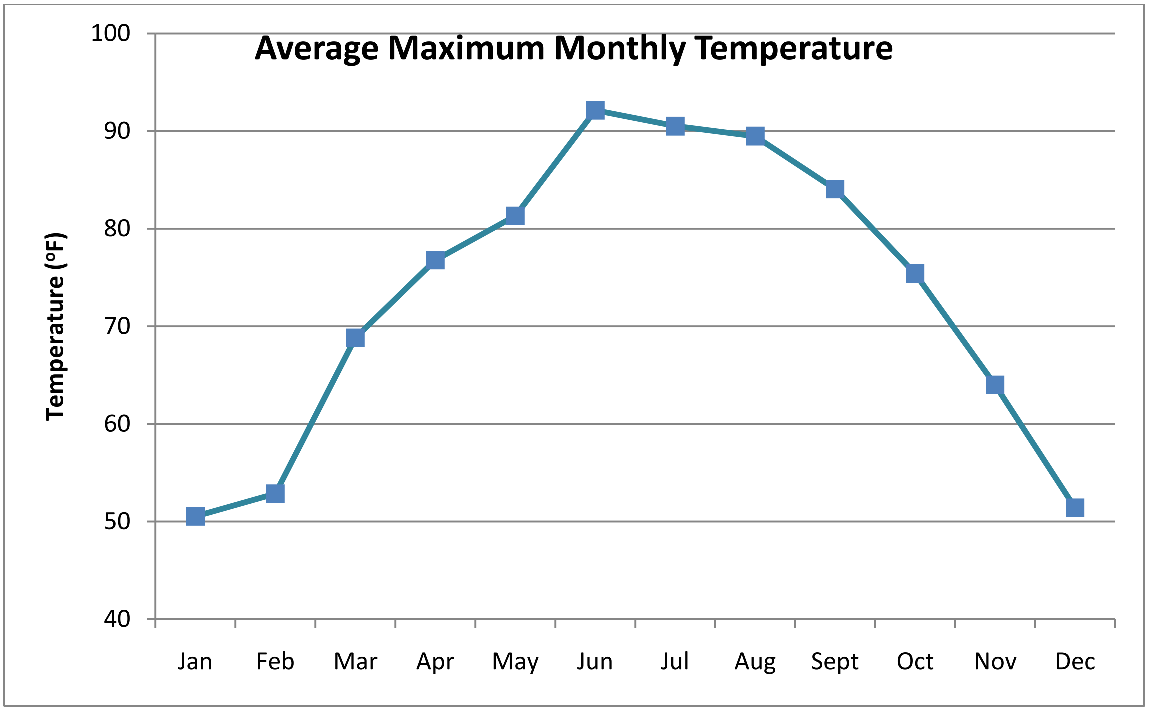


Figure 4.7. **Maximum monthly temperature experienced at the SMWS during 2012.**

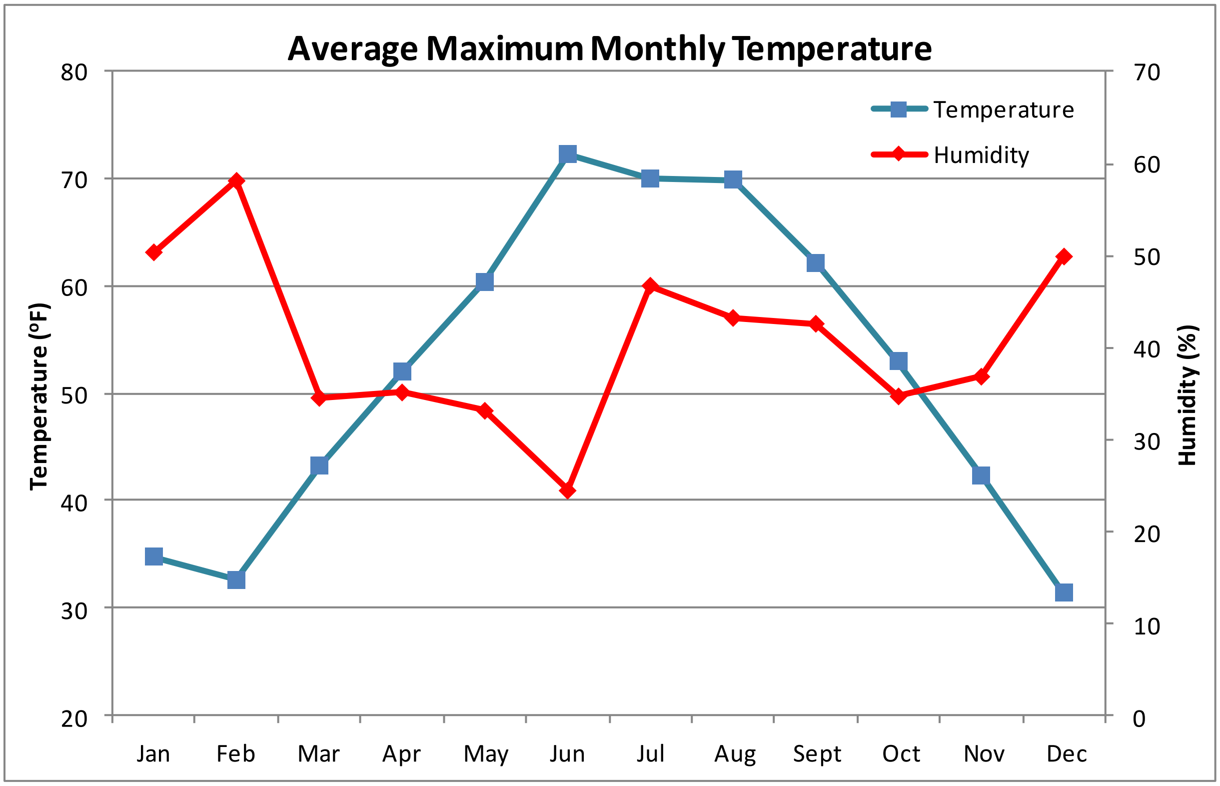


Figure 4.8. **Daily average