

Long-Term Studies of Ground-Dwelling Arthropod
Biodiversity at Bandelier National Monument

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Prepared by

Sandra L. Brantley
and
David C. Lightfoot

Division of Arthropods
Museum of Southwestern Biology
University of New Mexico
MSC 03 2020
Albuquerque, NM 87131-0001

Presented to

Craig D. Allen
Research Ecologist
U.S. Geological Survey
Biological Resource Discipline
Jemez Mountains Field Station
Los Alamos, NM 87544

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Introduction

This annual report summarizes recent results of an on-going long-term monitoring study of ground-dwelling arthropods at Bandelier National Monument that was initiated in 1992. Interannual variation in abundance is notoriously high in arthropod populations so that long-term monitoring is necessary to detect changes that may be due to climate or land use shifts. Studies of mountain ground-dwelling arthropods in the U.S. have been few, especially at the community level. The Bandelier study was designed to describe patterns of these communities across an elevation gradient and to associate those changes with large-scale weather patterns, such as El Niño Southern Oscillation (ENSO), which has a strong impact on the southwestern U.S. From long-term study we gain baseline data to compare with responses to abnormally dry (La Niña) or wet (El Niño) years and to detect possible time lags in responses.

In areas with high topographic variation, such as the southwestern U.S., mountains provide elevational gradients without change in latitude, so that elevation effect may be studied more clearly. The gradient extends from lower elevations, which are dry and warm, to high elevations, which are cooler and receive more precipitation. These abiotic differences produce obvious changes in plant species and cover. The ENSO cycle can be thought of as a natural "treatment" applied across the gradient.

If arthropods respond over a short period to ENSO events, we expect to see one of two likely patterns. The first is that lowland species would be less affected by drought conditions because they already live at the dry end of the gradient. Species at high elevations, which generally do not experience dry conditions, might be more strongly and negatively affected. The second 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. The purpose of our research project was to determine if data on a group of organisms living across such an elevation gradient supported one of the above predictions, or perhaps some other pattern.

Methods

This research was conducted at Bandelier National Monument, in the Jemez Mountains of north-central New Mexico. Three study sites were established across an elevation gradient from approximately 6000 ft elevation at the base of the mountains, to approximately 9500 ft elevation near the summits of the mountains. Piñon pine (*Pinus edulis*) and one-seed juniper (*Juniperus monosperma*) made up the dominant vegetation at the low-elevation site (PJ),

ponderosa pine (*Pinus ponderosa*) was dominant at the mid-elevation site (PP) and several mixed 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 site (MC).

We installed permanent pitfall traps to capture ground-dwelling arthropods, to gather information on species composition and relative abundance at a site in each of the three elevation zones. Five replicate sets of traps were located at each of the three sites. Each of the five sets of traps consisted of six individual replicate traps positioned in a line, approximately 5 m apart, for a total of 30 traps at each site. (An additional mixed-conifer site, Site F, was established in 1993, in a prescribed burn area examining the effects of fire on the Jemez Mountain salamander.) 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 even with the ground. A plastic cup half full of propylene glycol was placed in each can and a small wooden cover was positioned about 5 cm about each trap for protection from sunlight and precipitation. All traps were left open continuously year-round. Arthropods were collected from all of the traps in April, June, August and October. Trap samples were sorted and tabulated to the species level. All data were pooled for a given year.

Only arthropod taxa that are known to be ground-surface active, appropriately sampled by pitfall traps, were tabulated. We call these "target" taxa. 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 in this study. Those taxonomic groups included the following: spiders (Araneae; predators), bristletails (Archaeognatha, formerly Microcoryphia; detritivores), crickets (Orthoptera: Gryllidae, Rhaphidophoridae, Stenopelmaticidae; omnivores), darkling beetles (Coleoptera: Tenebrionidae; detritivores) and ground beetles (Coleoptera: Carabidae; predators).

Results

Accomplishments for 2007

All arthropod pitfall trap samples collected in 2007 were sorted, target taxa identified, and count data for each taxon/pitfall trap were recorded. The data were entered into a Microsoft Excel file on a CD included with this report. The results of the 2007 data are presented in this report along with selected data from 1992-2006 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. Seasonal data are still available in the Excel files. Beginning with this report abundance data for the major taxa will be shown in on three graphs per page, one for each site, instead of presenting all the sites on one graph. 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 current taxonomic status included: 1) Ross Arnett, *American Insects*, 2) Entomological Information Service, *Nomina Insecta Nearctica*, 3) Norman I. Platnick, *Advances in Spider Taxonomy* and 4) original descriptive literature and correspondence with expert taxonomists.

Precipitation

Weather data for 1999-2007 were available from the three elevations of interest: Firetower TA-16, representing piñon-juniper at 6500 ft., Los Alamos TA-6 Tower, representing ponderosa pine at 7424 ft., and Cerro, representing mixed-conifer at 9160 ft. (Fig. 1). For 2004 data for mixed-conifer elevation came from both the Cerro and Quemazon stations. Data for the years before 1999 came from different locations and are contained in our earlier annual reports. We thank Kay Beeley for compiling the precipitation data for us. Precipitation for 2007 was slightly lower than 2006 in the mixed conifer and ponderosa zones, and similar to 2006 in the PJ zone (Fig. 1). Precipitation has declined slightly each year since 2005 across all study sites. 2007 was a relatively wet winter and spring, with a dry summer.

Ground-dwelling Arthropods

Arthropod abundances were high when this study began in 1992, an El Niño year (Fig. 2). Numbers declined at all sites in the drought of 1994-1995 and stayed low through 2002. In 2003 numbers increased for most of the dominant species and declined again in 2004, and then rose sharply in 2005, 2006 and 2007 (Table 1, Fig. 2). Some groups showed a decline beginning in 2001: *Pardosa uncata*, *Togwoteeus biceps*, and both *Ceuthophilus* species. The rest did not start declining until 2002: *Oriulus venustus*, *Trachyrhinus marmoratus*, *Machilinus aurantiacus*, and the 5 beetle species. This pattern suggests that no ground arthropod taxon remains unaffected by longer-term drought; although some groups manage a single dry year well. Species may also have intrinsic rates of change in population size, which are independent of some climate conditions (such as bristletails, Fig. 5). Arthropod species numbers have also declined since 1992-1993 (Fig. 3), were relatively steady through 2000, and then dropped again in 2001. Since then species numbers have returned to levels seen in the mid-1990s. Not every species was collected every year, making long-term studies of particular importance in characterizing the biodiversity at the sites. While richness and abundance fluctuate seasonally and annually, the dominant species tend to remain dominant. Species are well known to respond independently to environmental factors, so that responses of one species are not necessarily indicative of the responses of others (compare Figs. 4-10). It is also important to note that each El Niño / La Niña event is unique in its pattern across the state. For example, the El Niño of 1992-1994 influenced arthropod abundance (at least in part) to an extent that has not been seen again until 2005, including the 1997-1998 El Niño. Table 1 below compares 2000-2007 for total numbers of arthropods collected (relative abundance) and the numbers collected for the most abundant species. In 2007, arthropod groups that have tended to respond

positively to El Nino events and winter rainfall, such as spiders, camel crickets and bristletails, were abundant in the early summer. Those groups appear to have accounted for much of the high numbers of arthropods during 2007. However, extremely high numbers of one species of carabid ground beetle (see below) accounted most for the overall high numbers of arthropods from the ponderosa sites during 2007.

Table 1. Comparison of relative abundance for selected species at the study sites.

Taxon	Relative Abund. 2002	Relative Abund. 2003	Relative Abund. 2004	Relative Abund. 2005	Relative Abund. 2006	Relative Abund. 2007
All species	1230	7308	5491	16,035	12,640	20,603
<i>Oriulus venustus</i> (millipede)	19	93	28	19	22	23
<i>Pardosa uncata</i> (wolf spider)	22	81	30	314	280	244
<i>Togwoteeus biceps</i> (harvestman)	0	139	1	598	1233	702
<i>Trachyrhinus marmoratus</i> (harvestman)	22	99	252	53	27	125
<i>Machilinus aurantiacus</i> (bristletail)	2	1677	411	2376	80	1014
<i>Ceuthophilus pallidus</i> (camel cricket)	27	243	527	589	431	429
<i>Ceuthophilus utahensis</i> (camel cricket)	171	1389	672	1652	2759	2078
<i>Carabus taedatus</i> (ground beetle)	67	307	146	156	103	65
<i>Pterostichus adstrictus</i> (ground beetle)	36	197	85	214	230	8005
Subfamily Aleocharinae (rove beetle)	36	318	233	662	524	917

<i>Eleodes extricatus</i> (darkling beetle)	54	324	306	640	503	621
<i>Eleodes obscurus</i> (darkling beetle)	54	199	101	77	106	367

Table 2. Total numbers of target taxa collected by site and season for 2007.

