Long-Term Ground-Dwelling Arthropod Dynamics across an Elevation Gradient at Bandelier National Monument, New Mexico: 2014 Annual Report

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July 14, 2017

Introduction

This annual report summarizes recent results of an on-going long-term monitoring study of ground-dwelling arthropods at Bandelier National Monument. This study is sponsored and implemented by the U.S. National Park Service; Valles Caldera National Preserve and Bandelier National Monument, the U.S. Geological Survey, Jemez Mountains Field Station, and the Division of Arthropods, Museum of Southwestern Biology, University of New Mexico. The purpose of this research is to evaluate the responses of ground-dwelling arthropods to variation in climate across an elevation gradient in the Jemez Mountains of north-central New Mexico, USA.

Climate change has become a serious environmental perturbation that has enormous consequences for natural resource management, especially in the American Southwest. As the climate of the Southwest becomes warmer and more variable with increased frequency of extreme weather events, natural resource managers need a better understanding of how ecosystem function and component biota are responding to climate change. Ground-dwelling arthropods are abundant, high in species richness, and ecologically sensitive to climate conditions. Studies of montane ground-dwelling arthropods in the U.S. have been few, especially at the species community level. This study was designed to describe patterns of these ground-dwelling arthropod communities across an elevational gradient, and to associate those changes with large-scale weather patterns, such as El Niño Southern Oscillation (ENSO) events and ongoing atmospheric warming and changes in precipitation patterns that are changing the overall climate of the American Southwest. Long-term (i.e., decade plus) research enables us to evaluate changes in arthropod community compositions in order to relate such changes to especially dry (La Niña) or wet (El Niño) years, and to detect possible time lags in responses among different taxonomic and ecological groups of arthropods.

Mountains of the Southwest provide elevational gradients that extend from lower elevations, which are typically dry and warm, to high elevations, which are typically cooler and receive more precipitation. These abiotic differences produce obvious changes in vegetation patterns and associated animals. The ENSO cycle and other patterns of climate change can be considered natural "treatments" applied across the gradient.

If arthropods respond to ENSO events or other changes in precipitation, we expect to see one of two likely patterns. Our first research hypothesis is that lowland species would be less affected by drought conditions because they are adapted to dry and warm conditions. Species at high elevations, which generally do not experience warm or dry conditions, might be more strongly and negatively affected. Our second research hypothesis is that lowland species may experience more negative conditions when their habitats become even drier, while montane species are more buffered against the severity of the drought. Furthermore, both potential processes may occur simultaneously, with some arthropods responding one way, while other arthropods respond the other way. The purpose of this research project was to determine if data on a group of organisms living across such an elevational gradient supported one of the above predictions, or perhaps some other pattern.

This project has been funded by Dr. Craig Allen, formerly of the U.S. National Park Service, now of the U.S Geological Survey, from 1992 until 2013. Dr. Robert Parmenter of the National Park Service provided funding in 2015 to process a backlog of samples; 2014, 2015, and 2016. This entire study was terminated in April, 2017. This report provides information on the 2014 arthropod samples.

Methods

This research was conducted at Bandelier National Monument, in the Jemez Mountains of north-central New Mexico. Three study zones were established across an elevation gradient from approximately 1,830 m elevation at the base of the mountains, to approximately 3,000 m elevation near the summits of the mountains. Two-needle pinyon pine (*Pinus edulis*) and one-seed juniper (*Juniperus monosperma*) made up the dominant vegetation at the low-elevation zone (PJ), ponderosa pine (*Pinus ponderosa*) was dominant at the mid-elevation zone (PP) and several conifer species, such as Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), white fir (*Abies concolor*), ponderosa pine and quaking aspen (*Populus tremuloides*), dominated at the high-elevation mixed-conifer zone (MC).

Arthropod pitfall traps were installed in replicated arrays within each elevation zone to capture and to monitor arthropod species compositions over space and time. Five replicate sets of traps or sites were installed in each of the three zones. Each of the five replicate set or line locations were subjectively chosen to represent the range of woodland or forest stand structures (tree density and species composition) and soil types present within each of the three elevation zones or sites. Dr. Craig Allen, Dr. Robert Parmenter and Dr. David Lightfoot selected those sites in 1991. Each of the five sites consisted of six individual replicate traps that serve as statistical subsamples, positioned systematically in a line, with each trap positioned 5 m apart, for a total of 30 traps in each zone. Each line serves as a statistical sample, for a total of five samples per zone or site. The orientation of each line was selected to provide relatively homogeneous soils and vegetation across each line. The replicate lines were placed at least 200 m apart. Each trap consisted of a steel can 8 cm in diameter buried in the ground with the can opening level with the soil surface. A 0.27 l plastic cup half full of propylene glycol was placed in each can and a small wooden cover was positioned about 5 cm above each trap for protection from sunlight and precipitation. All traps were left open continuously year-round. Arthropods were collected by Bandelier National Monument personnel (supervised by Kay Beeley, Bandelier National Monument) from all of the traps in April, June, August and October of each year, from 1992 to 2014. Trap samples were transported to the University of New Mexico, Museum of Southwestern Biology, where they sorted and tabulated to the species level by or under the supervision of David Lightfoot and Sandra Brantley.

Only arthropod taxa that are known to be ground-surface active, appropriately sampled by pitfall traps, were tabulated. Other taxa that are not appropriately sampled by pitfall traps were not tabulated. Of the target taxa, only those groups that were represented by large numbers of individuals were used for analysis. Those taxonomic groups included

the following: spiders (Araneae; predators), darkling beetles (Coleoptera: Tenebrionidae; detritivores), ground beetles (Coleoptera: Carabidae; predators), centipedes (Chilopoda; predators), and millipedes (Diplopoda; detritivores). A list of targe taxa that were tabulated from the samples is provided in Appendix 1.

Samples were sorted, and target taxa identified and counted for each trap. Sandra Brantley identified and counted non-insect target taxa and Mark Ward identified and counted insect target taxa for 2013. The data were entered into a Microsoft Excel file included with this report, along with selected data from 1992-2012 for comparison. Seasonal data were presented until the 2000 report, when the data set became too large, so that only annual data could be shown. The species list for all target taxa is included as Appendix 1. Several taxonomic changes have occurred over the course of this study; current names are linked to old ones in the species list (Appendix 1). The major sources we used for determining original taxonomic classifications included: 1) Ross Arnett, *American Insects*, 2) Entomological Information Service, *Nomina Insecta Nearctica*, 3) World Spider Catalog, 4) ITIS (Integrated Taxonomic Information System) and 5) original descriptive literature and correspondence with expert taxonomists. As new taxonomic changes have occurred across the target taxa since 1992, we adapt our classifications to keep current with the taxonomy of those target taxa. We continue to work on reconciling species names across the annual datasets. In some cases species names, genus, subfamily and family classifications have changed, and in others we now have names where we formerly had only morphospecies numbers. This process will allow us to better compare richness patterns over the years.

Results

Precipitation

Precipitation data for 1999-2014 were available from the three elevations of interest: the NADP rain gauge located at the Fire Tower, representing the pinyon-juniper zone at 6,500 ft., Los Alamos National Laboratory TA-6 station, representing the ponderosa pine zone at 7,424 ft., and Cerro, representing the mixed-conifer zone at 9,160 ft. (Figure 1). Precipitation declined to low amounts in 2011 and even more so in 2012 during a drought, and increased again in 2013 and in 2014 all elevations. Total annual precipitation amounts were more similar to those received in years 2006-2010, although slightly higher in mixed conifer forest than amounts received during this time period. In 2014, precipitation declined across all elevations from 2013, but especially at the high elevation Cerro station (Figure 1).