temperature and relative humidity over the course of 2012.**

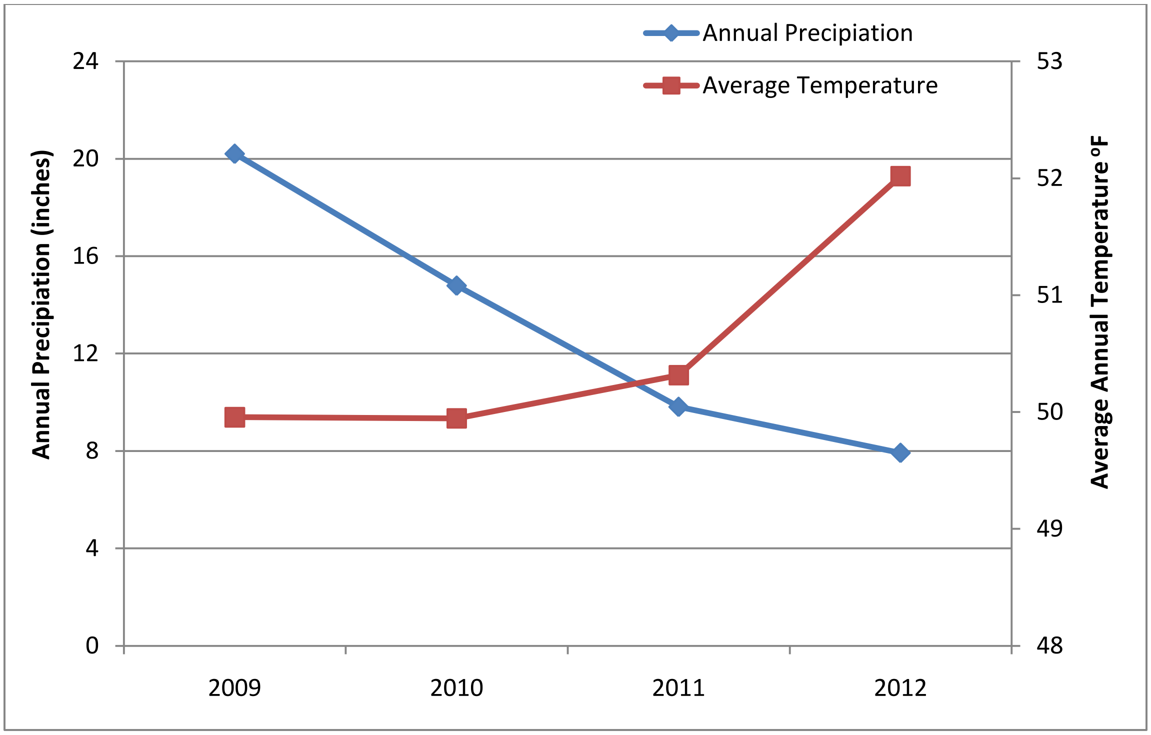


Figure 4.9. **Annual precipitation and average annual ambient temperature at the SMWS 2009-2012.**