Collecting period	Piñon-juniper site	Ponderosa pine site	Mixed conifer site	Total
Oct06-Apr 07	313	642	652	1607
Apr 07-Jun 07	927	1139	985	3051
Jun 07-Aug 07	2158	7293	1697	11148
Aug 07-Oct 07	923	2213	1661	4797
Total	4321	11287	4995	20603

Spiders were widely distributed throughout the sites (Fig. 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 the wet winter of 2005. The El Niño of 1997-1998 was not a strong one for New Mexico and produced little effect on the spiders at the PJ and PP sites, but probably did influence the abundance seen at the MC site. Most of the abundance at MC comes from wolf spiders (Lycosidae), especially *Pardosa uncata* and *P. yavapa*. Ground spiders (Gnaphosidae) dominate at PP, while a different wolf spider, *Schizocosa mccoeki*, dominates at PJ. The wolf spider *P. orophila* virtually disappeared from the PJ site during the mid-1990's through 2004, but has been collected again in low numbers from 2005-2007.

Bristletails (mostly *Machilinus aurantiacus*) were collected primarily at PJ, although in wetter years they have turned up at PP as well. Their populations seem to alternate years for high and low numbers, except that drought apparently can reduce numbers greatly, to the point of local extinction in some years (Fig. 5). Bristletail numbers in 2007 declined in numbers from 2006 in the MC sites, but increased from 2006 in the PP and PJ sites. These small detritivores are an important food source for larger arthropod species but are rarely counted in arthropod studies.

Cricket abundance data (Fig. 6) included field crickets, camel crickets and Jerusalem crickets. The species are rather restricted by habitat: Jerusalem crickets (*Stenopelmatus fuscus*), field crickets (*Gryllus* sp.) and one camel cricket (*Ceuthophilus pallidus*) are found primarily at the PJ site; field crickets and the other camel cricket (*C. utahensis*) are found at the PP site; *C. utahensis* is found

primarily at the MC site. Numbers in 2001 - 2002 were reduced at all sites approximately to 1995 levels. In 2003 numbers increased in PJ and MC, and declined slightly in PP. *C. pallidus* numbers at the PJ site have steadily increased since 2001, to high abundance in 2006, similar to 1993. Cricket numbers in 2006 were especially high at the MC site, but not at the PP and PJ. See the table above to compare *C. pallidus* and *C. utahensis*. Overall 2007 cricket numbers were lower than 2006 at the MC sites, but higher than 2006 in the PP and PJ sites. Jerusalem crickets were especially abundant in 2007, but only at the PJ sites.

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 away from riparian or other moist habitats, and as expected, at Bandelier most individuals were found at the MC site (Fig. 7). Numbers declined in 1995 and 1998 at all sites, and recovered more quickly at MC than at the other two sites. In the wet years 2005-2007 the carabids increased at PJ and MC, but at PP we collected over 8,000 specimens of *Pterostichus adstrictus*. The species is common at Bandelier, but we have not seen such high numbers of any carabid during the 15 years of this study. It is important to note that the larval stages of these beetles are not well sampled by pitfall trapping (they live in the upper soil), so that we have no way to assess their changes in abundance and what effect those changes may have on adult population numbers. It is also possible that the numbers of *P. adstrictus* in the traps negatively affected the abundance of other taxa in those traps.

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 can be difficult, especially within the subfamily Aleocharinae. At Bandelier they are rarely collected from PJ (Fig. 8), where they may be limited by the lack of ground cover. The beetles are usually associated with grass or litter. There were virtually no staphylinids collected at PP or MC in 2002. Numbers continued to be low in 2003 and 2004, and increased in 2005 and maintained similar abundance in 2006. In 2007, rove beetle numbers increased further at the MC sites, but remained at similar levels to 2005 and 2006 at the PP and PJ sites.

Darkling beetles (Tenebrionidae) have been present in low but consistent numbers at PP and MC over the course of this study, even during drought years (Fig. 9). They are dominant species at PJ, while many of the other taxa we report on are more abundant at higher elevations. These beetles seem to be relatively unaffected by short-term environmental changes. For example, compare their numbers with those of crickets (Fig. 6) or spiders (Fig. 4), but even their numbers have increased at PJ between 2005 and 2007.

An additional line of pitfall traps (Line F) was established at the MC site to monitor ants (as a food resource for salamanders) following a prescribed burn.

Abundance data for ants from pitfall traps (which primarily target solitary wandering arthropods) should be used cautiously because establishment or decline of colonies near traps can greatly affect pitfall captures. The E line is the closest line and was most similar to the F line before the burn, and so was chosen for comparison to see if the F line ant community became similar to that of the E line. However, lines E and F have varied unpredictably in relation to each other over the course of this study (Fig. 10). In 2007, ant numbers from lines E and F were similar to each other.

Sixteen 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 rare species. The PP and MC sites are more similar to each other than they are to the PJ site, which is also the site with the most variation in abundance. Separating the effects of precipitation from other sources of variation will be difficult even with a long-term dataset, because species respond individually to environmental changes. We have characterized the arthropods from each vegetation zone, documented rare species and uncovered a few undescribed species. It appears that both wet and dry years influence abundance, but dry years have the greater impact. The value of this data set is not only in the number of years covered, but in the number of species tracked, in documenting arthropods from forests of a semi-arid region, and in the inclusion of invertebrate data for conservation/management planning.

Taxa of special interest from 2007

The ground beetle *Pterosichus adstrictus* was extremely abundant at the ponderosa site, at PP sites. We also noticed unusually large numbers of noctuid moth larvae and adults in early season 2007 pitfall trap samples. Those moths are not target taxa, so we did not count individuals. However, they would be potential food items for *Pterosichus* ground beetles, and the high numbers of moths may account for the high numbers of *Pteosichus* and other ground beetles.

The linyphiid spiders are small (2-6mm), sheet web weavers found worldwide, but especially in temperate climates. In North America they are relatively well-known from Canada, the eastern US, and the Pacific Northwest. They are poorly known from the southwestern US, although there is suitable habitat for them at high elevation. Sandra Brantley has formed a group of colleagues to work on linyphiids of this region, and has saved specimens from Bandelier, an important core for this effort.

Publications representing this project: 2007

Lightfoot, D. C., S. L. Brantley, and C. D. Allen. 2008. Geographic patterns of ground-dwelling arthropods across an ecoregional transition in the North American Southwest. *Western North American Naturalist* 68, no. 1: 83-102.

Contributed Talks/Posters

Lightfoot, D. C. and Brantley, S. L. 2007. The Colorado Plateau ATBI and the Museum of Southwestern Biology. Oral presentation. The Ninth Biennial Conference of Research on the Colorado Plateau. Flagstaff, AZ. October.

S. L. Brantley. 2008. Association of spider abundance with El Nino events: 15 years of data from 3 elevations in the Jemez Mountains, New Mexico. Abstract of presentation at the 2008 American Arachnological Society: The El Nino weather pattern strongly affects precipitation in the southwestern US, generally producing more precipitation than average (El Nino) or less precipitation than average (La Nina) from October to May. In the Jemez Mountains of north-central New Mexico I use pitfall traps to monitor ground-dwelling arthropods at three elevation zones: piñon-juniper woodland (1948 m), ponderosa pine forest (2454 m), and mixed conifer forest (2717 m), and ask how the fauna in each zone are affected by these events. Here I report on richness and abundance data for 7 families of spiders from 1993-2007. Results showed that single wet or dry years did not produce significant changes in spider abundance, but a series of wet or dry years had a strong impact. The mostly dry years 1995-1997 and 1999-2004 greatly reduced abundance at all sites, with the piñon-juniper habitat affected most strongly. Abundance during the wet years 1991-1994 and 2005-2007 was more variable across taxa and elevation zone. Cluster analysis based on spider abundance showed that dry years clustered together, but the two extended wet periods did not. Species tended to remain in their elevations zones rather than move during the extended wet or dry periods. Dominant species remained dominant throughout the 15 years, while rarer species reached very low numbers or were not collected at all during dry years.