Wildfire History

Wildfire size, frequency and severity have been increasing in the Jemez Mountains largely due to overgrown forests and increasing temperatures and drought from climate change. Wildfire has now become an environmental factor that must also be considered in this study. The Las Conchas wildfire (June 26-August 3, 2011) burned large portions of Bandelier National Monument and the Valles Caldera National Preserve. The Las Conchas Fire damaged our sites in the ponderosa pine and mixed-conifer pitfall zones,

but not in the pinyon-juniper zone. The Las Conchas Fire was the second wildfire that has burned through some of the study sites since they were established in 1992 (Table 1). A summary of documented wildfire and prescribed fire severity at all mixed-conifer and ponderosa pine sites dating back to the La Mesa Fire of 1977 is included (Table 1). No sites in the piñon-juniper zone were burned by any of these fires.

Table 1. A history of wildfire and prescribed fire severity at pitfall transect lines in the forests of the Jemez Mountains, New Mexico dating back to the most recent wildfire preceding study implementation (1977-present). Data provided by Kay Beeley, Bandelier National Monument.
*** Mod and High burns present upslope of this site. Lots of ash/soil moved downslope over these traps. ** Canopy was not consumed. Needle drop could be important. Surface burned hot.**

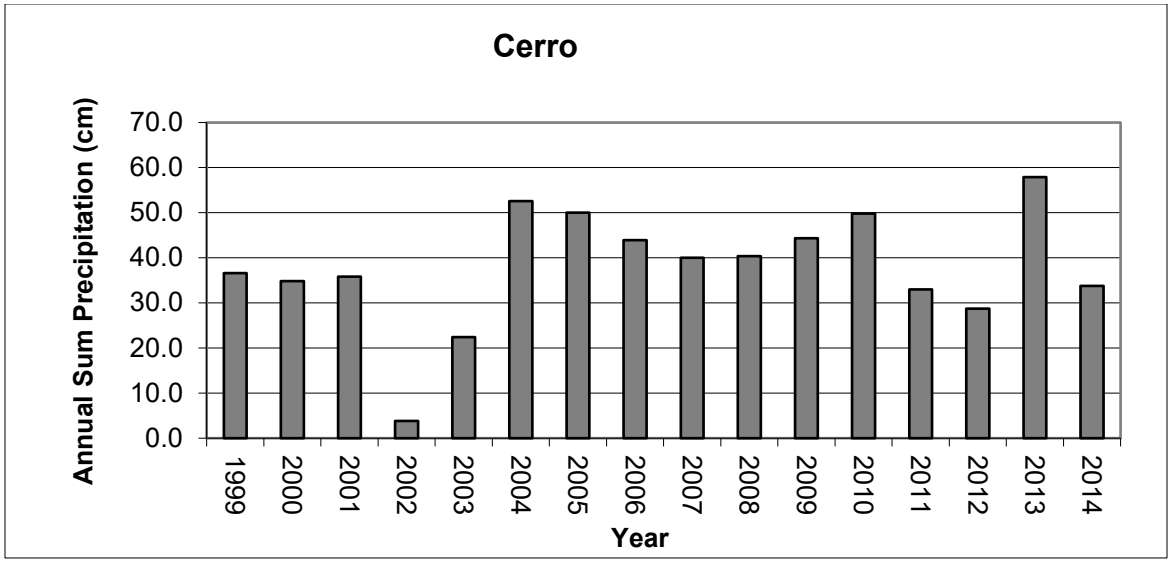
Site (Zone-Transect Line)	La Mesa Wildfire (1977)	PA 27 Prescribed Fire (1994)	PA 29 Prescribed Fire (1998)	Cerro Grande Wildfire (2000)	PA 9 Prescribed Fire (2007)	Las Conchas Wildfire (2011)
MC-A	0	0	0	Mod	Low	Low
MC-B	0	0	0	0	Low	High
MC-C	0	0	0	0	0	Low*
MC-D	0	0	0	Mod	Low	Low or 0
MC-E	0	0	0	0	Un/Low?	Mod or Low
MC-F	0	0	0	0	Un/Low?	High
PP-A	Low	0	0	0	0	High
PP-B	Low	0	0	0	0	Mod/High**
PP-C	Low	Low	0	0	0	Low
PP-D	Low	0	Low	0	0	Low/Mod
PP-E	Low	0	Low	0	0	Low
PP-RG	High	0	0	0	0	High

Ground-dwelling Arthropods

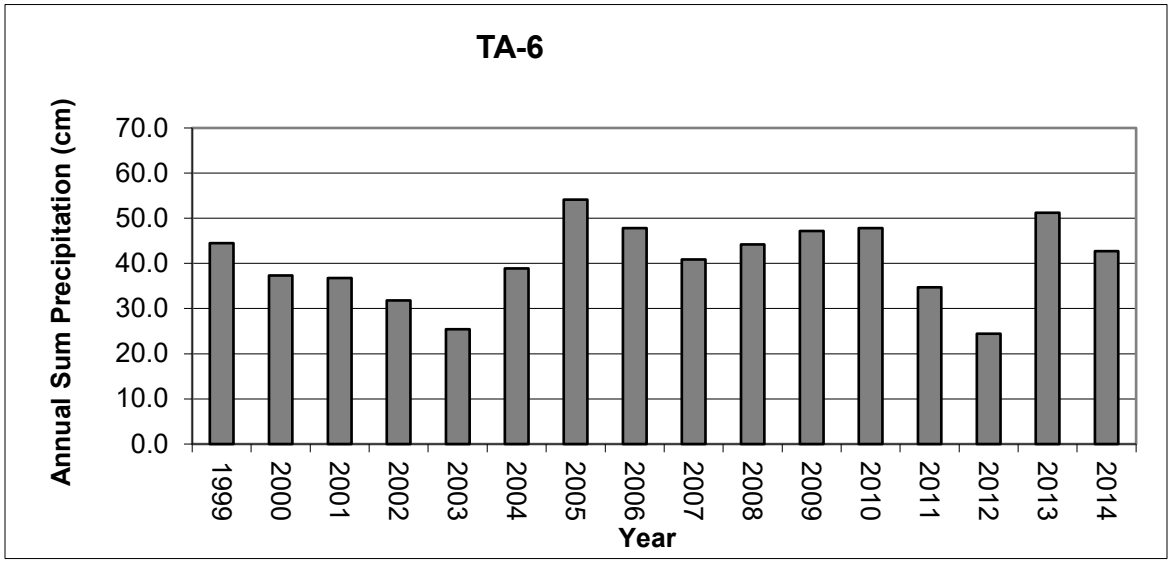
Arthropod abundances were high when this study began in 1992, an El Niño year (Figure 2). Numbers declined in all zones in 1994-1995 and stayed low through 2002. In 2003 numbers increased for most of the target taxa and declined again in 2004, and then rose sharply in 2005 (Figs. 2, 4-10). In 2005 the PJ zone received the most precipitation since this project began (Figure 1). Arthropod numbers there were higher than in the other two zones during every collecting period; half of the relative abundance came from this zone alone, suggesting that the PJ zone is generally under marginal conditions and susceptible to drought, but that arthropods can respond quickly under periods of high precipitation. Abundance at all zones continued to be high from 2006-09, approaching that of the series of strong El Niño years of the early 1990's. In 2010 numbers started to decline at PJ and PP, but not at MC. In 2011 abundance declined at all zones: at PJ probably because of the 2011/2012 drought, and at PP and MC likely due to the effects of drought and Las Conchas fire. Abundance continued to decline in the MC zone 2013 and 2014, to the lowest numbers observed across that zone since the study began in 1992 (Figure 1). Such low numbers in the MC were possibly due to

the Las Conchas Fire that burned several replicate lines in 2011, and the 2011/2012 extreme drought. Abundance in both PJ and PP zones increased in 2012 and 2013, but also declined in 2014, to a less extent than in the MC. Abundance in the PP zone appeared to dramatically increase in 2013 though with a very high standard error, and then in 2014 dropped to numbers in 2012.