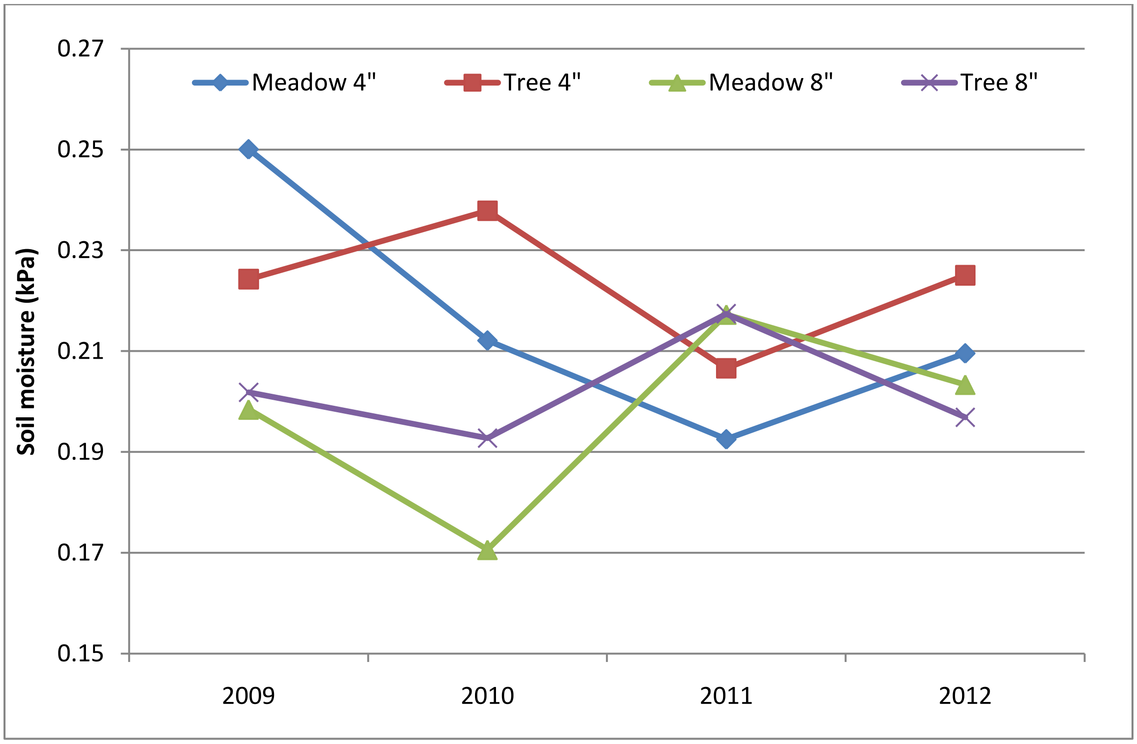


Figure 4.10. **Average annual soil moisture from the two shallow depths at the tree and meadow sites with no difference seen between the 4 and 8 inch depths.**