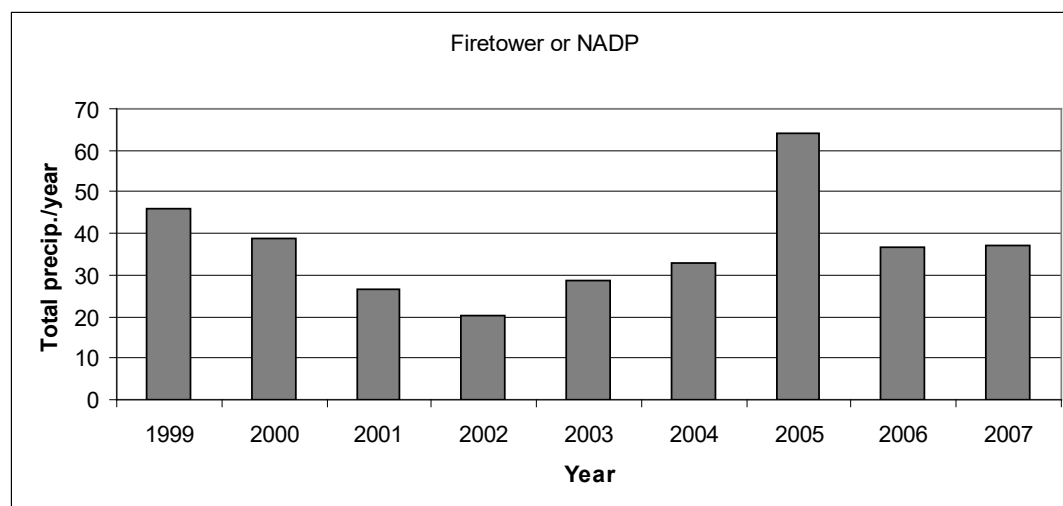
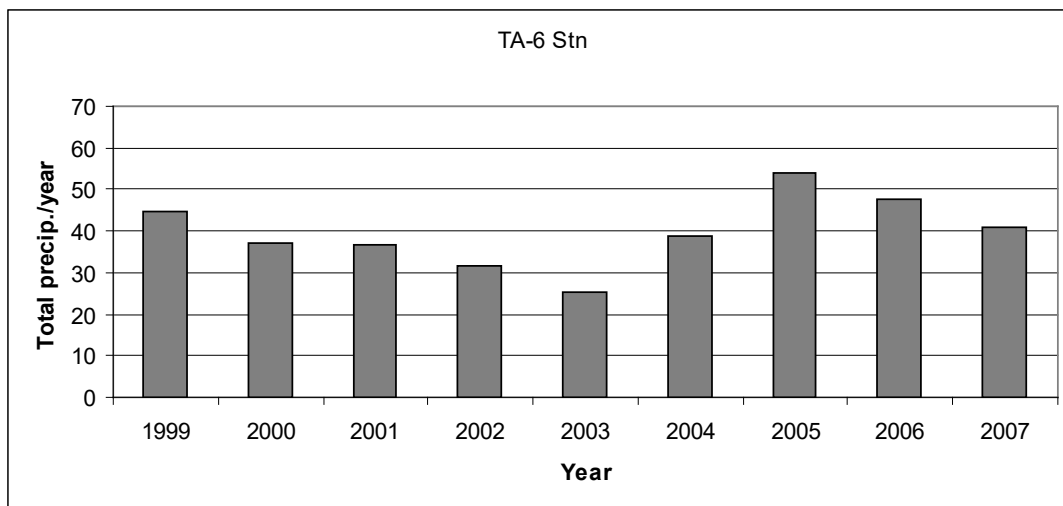
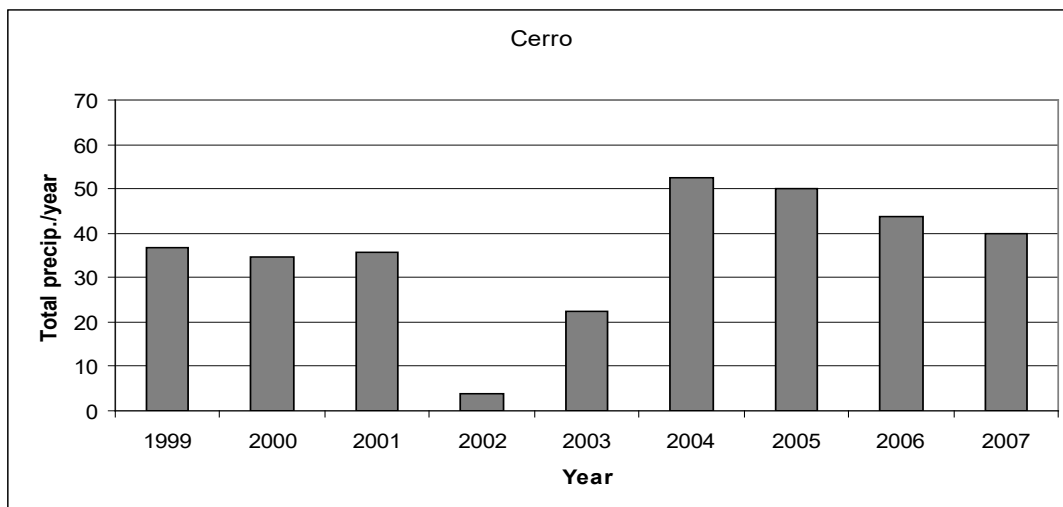


Fig. 1. Bandelier precipitation (Cerro = mixed conifer, TA-6 = ponderosa, Firetower = pinyon/juniper).

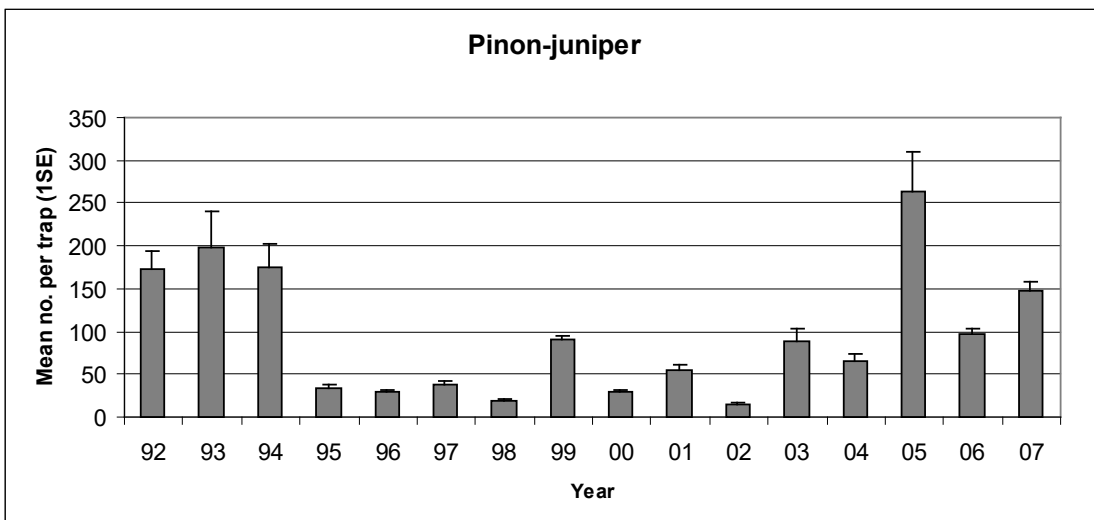
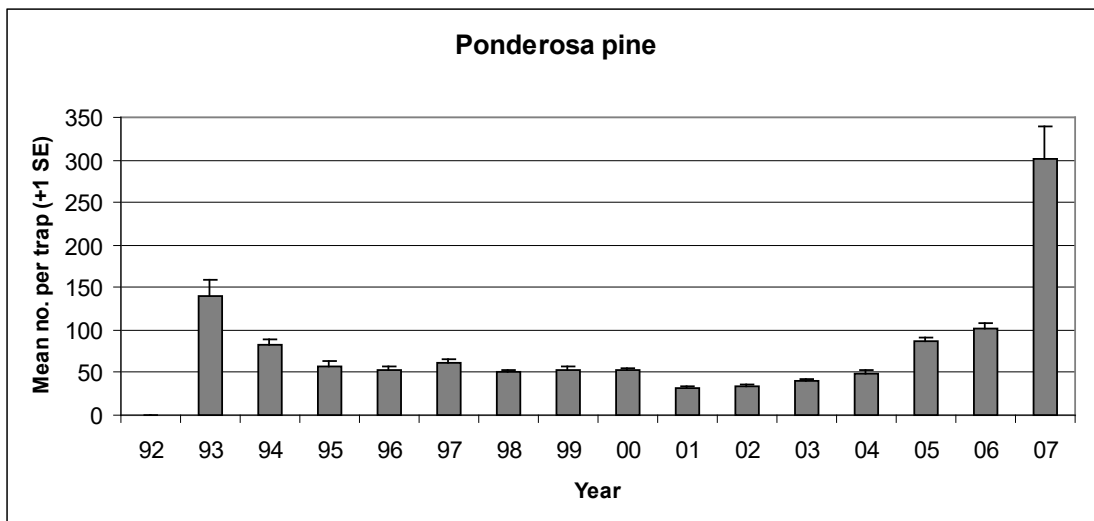
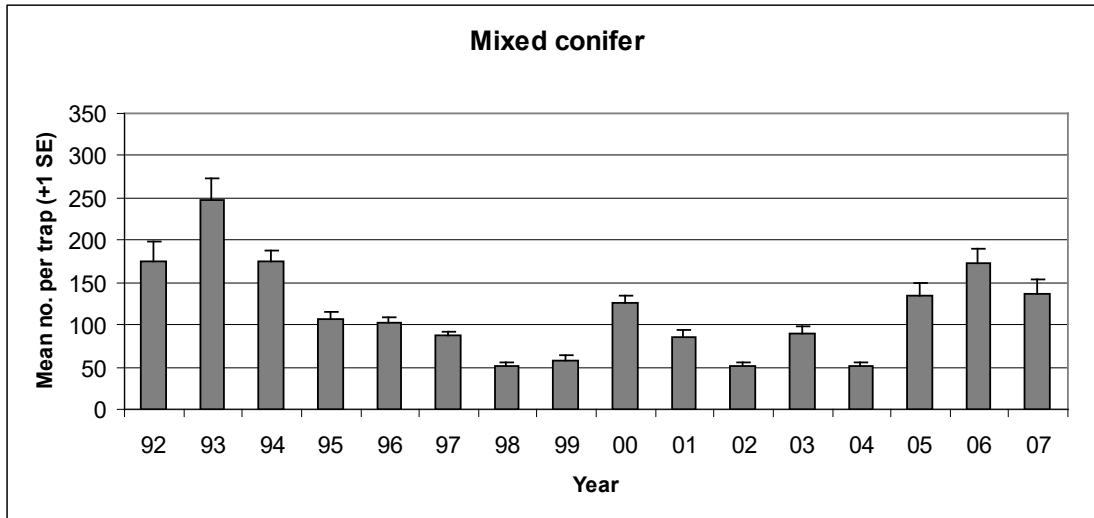