Taxon richness also has varied over the years, but less so than individual abundance, across all zones, with the greatest overall decline in 2001 across all zones (Figure 3). In 2011 richness declined, probably as a combination of drought and the fire. Taxon richness has steadily declined from 2006 to 2014, and that decline is probably largely due to reductions in target taxa since 2006, imposed by us. While richness and abundance fluctuated seasonally and annually, the dominant species tended to remain dominant.



a.



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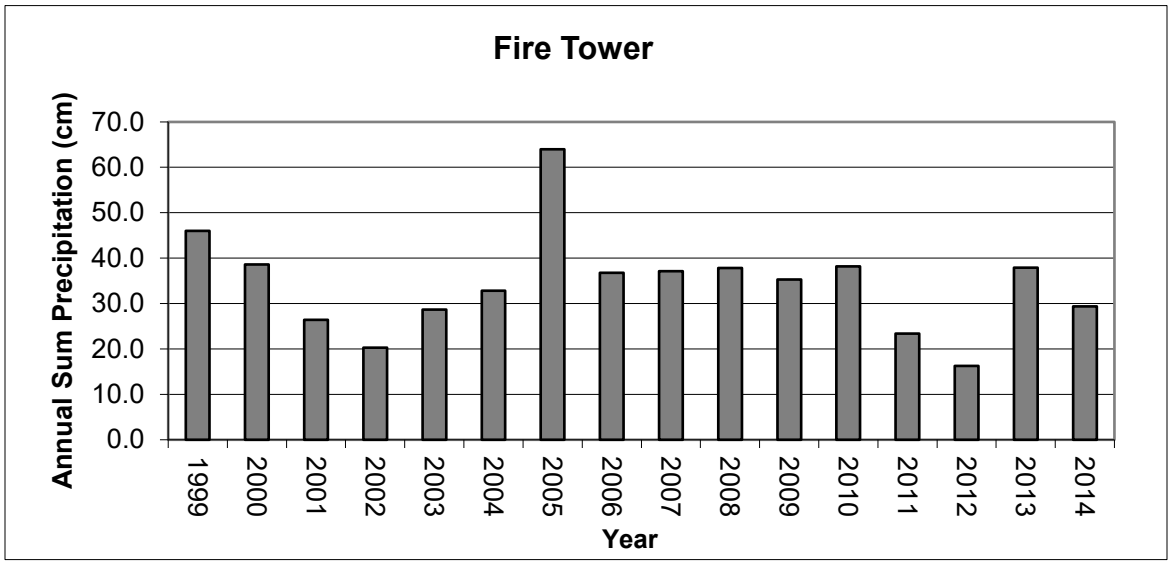

c.

Figure 1. Bandelier precipitation at three elevations, summed over 12 months of each calendar year; a. Cerro (9,160 ft.), b. TA-6 (7,424 ft), and c. Fire Tower rain gauge (6,500ft.),1999-2013.

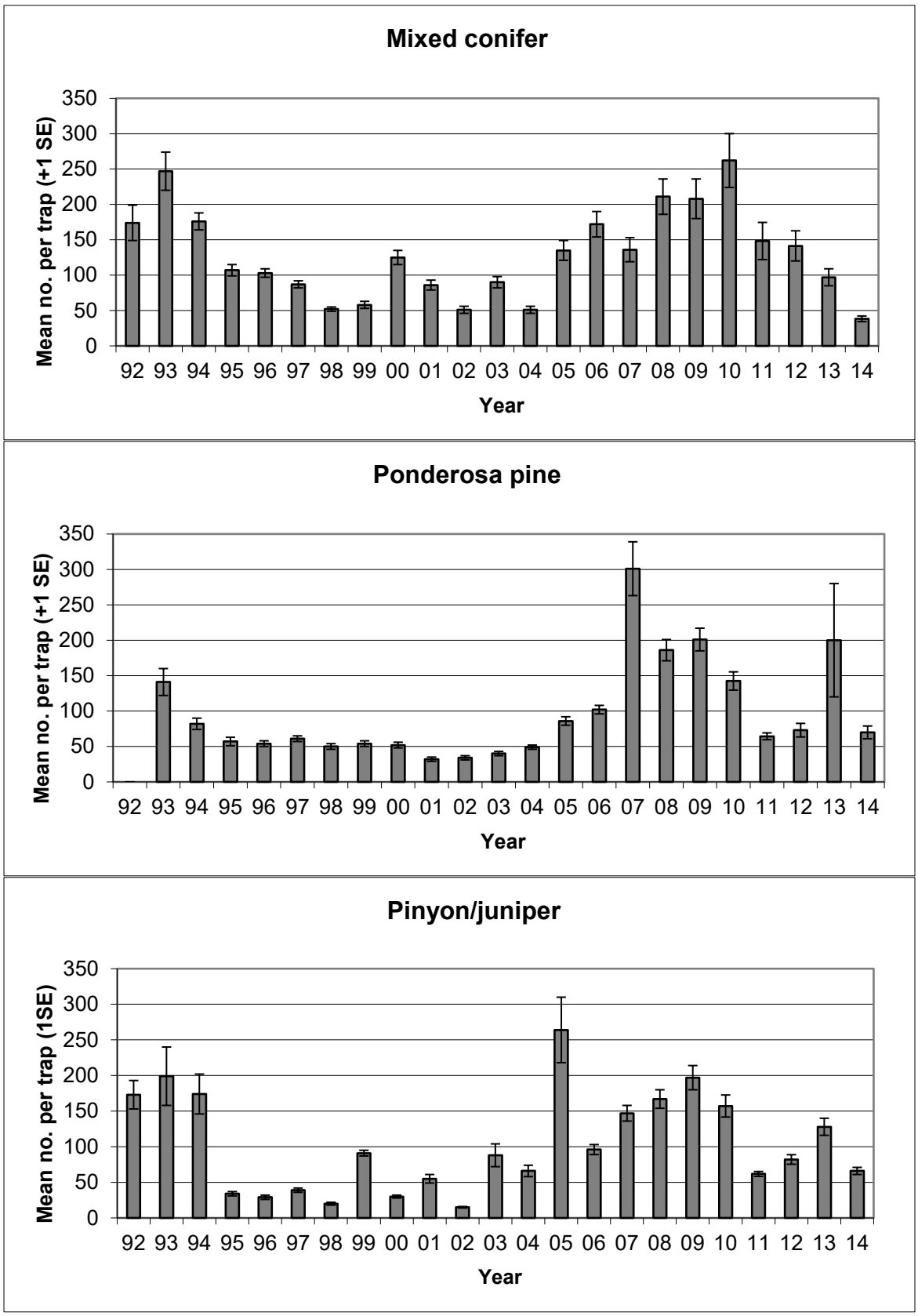

Figure 2. Mean total target taxa arthropod counts per trap by zone and year.