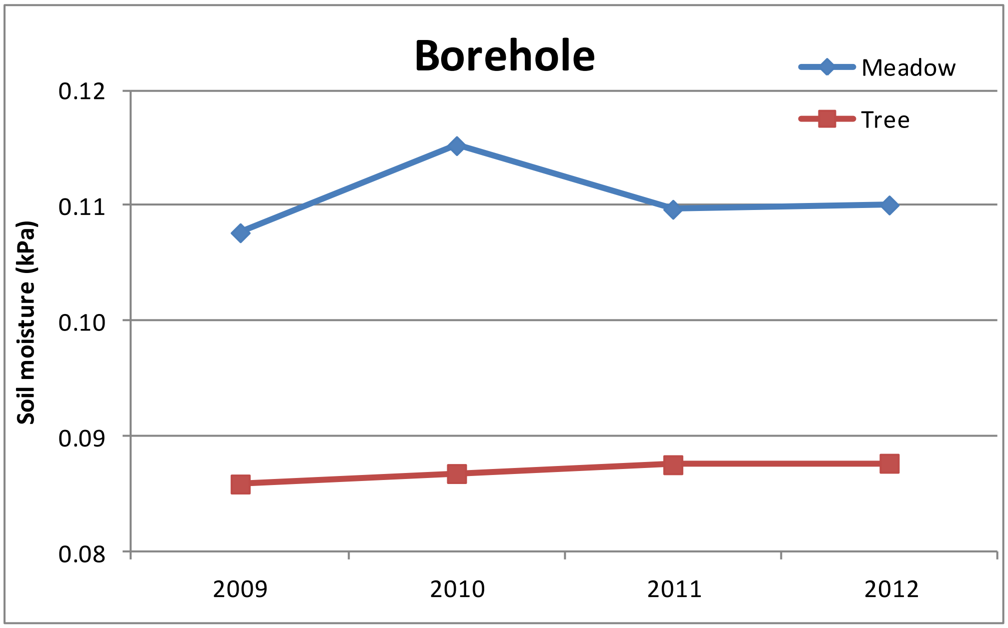


Figure 4.11. Average annual soil moisture from the two deep borehole depths (21’6”) at the tree and meadow sites show no significant time differences throughout the 4 years of monitoring.

5.0 PLANNED MONITORING FOR 2013 (YEAR SIX)

SWCA will continue the current monitoring efforts for year six of this project by monitoring the post-thinning treatment conditions in the late spring. If additional funding is awarded monitoring will continue in the Fall 2013 and Spring 2014. SWCA will also continue to manage the SMWS and the associated weather data if funding is awarded.

Post-wildfire monitoring has been suspended for 2013 because of safety issues regarding falling dead trees. Post-fire monitoring may commence in a year or two, if sufficiently few dead trees remain at the monitoring sites. At this time, SWCA does not anticipate changes in the current monitoring designs or methods for forest thinning monitoring. Reporting will include regular monthly progress reports and a 2013 Annual Report.

6.0 ACKNOWLEDGEMENTS AND CONTRIBUTORS

The New Mexico Water Trust Board provided funding for this project. The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee provided oversight and coordination of this project, in cooperation with the New Mexico Forest and Watershed Restoration Institute and New Mexico State Forestry. Dierdre Tarr of the Claunch-Pinto Soil and Water Conservation District and Joe Zebrowski from the New Mexico Forest and Watershed Restoration Institute provided valuable oversight and support. The Bouton, Candelaria, Kelly, Mitchell, Neff, Salazar, Sanchez, Vigil, and Wester families kindly offered access to their land to conduct forest thinning and monitoring research, along with the Chilili Land Grant, Manzano Land Grant, and the Manzano Mountain Retreat. New Mexico State Forestry, the U.S. Forest Service, the U.S. Geological Survey, and the Claunch-Pinto, East Torrance, and Edgewood Soil and Water Conservation Districts have all provided advice and support. Vernon Kohler and Kelly Archuleta from the Claunch-Pinto and Edgewood Soil and Water Conservation Districts have been assisting with field data collections. Mike Matush from the New Mexico Environment Department, Surface Water Quality Bureau, has been helpful in designing and installing stream monitoring stations. The Estancia Basin Water Planning Committee also contributed funding to install the new Chilili ponderosa pine monitoring study site. Joseph Fluder, project manager from 2007-2012, now provides oversight, and quality assurance and control. In addition to the authors, SWCA staff Ryan Trollinger, Justin Elza, and Alayne Szymanski contributed to the preparation of this report.

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APPENDIX A
LIST OF PLANT SPECIES ENCOUNTERED ON FOREST MONITORING STUDY PLOTS