Fig. 2. Mean arthropod relative abundance by site and year.

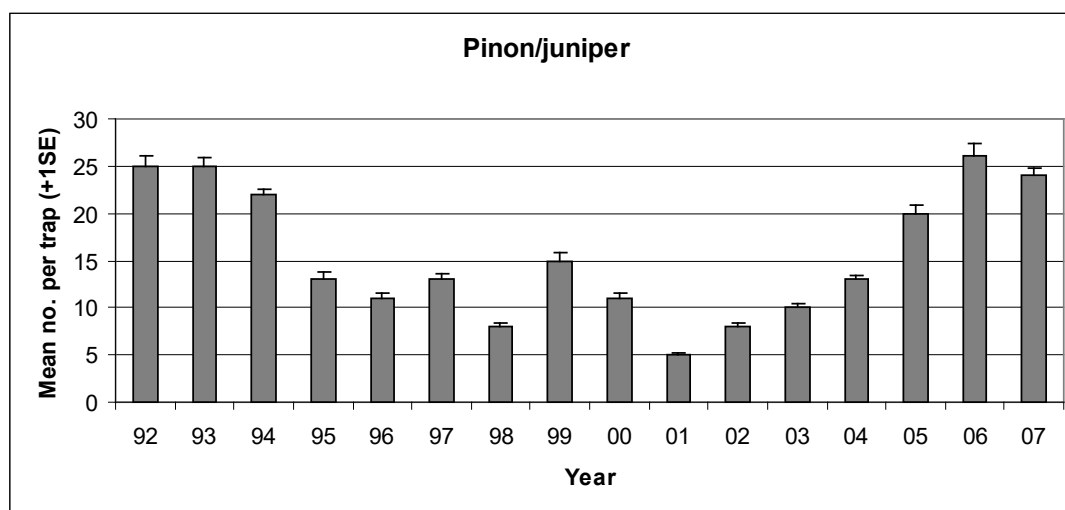
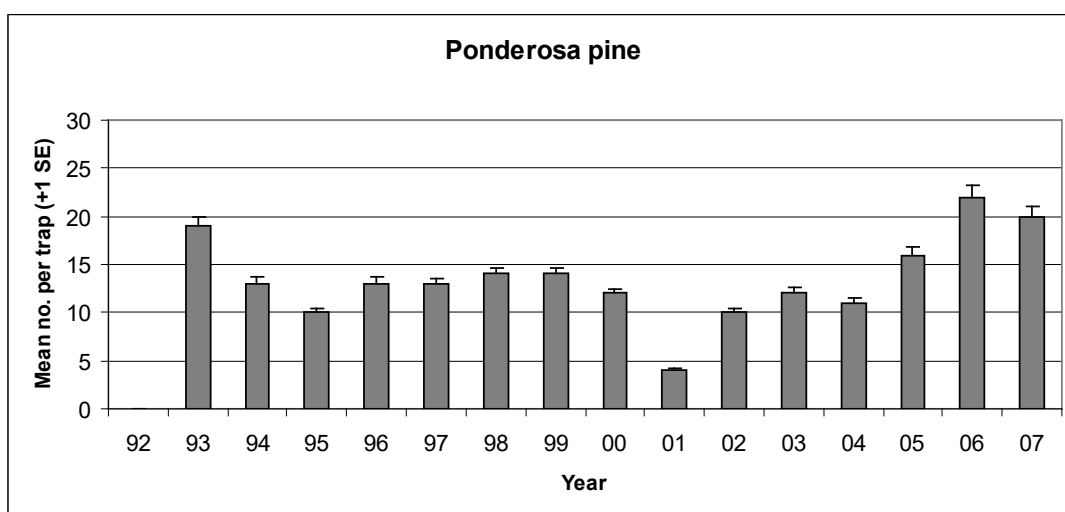
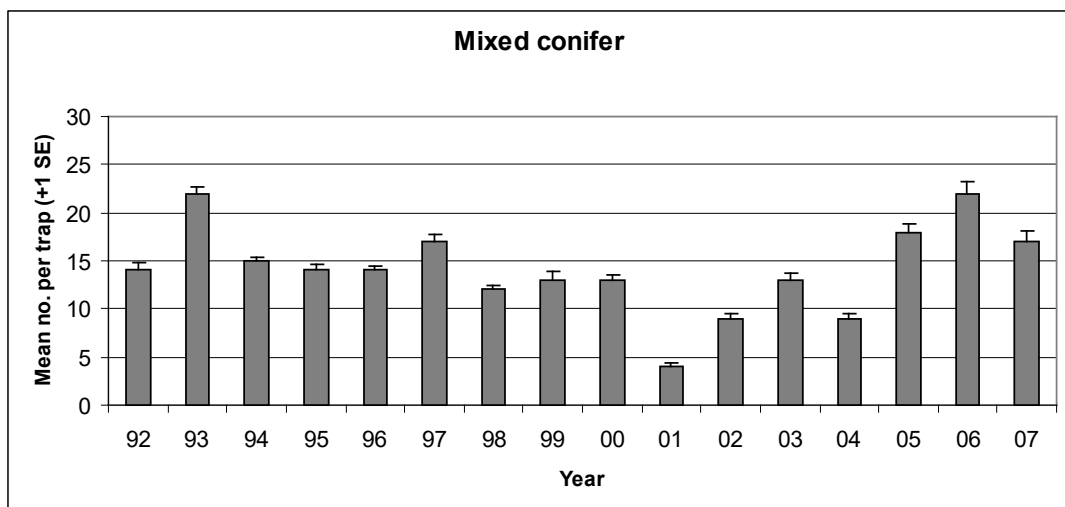


Fig. 3. Mean arthropod species richness by site and year.