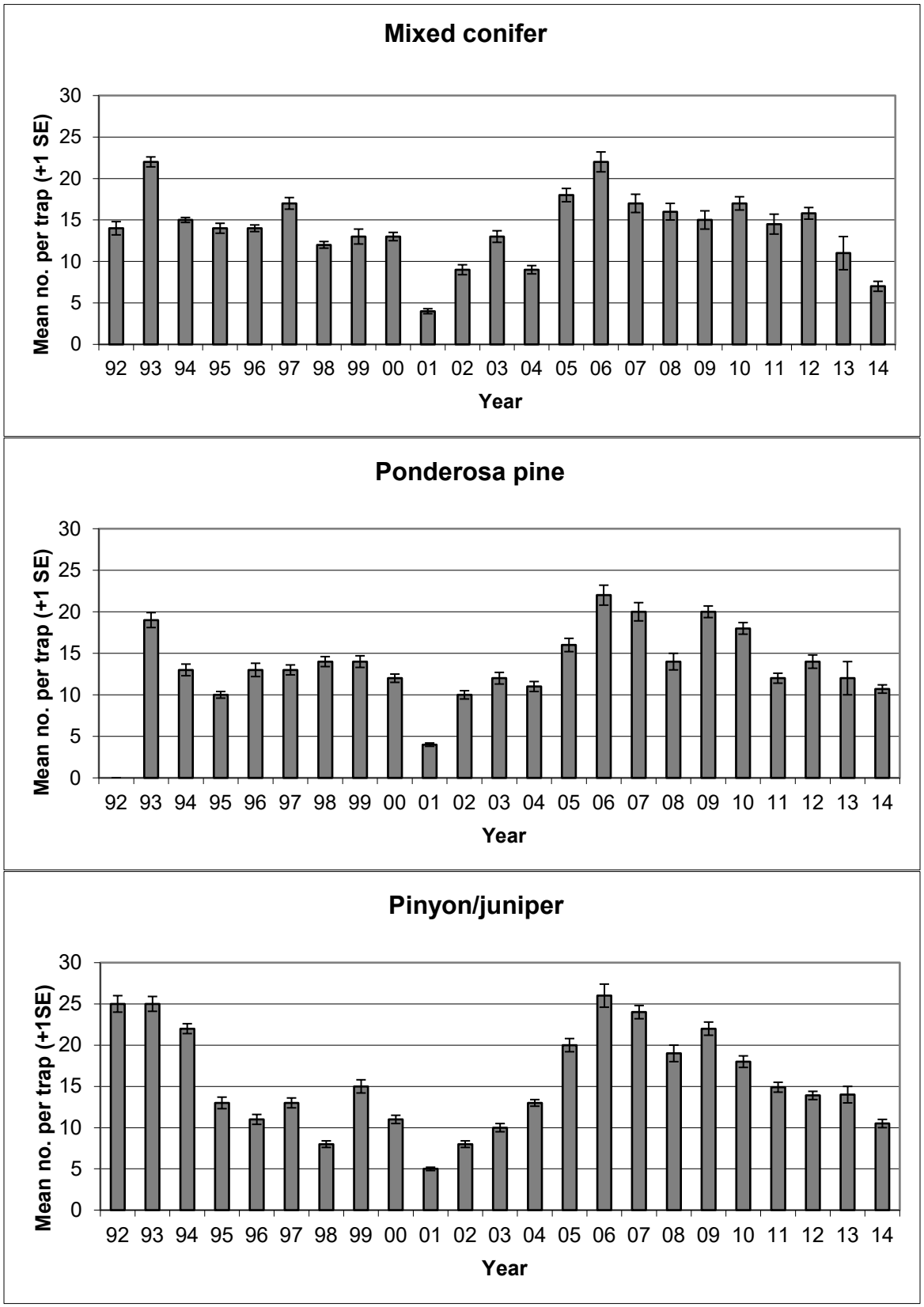

Figure 3. Mean total arthropod species richness per trap, by zone and year.

Spiders were widely distributed throughout the sites (Figure 4), with high abundance during the El Niño years of the early 1990's. Their numbers fell sharply during the drought of the mid-1990's and did not recover until 2005-2009 and started to decline in 2010. The El Niño of 1997-1998 was not a strong one for New Mexico and produced little effect on the spiders in the PJ and PP zones, but probably did influence the abundance seen in the MC zone. Most of the abundance at MC comes from wolf spiders (Lycosidae), especially *Pardosa uncata* and *P. yavapa* and the small-bodied linyphiid sheet weavers. Ground spiders (Gnaphosidae) dominate at PP, while a different wolf spider, *Schizocosa mccooki*, dominates at PJ. The wolf spider *P. orophila* virtually disappeared from the PJ zone during the mid-1990's through 2004, but has been collected again in low numbers from 2005-2010 (numbers fell from 30 in 2009 to 7 in 2010 to 4 in 2011 PP, to 1 each in PJ and PP in 2012 to none in 2013). In the PP zone, the vegetation overstory had increased in the last several years, especially in the RG site, until the Las Conchas Fire burned the trees back again. Spiders are often active during the winter and in 2010 made up 53% of the arthropods collected in the April samples, and 33% of the April 2011 samples. This collection was made before the fire and shows the drop was probably due to lack of precipitation in late winter and spring. Spiders made up 36% of the April 2012 total. Spider numbers have been increasing in the PP and PJ since 2011, apparently recovering from drought, while in the MC, spider numbers apparently (however, note unexplained wide error bars in 2013 that may indicate a data or analysis problem) were up in all zones for the year in 2014.

Bristletails have been found largely in the PJ, but also much less so in the PP, and rarely in MC (Figure 5; note differences in vertical axis scales). Their populations seem to alternate years for high and low numbers (their life cycles extend over 2-3 years), except that drought apparently can reduce numbers greatly, to the point of no individuals some years (Figure 5). Bristletail numbers have peaked in 1993/1994, and in 2003/2005, likely in response to El Niño high precipitation years, and declined considerably in 1995, 2002, and 2011, all drought years (Figure 5). *Machilinus aurantiacus* is the primary species in this study, and occurs in wetter microhabitats in the PJ in association with oak (*Quercus* spp.) stands. Since the 2011 decline, bristletails increased in the PJ in 2014, increased in PP in 2013, then declined in 2014, and reappeared in MC for the first time since 2007.