Appendix A. List of Plant Species Encountered on Forest Monitoring Study Plots

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Gymnosperms						
Cypressaceae	*Juniperus*	*deppeana*	JUDE2	Alligator juniper	Tree	Perennial
Cypressaceae	*Juniperus*	*monosperma*	JUMO	Oneseed juniper	Tree	Perennial
Cypressaceae	*Juniperus*	*scopulorum*	JUSC2	Rocky Mountain juniper	Tree	Perennial
Pinaceae	*Pinus*	*edulis*	PIED	Piñon pine	Tree	Perennial
Pinaceae	*Pinus*	*ponderosa*	PIPO	Ponderosa pine	Tree	Perennial
Angiosperms: Dicotyledons						
Amaranthaceae	*Amaranthus*	*albus*	AMAL	Prostrate pigweed	Forb	Annual
Amaranthaceae	*Amaranthus*	*cruentus*	AMCR	Red amaranth	Forb	Annual
Amaranthaceae	*Amaranthus*	*palmeri*	AMPA	Carelessweed	Forb	Annual
Anacardiaceae	*Rhus*	*trilobata*	RHTR	Skunkbush sumac	Shrub	Perennial
Apiaceae	*Lomatium*	*dissectum*	LODI	Fernleaf biscuitroot	Forb	Perennial
Asteraceae	*Achillea*	*millefolium*	ACMI2	Common yarrow	Forb	Perennial
Asteraceae	*Ageratina*	*herbacea*	AGHE5	Fragrant snakeroot	Forb	Perennial
Asteraceae	*Anaphalis*	*margaritacea*	ANMA	Western pearly everlasting	Forb	Perennial
Asteraceae	*Antennaria*	*microphylla*	ANMI3	Littleleaf pussytoes	Forb	Perennial
Asteraceae	*Artemisia*	*carruthii*	ARCA14	Carruth's sagewort	Forb	Perennial
Asteraceae	*Artemisia*	*dracunculus*	ARDR4	Taragon	Forb	perennial
Asteraceae	*Artemisia*	*frigida*	ARFR4	prairie sagewort	Forb	Perennial
Asteraceae	*Artemisia*	*ludoviciana*	ARLU	White sagebrush	Forb	Perennial
Asteraceae	*Aster*	*falcatus*	ASFA3	Russian milkvetch	Forb	Annual
Asteraceae	*Bahia*	*dissecta*	BADI	Ragleaf bahia	Forb	Annual
Asteraceae	*Brickellia*	*eupatorioides*	BREU	False boneset	Forb	Perennial
Asteraceae	*Brickellia*	*grandiflora*	BRGR	Tasselflower brickel	Forb	Perennial
Asteraceae	*Chaetopappa*	*ericoides*	CHER2	Rose heath	Forb	Perennial
Asteraceae	*Circium*	*undulatum*	CIUN	Wavyleaf thistle	Forb	Annual
Asteraceae	*Conyza*	*canadensis*	COCA5	Canadian horseweed	Forb	Annual
Asteraceae	*Erigeron*	*divergens*	ERDI4	Spreading fleabane	Forb	Biennial
Asteraceae	*Erigeron*	*flagellaris*	ERFL	Trailing fleabane	Forb	Biennial
Asteraceae	*Erigeron*	*formosissimus*	ERFO3	Beautiful fleabane	Forb	Perennial
Asteraceae	*Erigeron*	*speciosus*	ERSP4	Aspen fleabane	Forb	Perennial
Asteraceae	*Erigeron*	*divergens*	ERDI4	Spreading fleabane	Forb	Biennial
Brassicaceae	*Lepidium*	*alyssoides*	LEAL4	Mesa pepperwort	Forb	Perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Brassicaceae	*Schoenocrambe*	*linearifolia*	SCLI12	Slimleaf plainsmustard	Forb	Perennial
Brassicaceae	*Sisymbrium*	*altissimum*	SIAL2	Tall tumblemustard	Forb	Annual/Biennial
Cactaceae	*Cylindropuntia*	*imbricata*	CYIM2	Tree cholla	Succulent	Perennial
Cactaceae	*Echinocereus*	*viridiflorus*	ECVI2	Nylon hedgehog cactus	Succulent	Perennial
Cactaceae	*Escobaria*	*vivipera*	ESVI2	Spinystar cactus	Succulent	Perennial
Cactaceae	*Grusonia*	*clavata*	GRCL	Club cholla	Succulent	Perennial
Cactaceae	*Opuntia*	*engelmannii*	OPEN3	Cactus apple	Succulent	Perennial
Cactaceae	*Opuntia*	*phaeacantha*	OPPH	Tulip pricklypear	Succulent	Perennial