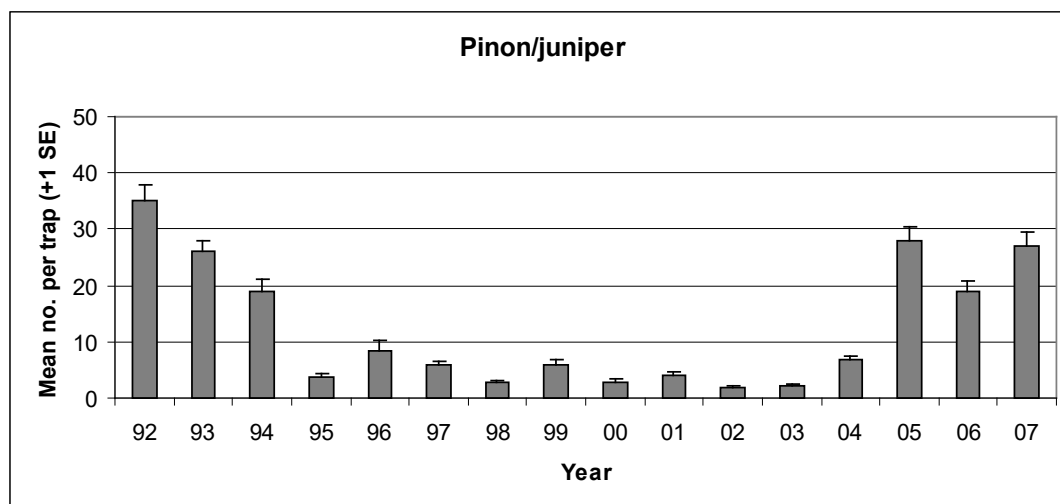
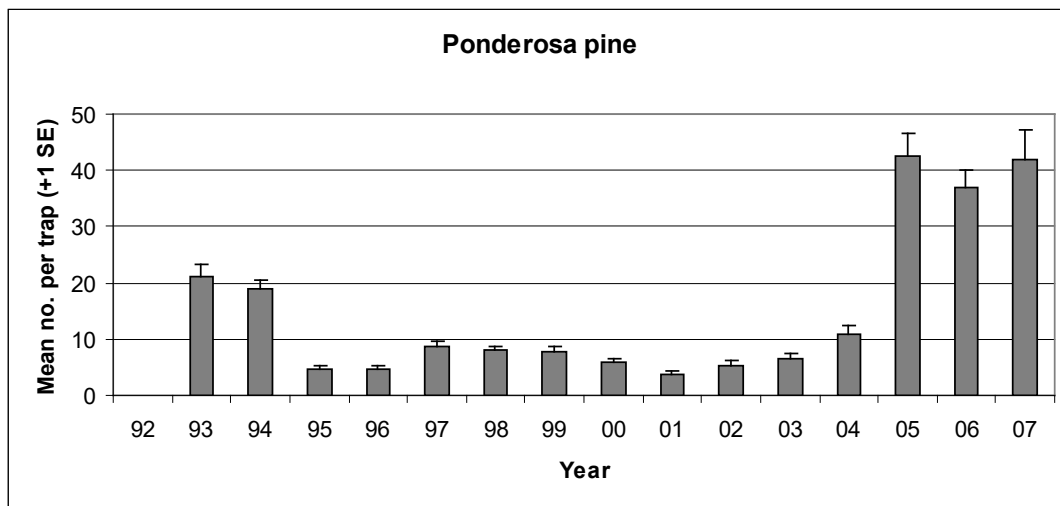
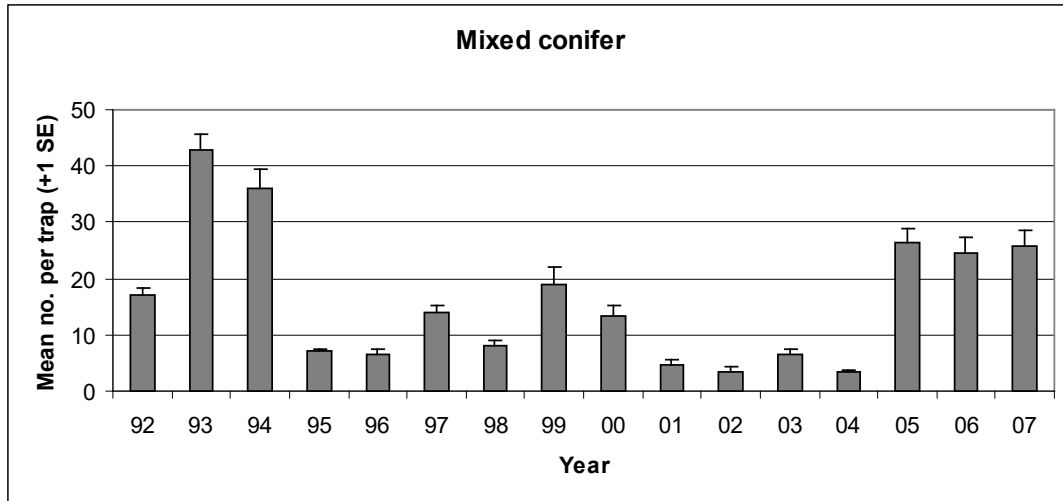


Fig. 4. Mean spider abundance by site and year.

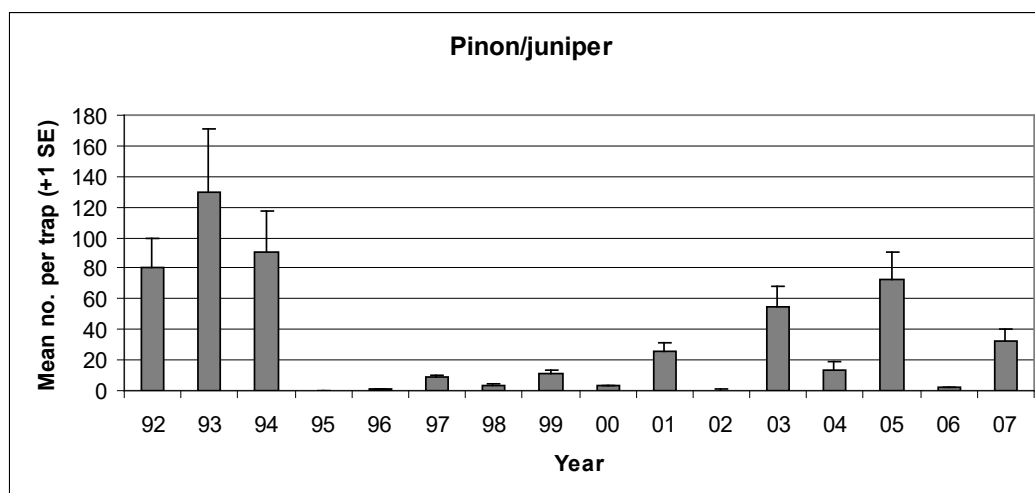
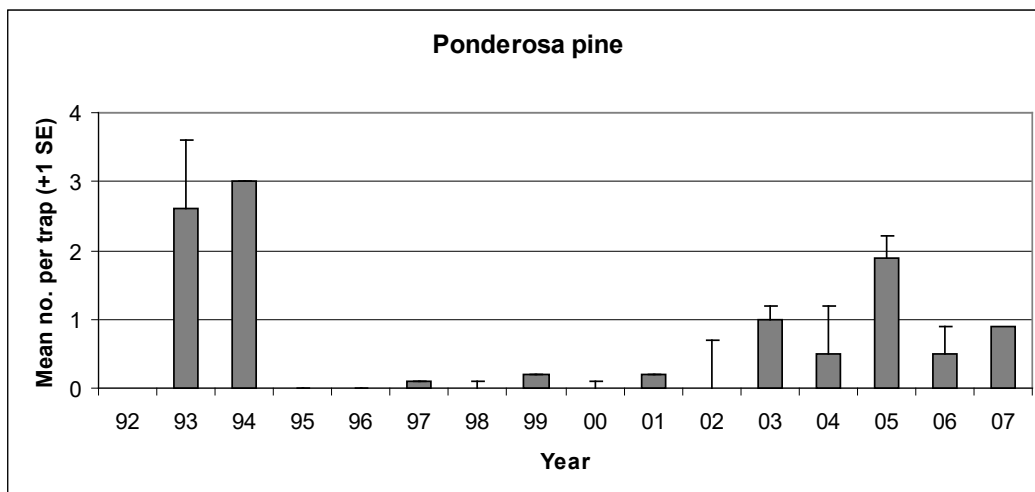
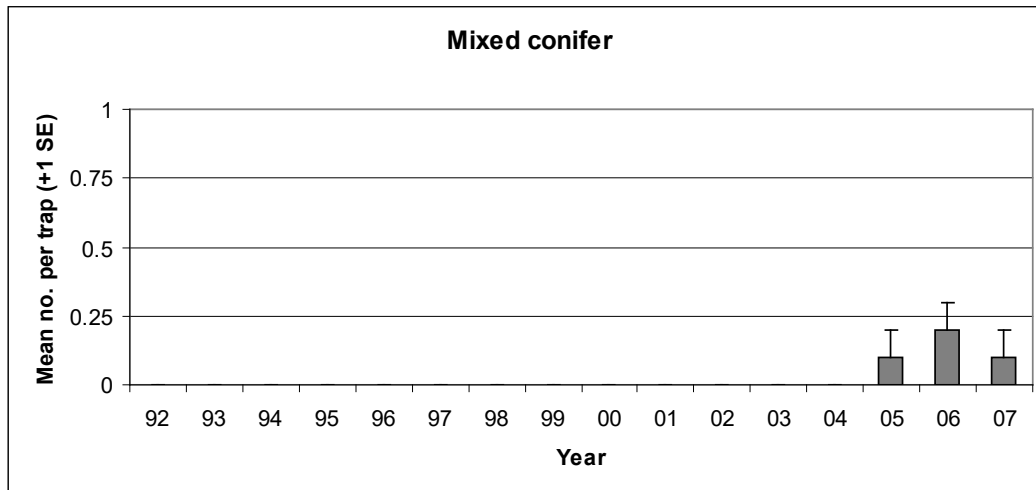


Fig. 5. Mean bristletail abundance by site and year. Please note the differences in the y-axis scales.