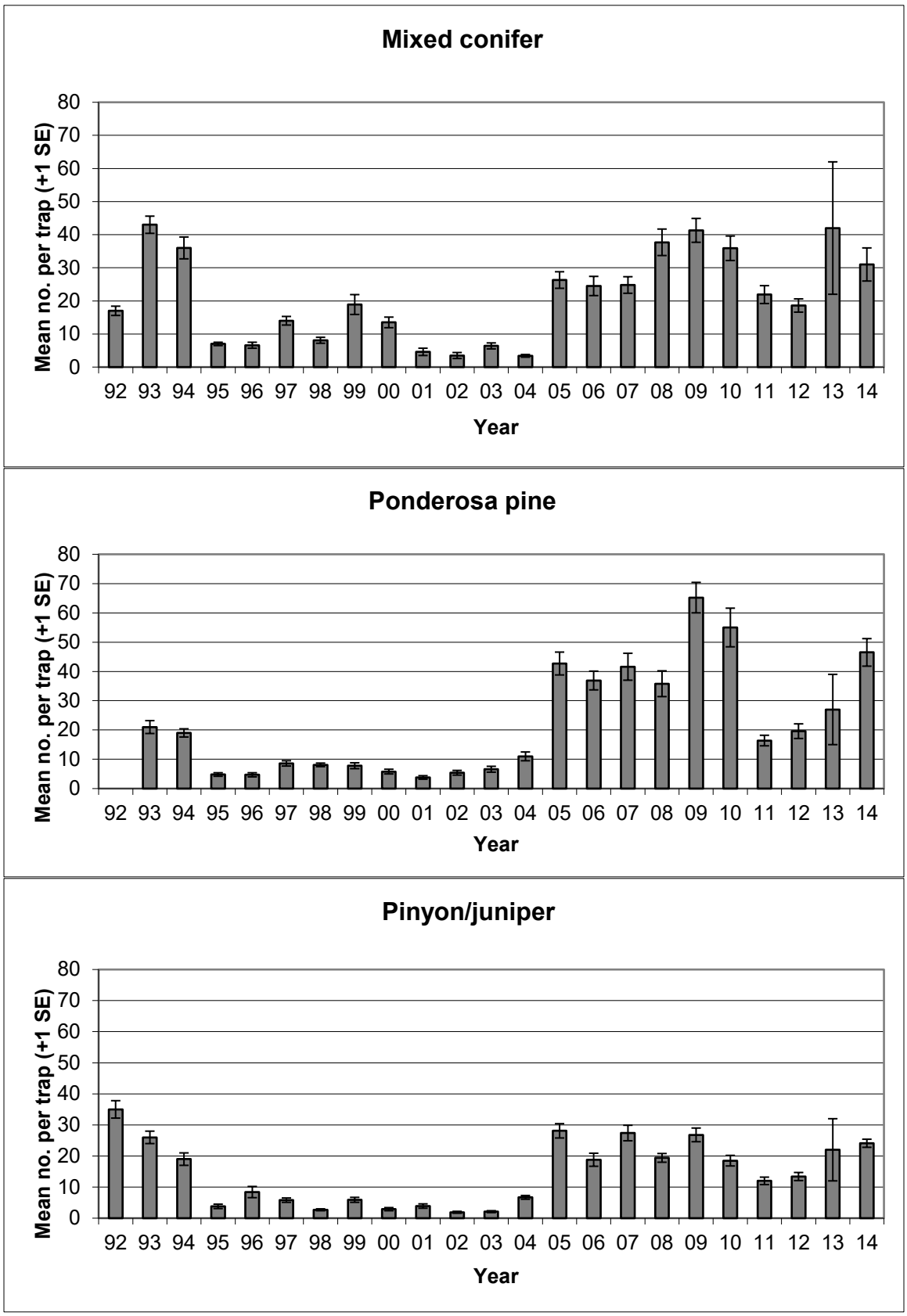

Figure 4. Mean spider counts per trap by zone and year.

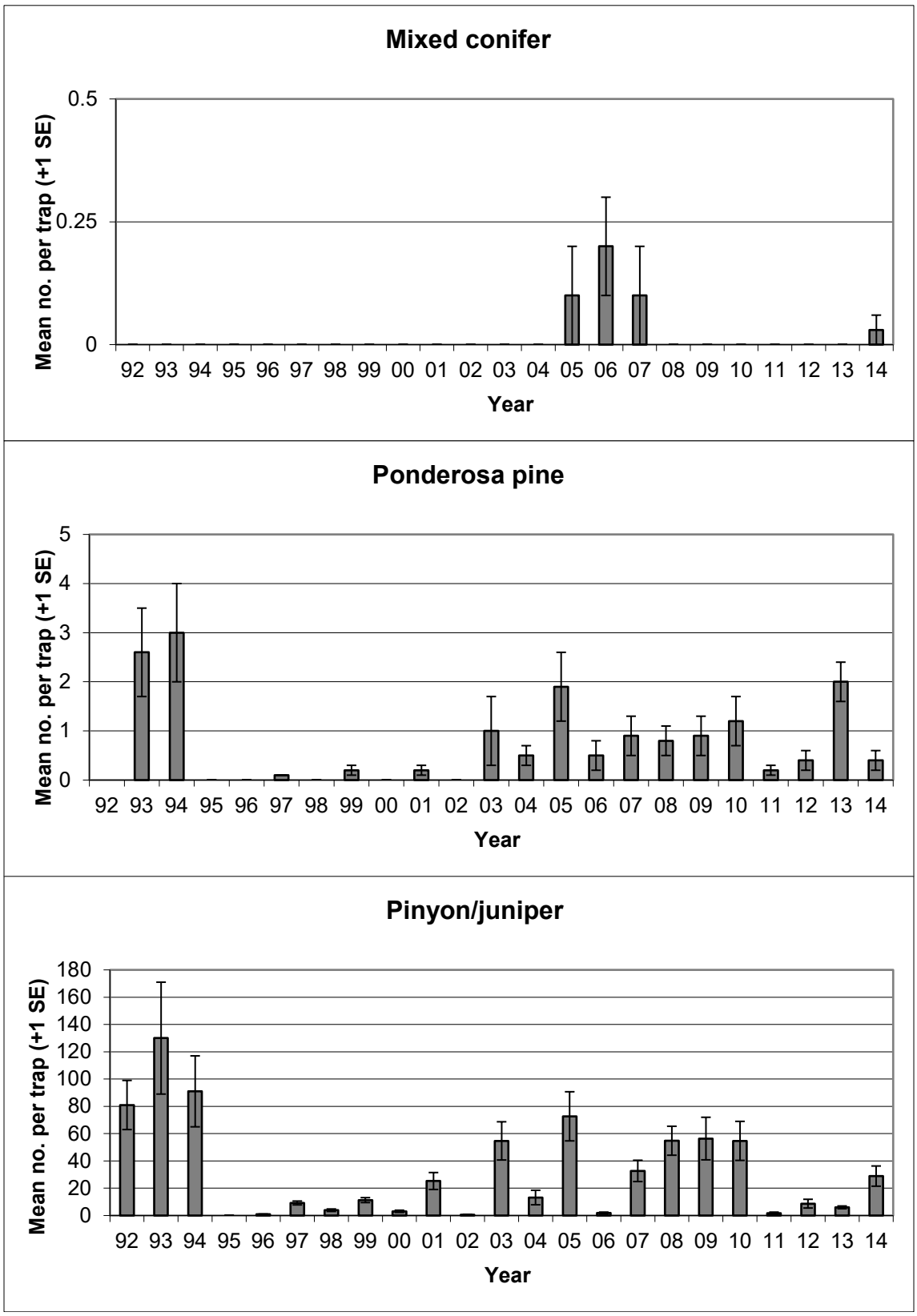

Figure 5. Mean bristletail counts by zone and year. Note differences in y-axis values.

Cricket abundance data (Figure 6) includs field crickets and scaly crickets (Gryllidae), Jerusalem crickets (Stenopelmatidae), and camel crickets (Rhaphidophoridae), all are scavengers/detritivores. Cricket species demonstrate seasonal fidelity; field crickets and scaly bush crickets are collected mostly in June (small juveniles) and October (adults) samples; camel crickets and Jerusalem crickets in June and August samples. Cricket species also tend to be somewhat restricted by habitat zone: Jerusalem crickets (*Stenopelmatus fuscus*), field crickets (*Gryllus veletis*), scaly bush crickets (*Cycloptilum comprehendens*) and one camel cricket (*Ceuthophilus pallidus*) are found primarily in the PJ zone; field crickets and the other camel cricket (*C. utahensis*) are found in the PP zone; and only *C. utahensis* is found primarily in the MC zone. Cricket numbers in 2001 - 2002 declined in all zones to 1995 levels, likely in response to drought. In 2003 numbers increased at PJ and MC, and declined slightly at PP. *Ceuthophilus pallidus* numbers in the PJ zone declined in 2009 and remained low until 2014 when numbers increased. Also in 2014, numbers of *Gryllus* and *Cycloptilum* were very high, and the three species of crickets increased to their greatest abundance by far since the study began in 1992 (Figure 6). *Ceuthophilus utahensis* numbers peaked in 2010 in the PP and MC, and gradually declined in the PP to low levels in 2013, but increasing again in 2104, while in the MC they have declined steadily since 2010.

Ground beetles (Carabidae) are well known indicators of moisture conditions in a variety of habitats. The arid Southwest has relatively few species of this large family and they tend to occur in riparian areas, high elevations of mountains or other moist habitats. There are about 20 species of ground beetles that regularly are found in samples. After the *Pterostichus* spp., the next most abundant carabid species is *Carabus taedatus*, found primarily at MC. In this study the greatest numbers and species richness have been found in the MC zone (Figure 7). Numbers declined in 1995, 1998, 2003/2004, and 2011 in all zones apparently due to drought, and recovered more quickly at MC than at the other two zones. In the wet years 2005-2007 the carabids increased at PJ and MC. Carabids have increased since 2011, especially at the PP and PJ zones, and reached the highest numbers at the PJ zone in 2014 since this study began, showing a similar pattern to cricket abundance at the PJ zone.