Cactaceae	*Opuntia*	*macrorhiza*	OPMA2	Twistspine pricklypear	Succulent	Perennial
Cactaceae	*Opuntia*	*polyacantha*	OPPO	Plains pricklypear	Succulent	Perennial
Caryophyllaceae	*Cerastium*	*brachypodum*	CEBR3	Shortstalk chickweed	Forb	Perennial
Caryophyllaceae	*Cerastium*	*nutans*	CENU2	Nodding chickweed	Forb	Annual/Perennial
Caryophyllaceae	*Pseudostellaria*	*jamesiana*	PSJA2	Tuber starwort	Forb	Perennial
Caryophyllaceae	*Silene*	*scouleri*	SISC7	Simple campion	Forb	Perennial
Chenopodiaceae	*Chenopodium*	*capitatum*	CHCA4	Blight goosefoot	Forb	Perennial
Chenopodiaceae	*Chenopodium*	*fremontii*	CHFR3	Fremont's goosefoot	Forb	Perennial
Chenopodiaceae	*Chenopodium*	*graveolens*	CHGR2	Fetid goosefoot	Forb	Annual
Chenopodiaceae	*Chenopodium*	*incanum*	CHIN2	Mealy goosefoot	Forb	Annual
Chenopodiaceae	*Chenopodium*	*leptophyllum*	CHLE4	Narrowleaf goosefoot	Forb	Annual
Chenopodiaceae	*Salsola*	*kali*	SAKA	Russian thistle	Forb	Annual
Euphorbiaceae	*Chamaesyce*	*albomarginata*	CHAL11	Whitemargin sandmat	Forb	Perennial
Euphorbiaceae	*Chamaesyce*	*chaetocalyx*	CHCHC3	Bristlecup sandmat	Forb	Perennial
Euphorbiaceae	*Chamaesyce*	*fendleri*	CHFE3	Threadstem sandmat	Forb	Perennial
Euphorbiaceae	*Chamaesyce*	*serpyllifolia*	CHSE6	Thymeleaf sandmat	Forb	Annual
Fabaceae	*Astragalus*	*mollisimus*	ASMO7	Wooly locoweed	Forb	Perennial
Fabaceae	*Astragalus*	*nuttallianus*	ASNU4	Smallflowered milkvetch	Forb	Perennial
Fabaceae	*Dalea*	*purpurea*	DAPU5	Purple prairie clove	Forb	Perennial
Fabaceae	*Hoffmannseggia*	*drepanocarpa*	HODR	Sicklepod holdback	Forb	Perennial
Fabaceae	*Lotus*	*wrightii*	LOWR	Wright's deervetch	Forb	Perennial
Fabaceae	*Lupinus*	*kingii*	LUKI	King's lupine	Forb	Perennial
Fabaceae	*Psoralidium*	*tenuiflorum*	PSTE5	Slimflower scurfpea	Forb	Perennial
Fabaceae	*Robinia*	*neomexicana*	RONE	New Mexico locust	Tree	Perennial
Fabaceae	*Vicea*	*americana*	VIAM	American vetch	Forb	Perennial
Fagaceae	*Quercus*	*gambelii*	QUGA	Gambel oak	Tree	Perennial
Fagaceae	*Quercus*	*grisea*	QUGR3	Gray oak	Tree	Perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Fagaceae	*Quercus*	*turbinella*	QUTU2	Sonoran scrub oak	Tree	Perennial
Geraniaceae	*Geranium*	*caespitosum*	GECAF	Fremont's geranium	Forb	Perennial
Hydrophyllaceae	*Nama*	*dichotomum*	NADI	Wishbone fiddleleaf	Forb	Annual
Lamiacea	*Agastache*	*pallidiflora*	AGPA	Bill Williams Mountain giant hyssop	Forb	Perennial
Lamiacea	*Hedeoma*	*drummondii*	HEDR	Drummond's false pen	Forb	Annual
Lamiacea	*Salvia*	*subincisa*	SASU7	Sawtooth sage	Forb	Annual
Linaceae	*Linum*	*aristatum*	LIAR3	Bristle flax	Forb	Annual
Linaceae	*Linum*	*vernale*	LIVE2	Chihuahuan flax	Forb	Annual
Malvaceae	*Spheralcea*	*angustifolia*	SPAN3	Copper globemallow	Forb	Perennial
Malvaceae	*Spheralcea*	*coccinea*	SPCO	Scarlet globemallow	Forb	Perennial
Malvaceae	*Spheralcea*	*fendleri*	SPFE	Fendler's globemallow	Forb	Perennial
Malvaceae	*Spheralcea*	*grossulariifolia*	SPGR2	Gooseberryleaf globe	Forb	Perennial
Malvaceae	*Spheralcea*	*hastulata*	SPHA	Spear globemallow	Forb	Perennial
Monotropaeae	*Monotropa*	*hypopithys*	MOHY3	Pinesap	Forb	Perennial