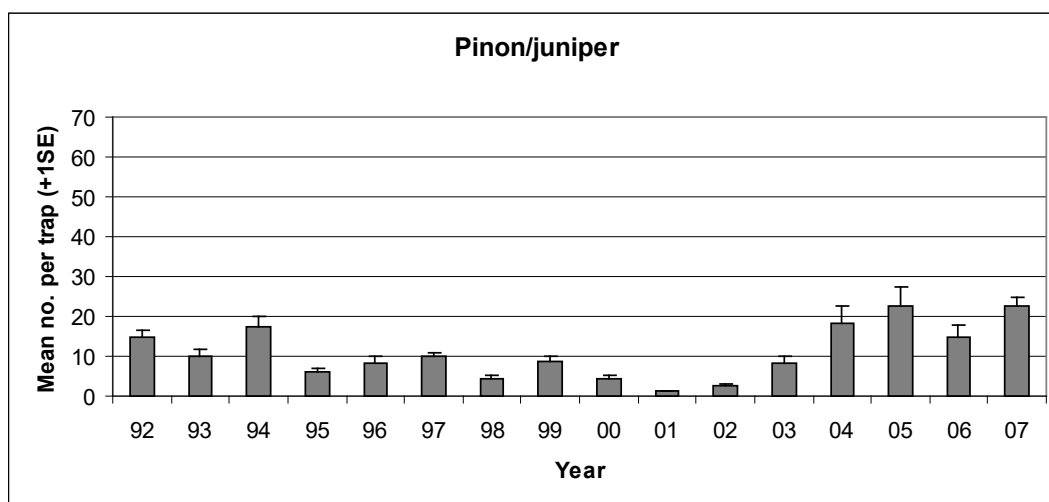
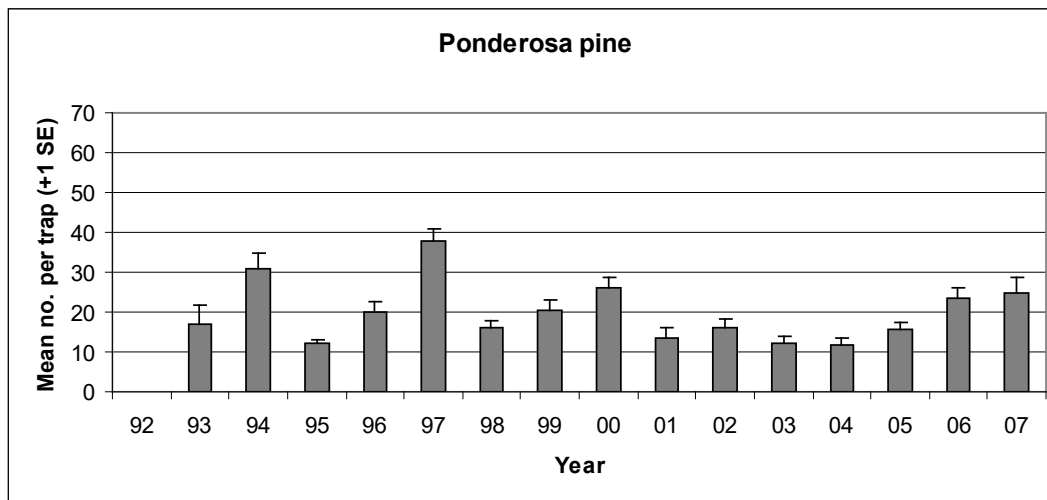
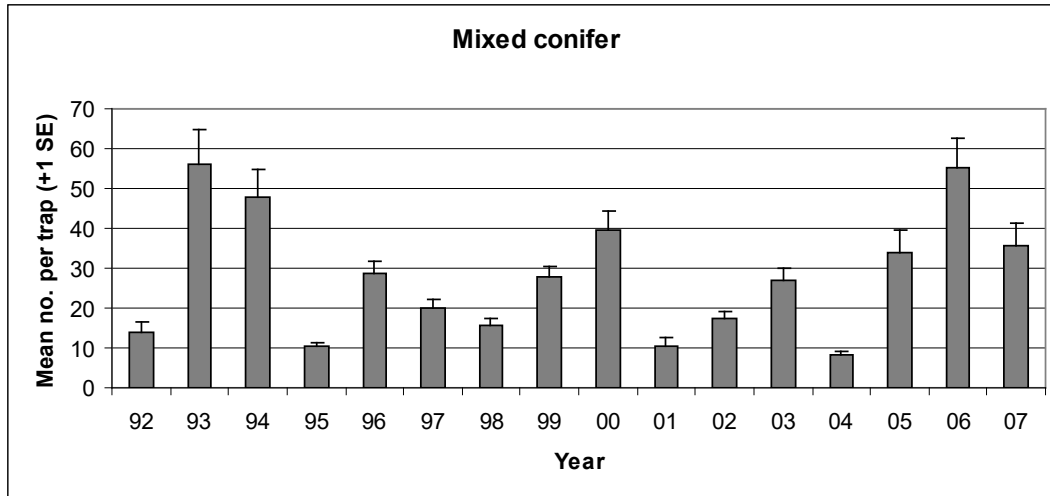


Fig. 6. Mean cricket abundance by site and year.

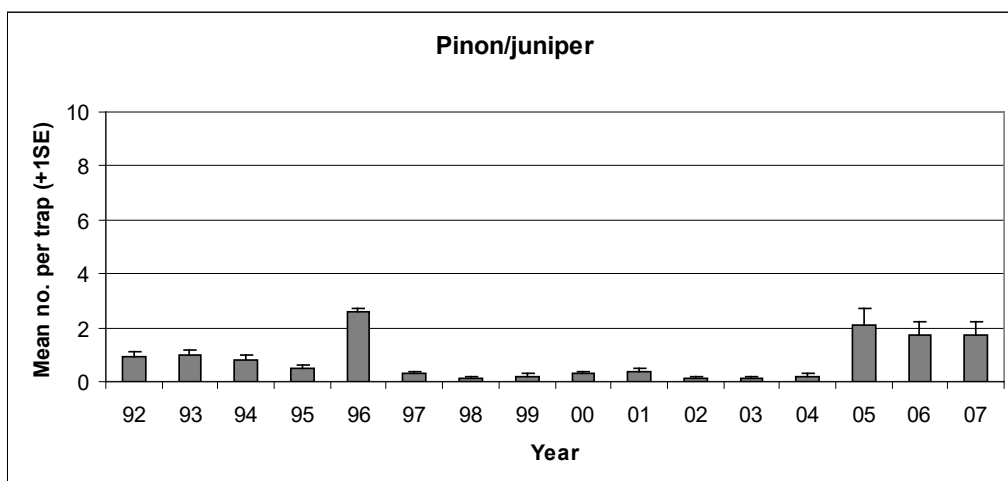
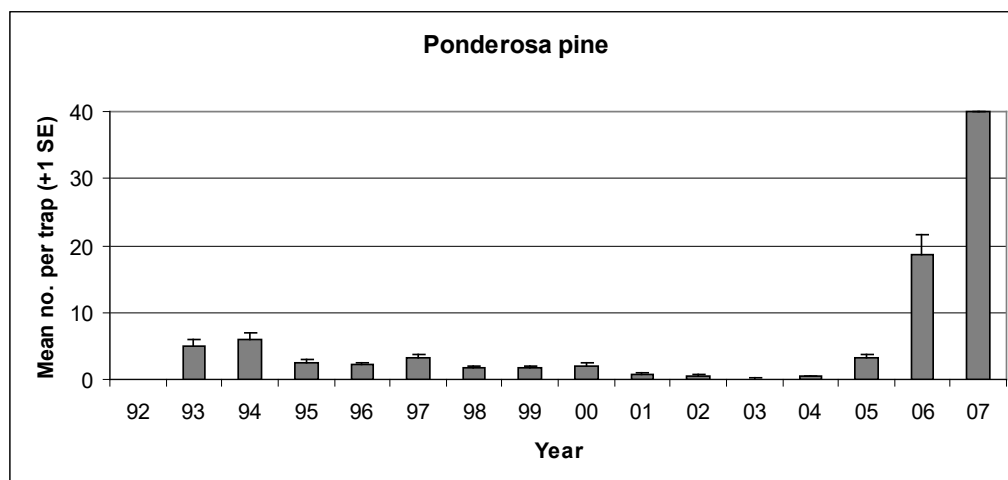
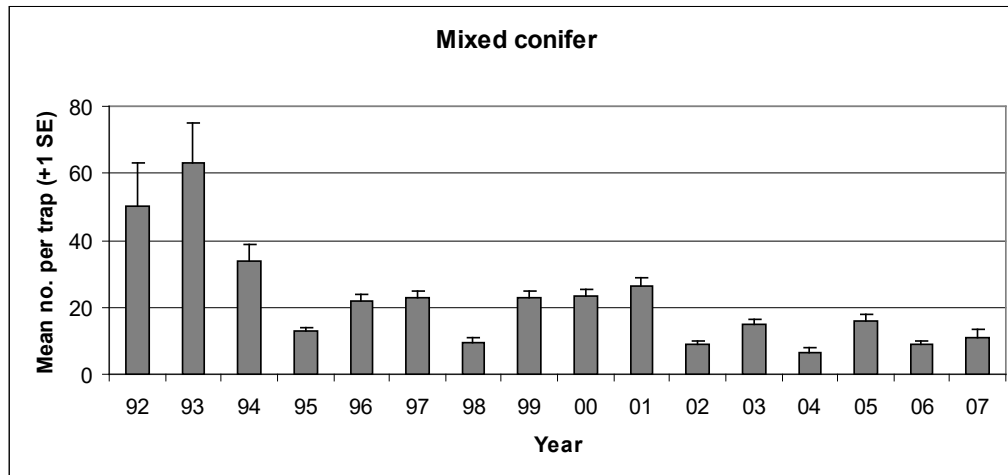