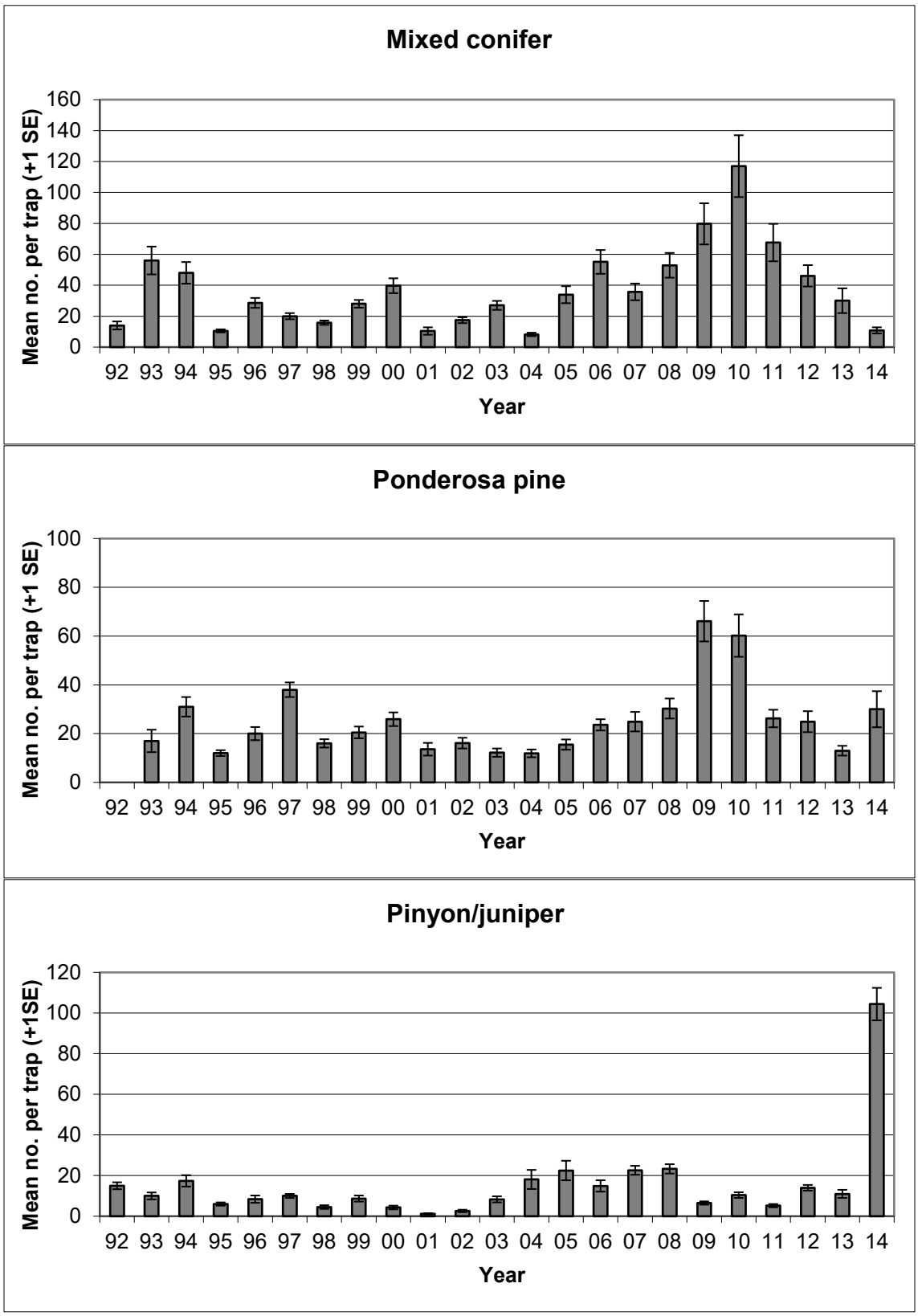

Figure 6. Mean cricket counts per trap by zone and year.

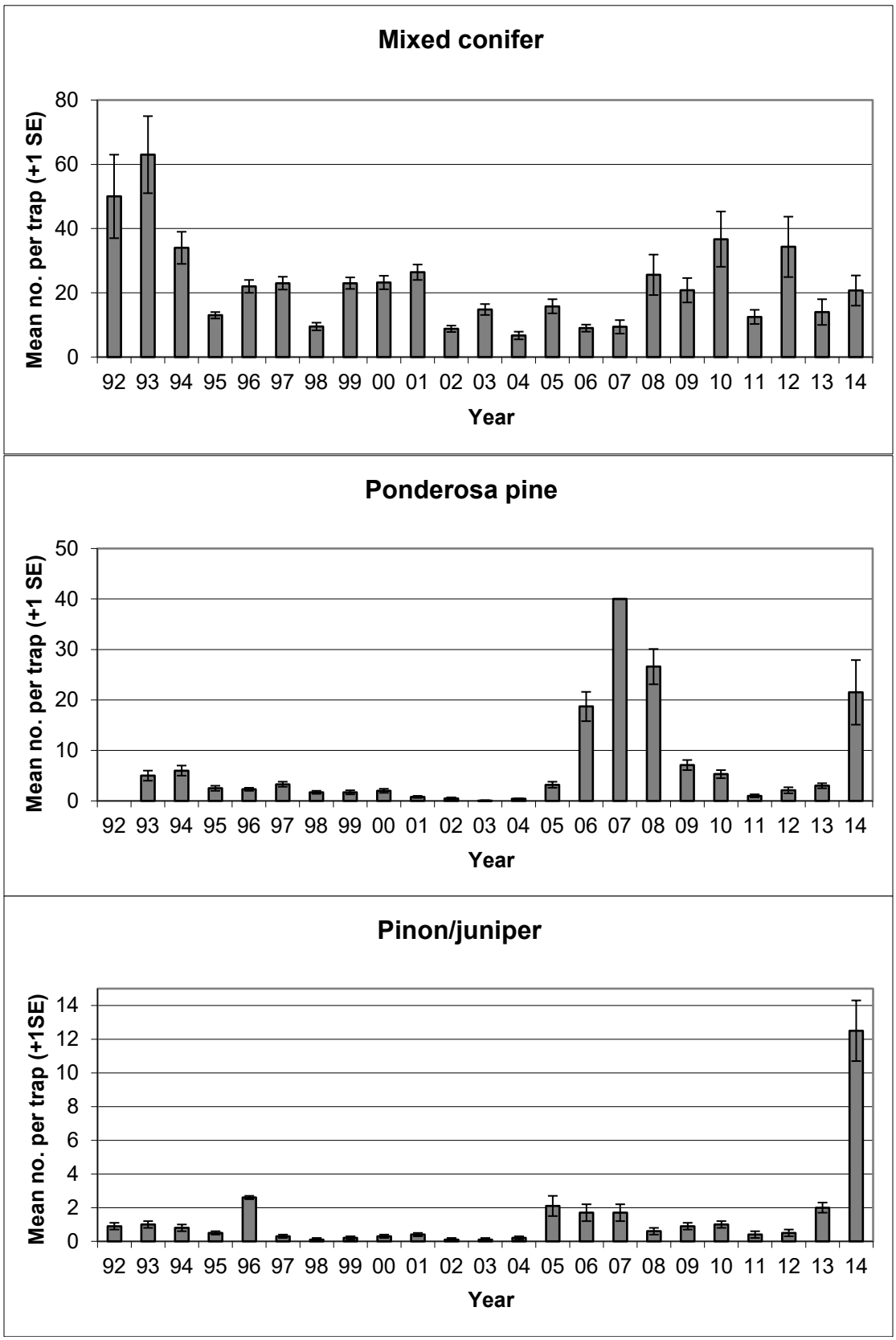

Figure 7. Mean ground beetle (carabid) counts per trap by zone and year. Note differences in y-axis values.