Nyctaginaceae	*Mirabilis*	*linearis*	MILI3	Narrowleaf four o'clock	Forb	Perennial
Nyctaginaceae	*Mirabilis*	*oxybaphoides*	MIOX	Smooth spreading four o’clock	Forb	Perennial
Oleaceae	*Menodora*	*scabra*	MESC	Rough menodora	Forb	Perennial
Onagraceae	*Oenothera*	*caespitosa*	OECA10	Tufted evening primrose	Forb	Annual
Oxalidaceae	*Oxalis*	*violacea*	OXVI	Violet woodsorrel	Forb	Perennial
Papaveraceae	*Argemone*	*squarrosa*	ARSQ	Hedgehog pricklypoppy	Forb	Perennial
Onagraceae	*Oenothera*	*caespitosa*	OECA10	Tufted evening primrose	Forb	Annual
Polemoniaceae	*Ipomopsis*	*aggregata*	IPAG	Scarlet gilia	Forb	Annual
Polygonaceae	*Eriogonum*	*alatum*	ERAL4	Winged buckwheat	Forb	Annual
Polygonaceae	*Eriogonum*	*annuum*	ERAN4	Annual buckwheat	Forb	Annual
Polygonaceae	*Eriogonum*	*microthecum*	ERMI4	Slender buckwheat	Shrub	Perennial
Polygonaceae	*Eriogonum*	*racemosum*	ERRA3	Redroot buckwheat	Forb	Perennial
Polygonaceae	*Eriogonum*	*wrightii*	ERWR	Bastardsage	Forb	Perennial
Polygonaceae	*Polygonum*	*douglasii*	PODO4	Douglas' knotweed	Forb	Annual
Portulacaceae	*Phemeranthus*	*brevicaulis*	PHBR15	Dwarf fameflower	Forb	Perennial
Portulacaceae	*Portulaca*	*oleracea*	POOL	Little hogweed	Forb	Annual
Portulacaceae	*Portulaca*	*pilosa*	POPI3	Kiss me quick	Forb	Annual
Primulaceae	*Androsace*	*septentrionalis*	ANSE4	Pygmyflower rockjasmine	Forb	Annual
Ranunculaceae	*Thalictrum*	*fendleri*	THFE	Fendler's meadow-rue	Forb	Perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Santalaceae	*Comandra*	*umbellata*	COUM	Bastard toadflax	Forb	Perennial
Primulaceae	*Androsace*	*septentrionalis*	ANSE4	Pygmyflower rockjasmine	Forb	Annual
Scrophulariaceae	*Castilleja*	*integra*	CAIN14	Wholeleaf Indian paintbrush	Forb	Perennial
Scrophulariaceae	*Cordylanthus*	*tenuis*	COTE3	Slender birdbeak	Forb	Annual
Scrophulariaceae	*Cordylanthus*	*wrightii*	COWR2	Wrights bird's beak	Forb	Annual
Scrophulariaceae	*Penstemon*	*barbatus*	PEBA2	Beardlip penstemon	Forb	Perennial
Scrophulariaceae	*Penstemon*	*jamesii*	PEJA	James' beardtongue	Forb	Perennial
Scrophulariaceae	*Penstemon*	*oliganthus*	PEOL	Apache beardtongue	Forb	Perennial
Scrophulariaceae	*Penstemon*	*virgatus*	PEVI4	Upright blue beardtongue	Forb	Perennial
Scrophulariaceae	*verbascum*	*thapsus*	VETH	Common mullein	Forb	Biennial
Solanaceae	*Physalis*	*hederifolia*	PHHE4	Ivyleaf groundcherry	Forb	Perennial
Solanaceae	*Solanum*	*elaeagnifolium*	SOEL	Silverleaf nightshade	Forb	Perennial
Solanaceae	*Solanum*	*triflorum*	SOTR	Cutleaf nightshade	Forb	Perennial
Verbanaceae	*Glandularia*	*bipinnatifida*	GLBIC	Davis Mountain mock vervain	Forb	Perennial
Verbanaceae	*Verbena*	*macdougalii*	VEMA	MacDougal verbena	Forb	Annual
Viscaceae	*Phoradendron*	*juniperinum*	PHJU	Juniper mistletoe	Herb	Perennial/Juniper parasite
Viscaceae	*Phoradendron*	*macrophyllum*	PHMA18	Colorado desert mist	Herb	Perennial
Angiosperms: Monocotyledons						
Agavaceae	*Yucca*	*baccada*	YUBA	Banana yucca	Succulent	Perennial
Agavaceae	*Yucca*	*glauca*	YUGL	Soapweed yucca	Succulent	Perennial
Commelinaceae	*Commelina*	*dianthifolia*	CODI4	Birdbill dayflower	Forb	Perennial