Fig. 7. Mean ground beetle (carabid) abundance by site and year. Please note the differences in the y-axis scales.

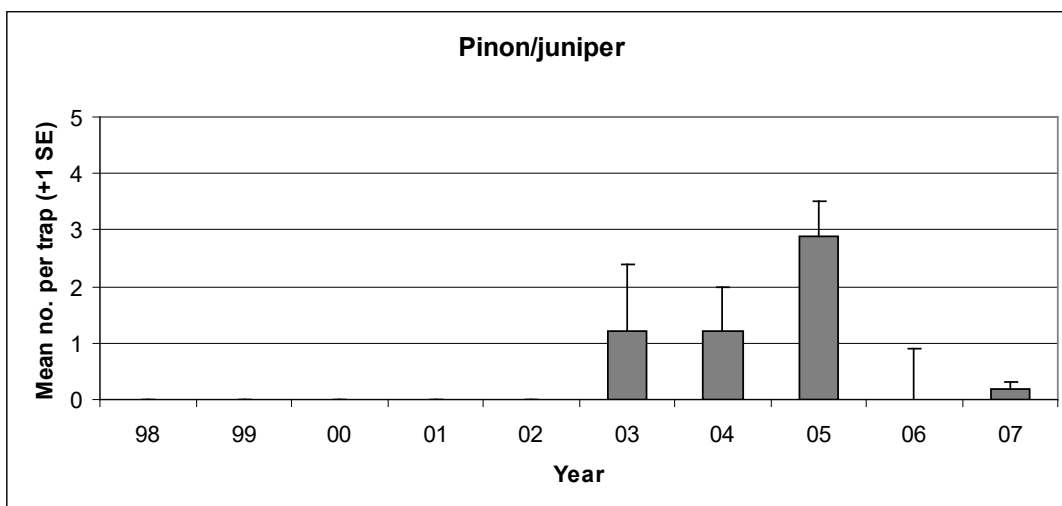
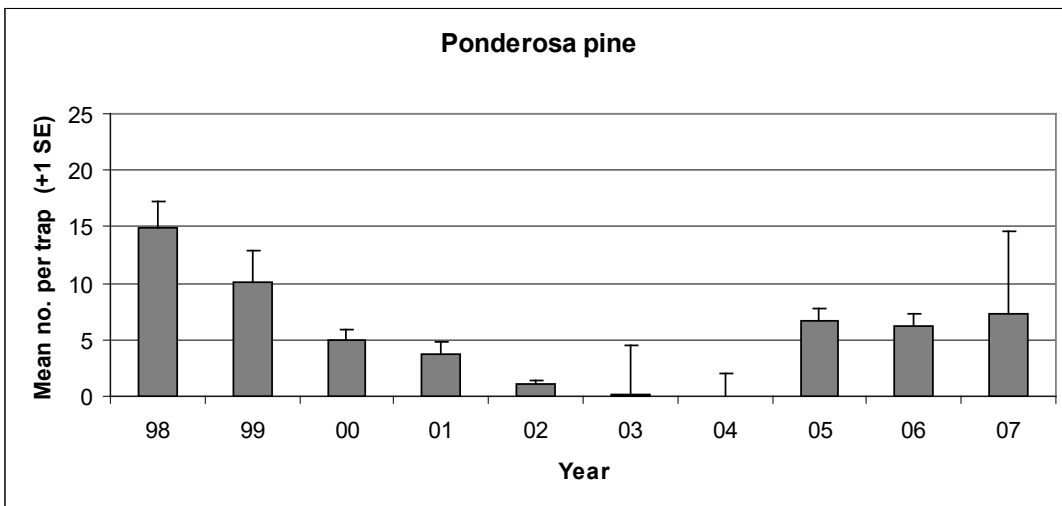
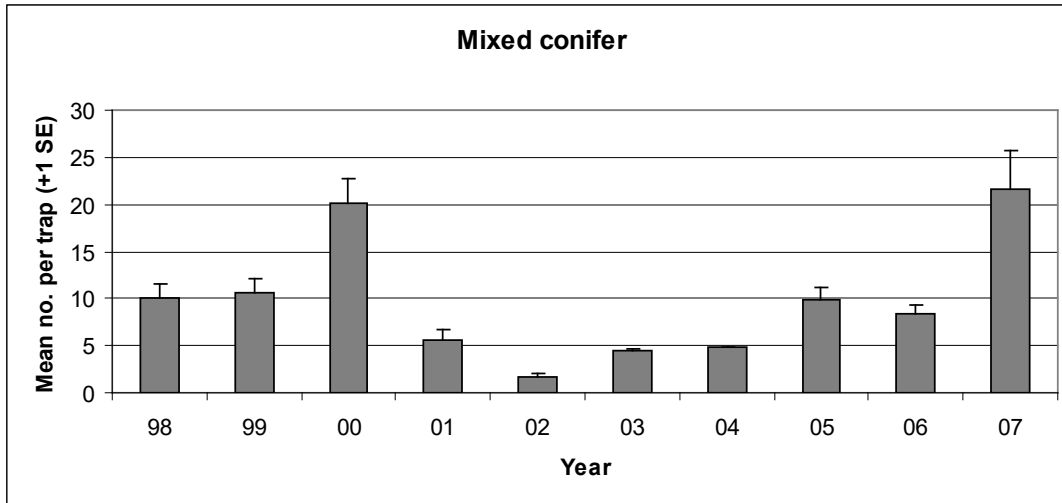


Fig. 8. Mean rove beetle (staphylinid) abundance by site and year. Please note the differences in the y-axis scales.