The **rove beetles** (Staphylinidae) are a large family with broad feeding habits ranging from predation to detritivory to fungivory. Many are small in size and their identification below subfamily is difficult, especially within the subfamily Aleocharinae. The beetles are usually associated with grass or litter and like the carabid beetles prefer mesic habitats. Rove beetles have declined most in association with the 2002 drought in the PP and MC zones and increased during El Nino events (Figure 8). In the past, rove beetles have rarely been collected from PJ and they increased to their highest numbers in 2013, and declined in 2014. No rove beetles were collected at PP or MC from 2002-04. From 2005-2009 numbers increased; with a jump in numbers at MC in 2008 and at PP in 2009. Numbers dropped sharply at PP and MC from 2010 through 2012, but increased again in 2013 and 2014.

Darkling beetles (Tenebrionidae) are the dominant taxon at PJ (Figure 9), followed by scaly bush crickets and camel crickets. These beetles seem to be relatively unaffected by short-term environmental changes, and with life-spans of several years, lag-time responses are probably occurring, but since we sample only adults, cannot account for larval responses to changes in rainfall. Darkling beetles have shown relatively stable numbers over time at all zones, with general increases between 2005 and 2009. Numbers fell in 2010 to levels comparable to 2008 and fell again to 2001 levels in 2011 and 2012, but increased again to 2005 levels in 2013 and 2014.

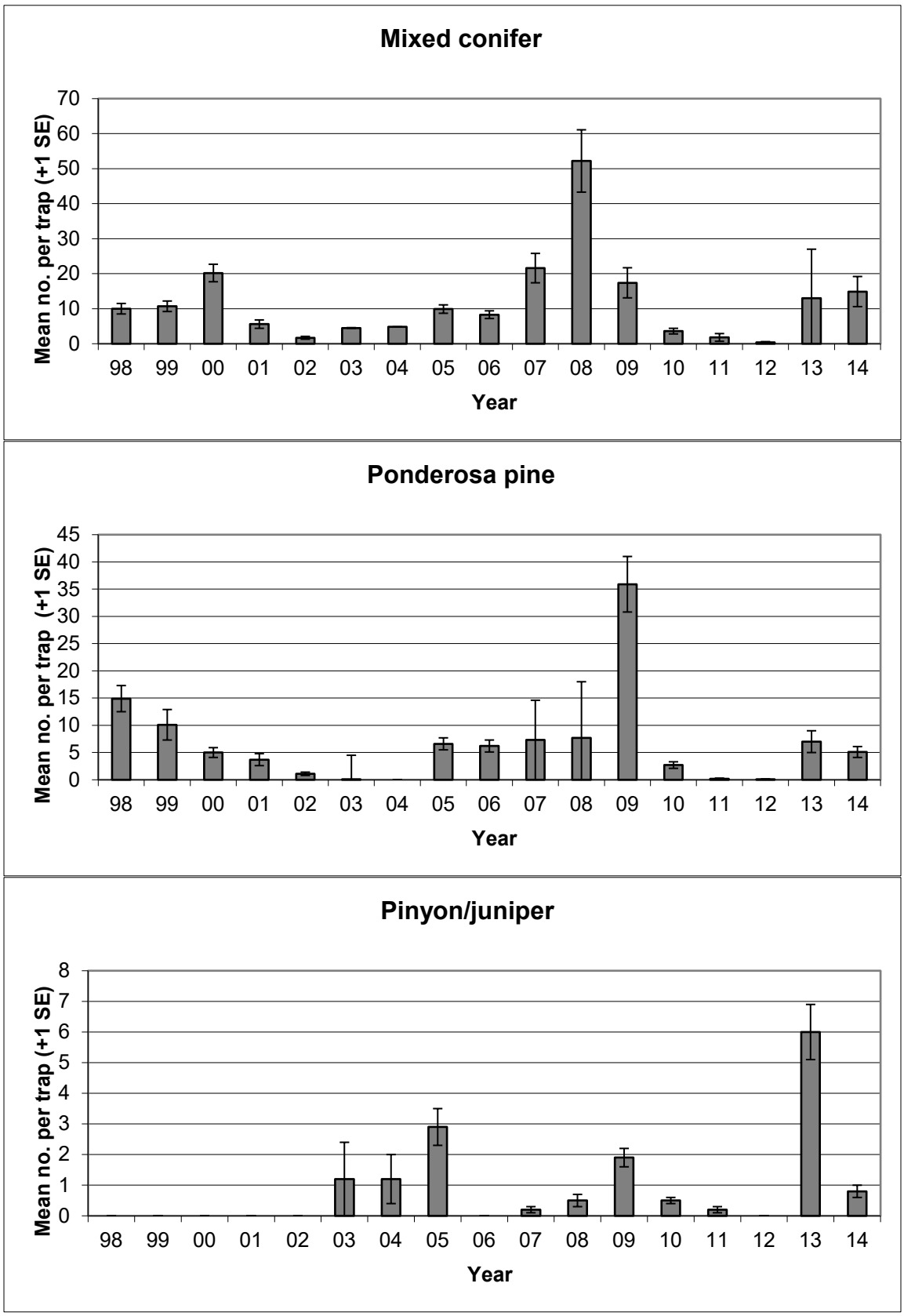

Figure 8. Mean rove beetle (staphylinid) counts per trap by zone and year. Note differences in y-axis values.