Cyperaceae	*Carex*	*geophila*	CAGE	White Mountain sedge	Sedge	Perennial
Cyperaceae	*Cyperus*	*esculentus*	CYES	Yellow nutsedge	Sedge	Perennial
Cyperaceae	*Cyperus*	*fendlerianus*	CYFE2	Fendler's flatsedge	Sedge	Perennial
Liliaceae	*Allium*	*cernuum*	ALCE2	Nodding onion	Forb	Perennial
Poaceae	*Achnatherum*	*robustum*	ACRO7	Sleepygrass	Grass	Perennial
Poaceae	*Alopecurus*	*aequalis*	ALAE	Shortawn foxtail	Grass	Perennial
Poaceae	*Andropogon*	*gerardii*	ANGE	Big bluestem	Grass	Perennial
Poaceae	*Aristida*	*adscensionis*	ARAD	Sixweeks threeawn	Grass	Annual
Poaceae	*Aristida*	*arizonica*	ARAR6	Arizona threeawn	Grass	Perennial
Poaceae	*Aristida*	*divaricata*	ARDI5	Poverty threeawn	Grass	Perennial
Poaceae	*Aristida*	*purpurea*	ARPU9	Purple threeawn	Grass	Perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Poaceae	*Blepharoneuron*	*tricholepsis*	BLTR	Pine dropseed	Grass	Perennial
Poaceae	*Bouteloua*	*aristidoides*	BOAR	Needle grama	Grass	Annual
Poaceae	*Bouteloua*	*curtipendula*	BOCU	Sideoats grama	Grass	Perennial
Poaceae	*Bouteloua*	*gracilis*	BOGR2	Blue grama	Grass	Perennial
Poaceae	*Bromus*	*arvensis*	BRAR5	Field brome	Grass	Annual
Poaceae	*Elymus*	*canadensis*	ELCA4	Canada wildrye	Grass	Perennial
Poaceae	*Elymus*	*elymoides*	ELEL5	Squirreltail	Grass	Perennial
Poaceae	*Elymus*	*hystrix L.*	ELHY	Eastern bottlebrush	Grass	Perennial
Poaceae	*Eragrostis*	*cilianensis*	ERCI	Stinkgrass	Grass	Annual
Poaceae	*Eragrostis*	*curvula*	ERCU2	Weeping lovegrass	Grass	Annual
Poaceae	*Eragrostis*	*mexicanus*	ERME	Mexican lovegrass	Grass	Annual
Poaceae	*Koeleria*	*macrantha*	KOMA	Prairie junegrass	Grass	Perennial
Poaceae	*Lolium*	*perenne*	LOPE	Perennial ryegrass	Grass	Annual
Poaceae	*Lycurus*	*phleoides*	LYPH	Common wolfstail	Grass	Perennial
Poaceae	*Lycurus*	*setosus*	LYSE3	Bristly wolfstail	Grass	Perennial
Poaceae	*Monroa*	*squarrosa*	MOSQ	False buffalograss	Grass	Annual
Poaceae	*Muhlenbergia*	*minutissima*	MUMI2	Annual muhly	Grass	Annual
Poaceae	*Muhlenbergia*	*montana*	MUMO	Mountain muhly	Grass	Perennial
Poaceae	*Muhlenbergia*	*thurberi*	MUTH	Thurber's muhly	Grass	Perennial
Poaceae	*Muhlenbergia*	*torreyi*	MUTO2	Ring muhly	Grass	Perennial
Poaceae	*Muhlenbergia*	*richardsonii*	MURI	Mat muhly	Grass	Perennial
Poaceae	*Panicum*	*capillare*	PACA6	Witchgrass	Grass	Annual
Poaceae	*Pascopyrum*	*smithii*	PASM	Western wheatgrass	Grass	Perennial
Poaceae	*Piptatherum*	*micranthum*	PIMI7	Littleseed ricegrass	Grass	Perennial
Poaceae	*Pleuraphis*	*jamesii*	PLJA	James' galleta	Grass	Perennial
Poaceae	*Poa*	*fendleriana*	POFE	Muttongrass	Grass	Perennial
Poaceae	*Setaria*	*viridis*	SEVI4	Green bristlegrass	Grass	Annual
Poaceae	*Sporobolus*	*cryptandrus*	SPCR	Sand dropseed	Grass	Perennial
Poaceae	*Thinopyrum*	*ponticum*	THPO7	Tall wheatgrass	Grass	Perennial
Non-Vascular Plants						
–	multiple	multiple	MOSS	Moss	Crypt	Perennial
–	multiple	multiple	CRUST	Cryptobiotic crust	Crypt	Perennial

Taxonomy and names follow the U.S. Department of Agriculture (2010) PLANTS Database.

Attachments

DVD with all raw data files along with an electronic .pdf version of the report

Addenda

(SMWS quarterly reports)