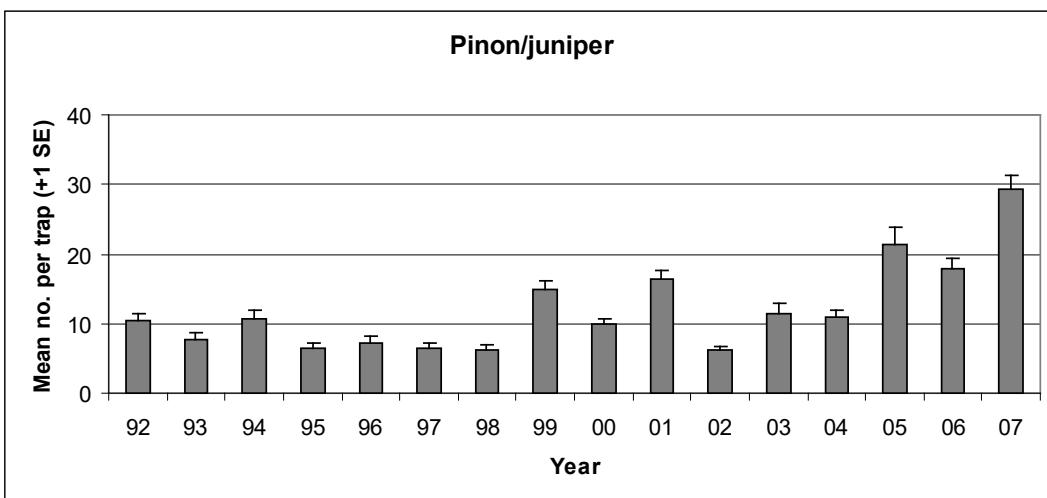
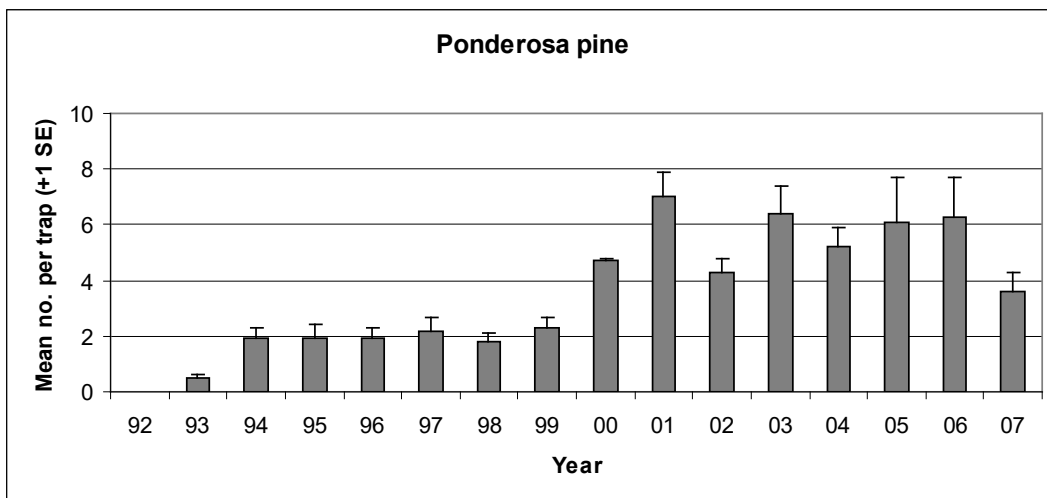
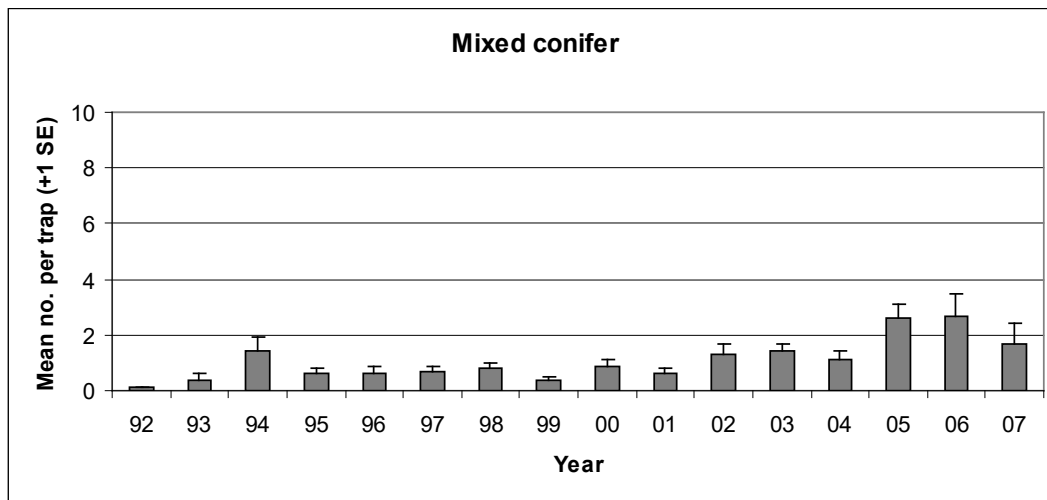


Fig. 9. Mean darkling beetle (tenebrionid) abundance by site and year. Please note the differences in the y-axis scales.

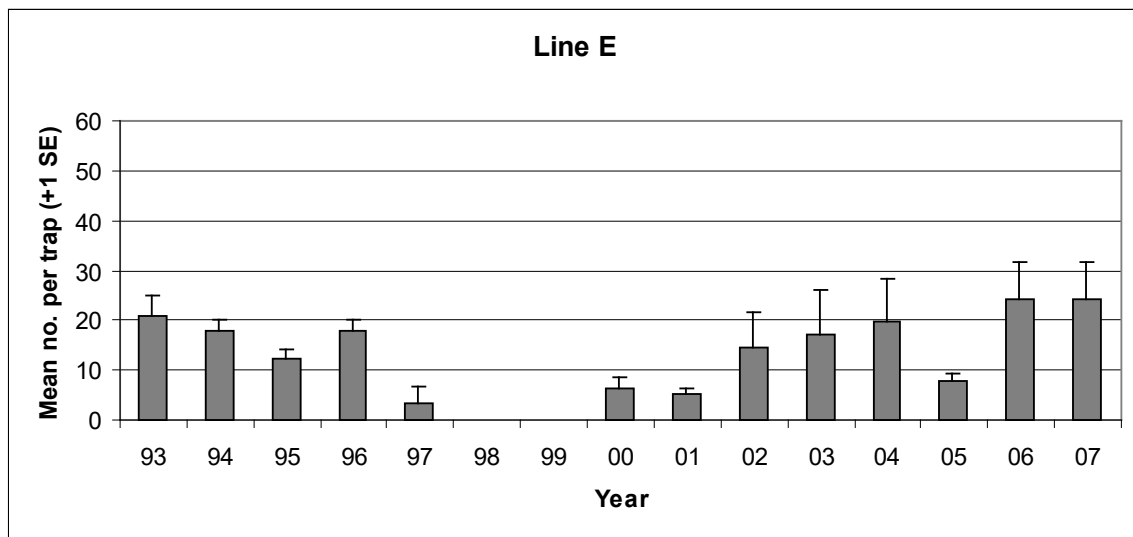
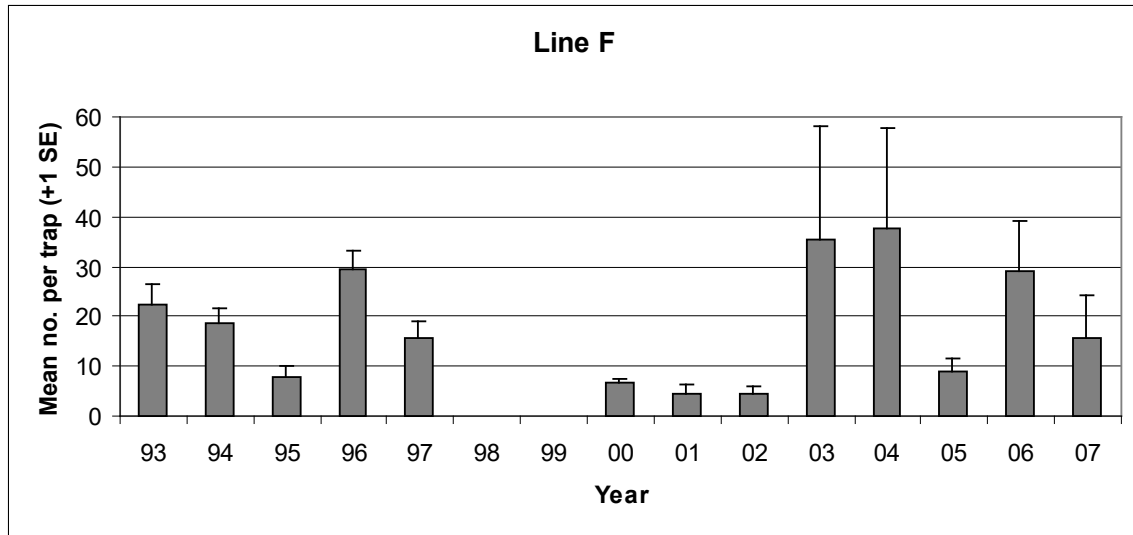


Fig. 10. Mean ant abundance on burned (F) and unburned (E) lines of pitfall traps at mixed-conifer site by year.