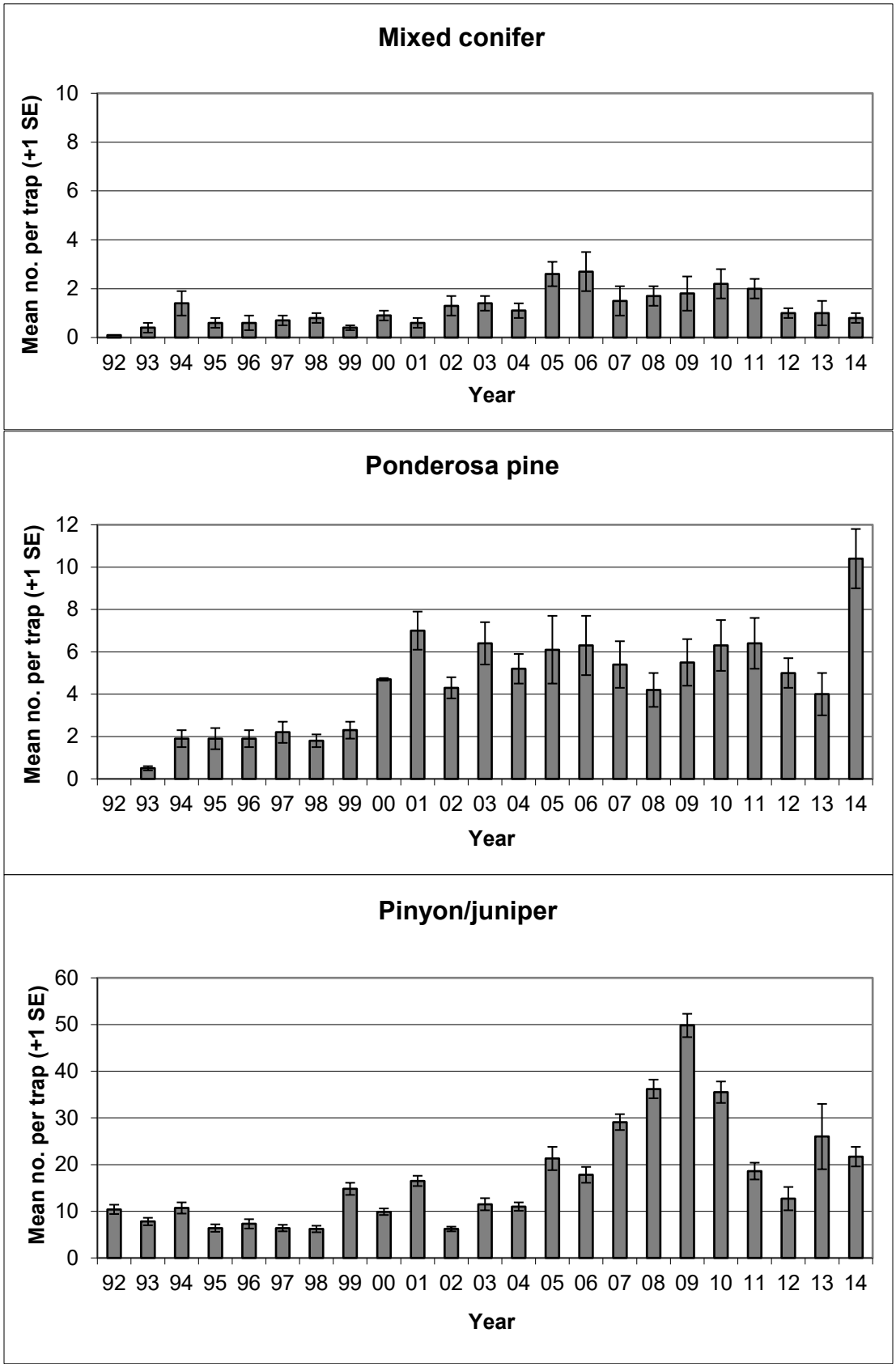

Figure 9. Mean darkling beetle (tenebrionid) counts per trap by zone and year. Note differences in y-axis values.

Discussion

Twenty-three years of arthropod data from pitfall traps have revealed habitat preferences of species from the three vegetation zones and have shown that abundances vary greatly from one year to another. Species richness patterns show that a few species dominate a given vegetation zone and that there are many species that occur in low abundance, resulting in a species list with several hundred taxa. In species richness the PP and MC zones are more similar to each other than they are to the PJ zone. Species show rather high vegetation zone fidelity and even when a species occurs in two zones, the abundance is almost always much higher in one than in the other. It appears that a single wet or dry year may have less impact on these mostly generalist species, but that a series of wet or dry years can strongly influence abundance (and richness at PJ).

The PJ zone shows the most variation in abundance and changes in richness. In the last several reports new records for species tended to come from this zone, but not every species is caught every year. PJ also seems to respond most to droughts that occur over several years (Figure 2). By comparison the MC zone is more stable. The PP zone had seen increasing abundance apparently as overstory vegetation returned (until the Las Conchas Fire of 2011). It is important to monitor arthropods at the species level whenever possible, because they are not redundant. There is turnover along the gradient, of course, but the trajectories of the species may be different. After the Las Conchas Fire, the traps at PP and MC give us a rare opportunity to document the pattern of the arthropods' return. However, it is unclear whether differences in fire severity at trap lines within a site may confound attempts to discern these patterns (Table 1).

These annual reports have been submitted each year based on processing, analysis and tabulation of target taxa found in each trap sample. However, we have changed the list of target taxa slightly in different years. Generally changes in target taxa have been reductions; dropping taxa groups for which we have experienced identification problems to the species level and have lost confidence in our identifications for individuals in those groups. Those changes do contribute to changes in the overall arthropod abundance and species richness data presented in Figure 1 and Figure 2. At some time in the near future, all of the data going back to 1992 should be reanalyzed using the most recent (2014) reduced set of target taxa. Such an analysis is beyond the scope of this current funding for 2014, 2015, and 2016 samples.

Taxa of special interest from 2014

The European earwig, *Forficula auricularia*. The exotic European earwig, *Forficula auricularia,* was first caputured in the MC zone, at the A and D sites in 2009. One individual of this species was found again in 2014 in one trap in the MC A line.

The crickets *Gryllus veletis* and *Cycloptilum comprehendens*. These two species of crickets were very abundant in the PJ in 2014, in far greater numbers than ever recorded for this study since 1992. Early and mid-summer samples had hundreds of

juveniles of both species. Numbers in trap samples declined as they became adults in the late summer. An average of over 100 individuals per trap were found in the PJ in 2014.

New cricket in the genus *Gryllus*. Another species of *Gryllus* was found in traps on the PJ D line. This species is undescribed and belongs to a group of species that occur in rocky microhabitats. Unlike *G. veletis*, this species is dark brown, not black, and has long cerci rather than short cerci. Specimens have been sent to D.B. Weissman, California Academy of Sciences, who is revising *Gryllus* of western North America, including the description of this species. This species has not been identified in samples until this find in 2014 samples.

Eleodes species. A species of *Eleodes*, similar in appearance to a small *E. sponsus*, was found at the PP A line. The specimen will be sent to Aaron Smith, Northern Arizona University, for identification. The species was given the code COTEEL90 until its taxonomic status is confirmed.

Eleodes extricatus, *E. debilis* and *E. carbonarius*. Specimens in traps that correspond to these three species were pooled into one taxon in 2014; *E. extricatus*. Individuals of these species are usually very difficult to tell apart. After conversations with Aaron Smith, Northern Arizona University, we decided to simply pool all names into one taxon to avoid identification errors. Another related former taxon, *E. obsoletus*, was recently formally synonomized under *E. extricatus*. Adult males of *E. extricatus* can be identified by lobes on the fore-femora, but females cannot, and those lobes vary from location to location as being present or absent across all of these taxa. Cuticle sculpturing differs slightly among the taxa, but when specimens are wet with ethanol, one cannot see the cuticle sculpturing. Otherwise, body sizes and shapes vary geographically to the point that one sorting pitfall samples simply cannot be sure which species are present in most cases. Eventually, all historic data for these species back to 1992 will be changed to one taxon name, *E. extricatus*.

Carabid ground beetles. The highest counts of carabid ground beetles form the PJ lines ever recorded since 1992, were recorded in 2014, averaging over 12 individuals per trap. Several species were involved, and like crickets, were unusually abundant across the PJ zone in 2014. Numbers also were high in the PP zone, but were low in the MC zone in 2014.

Rhadine. A species of the ground beetle genus *Rhadine* new to this study was found at the MC C line in 2014. This species is medium size, different from the large *Rhadine* 1 and the small *Rhadine* 2 that we have already encountered. This species was given the code COCARH03. The voucher specimen and All *Rhadine* specimens will be sent to Danny Shpeley at the University of Alberta for identification.

Synuchus. A species of the ground beetle genus *Synuchus* new to this study was found at the MC C line in 2014. Similar to *S. dubius*, but much more slender, this species was given the code COCASY01. The voucher specimen will be sent to Danny Shpeley at the University of Alberta for identification.

Acknowledgements

We thank Dr. Robert Parmenter and Dr. Craig Allen for providing funding and support for this research. Thank you Kay Beeley of Bandelier National Monument for supervising and participating in the maintenance and the collection of pitfall trap samples in the field and for obtaining and tabulating weather data for us. Thank you Wesley Noe, University of New Mexico undergraduate student (now graduated) for initially sorting target taxa from the 2014 field collected samples. Thank you Dr. Aaron Smith, Northern Arizona University for helping with darkling beetle identifications, and Dr. David Weissman, California Academy of Sciences, for helping with field cricket identifications. This research was funded by a Cooperative Agreement contract number P16AC00681 from the U.S. National Park Service, NPS Lands Conservation Fund, to the University of New Mexico, Biology Department.