

**LONG-TERM STUDIES OF ARTHROPOD
BIODIVERSITY AT BANDELIER NATIONAL MONUMENT**

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Final Report

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Introduction

This report summarizes findings from a monitoring study of ground-dwelling arthropods at Bandelier National Monument during 1994. A long-term study of ground-dwelling arthropods was begun at Bandelier National Monument during the summer of 1992 to monitor ground-dwelling arthropod communities in different environments across an elevation and temperature/moisture gradient to gain information on the effects of climate change on arthropod communities and population dynamics. In conjunction with the Sevilleta and Jornada Long-Term Ecological Research Projects, parallel monitoring studies at Bandelier will provide additional sites for a long-term regional database of plant and animal responses to climate change. A standardized regional approach to monitoring ecological processes is more meaningful to understanding climatically induced phenomena than small scale, narrowly focused and unrelated individual studies.

Long-term sampling of arthropod assemblages will also provide inventory information of arthropod species that occur at Bandelier National Monument. Data will be useful to assess arthropod species diversity patterns across elevational zones, and different seasons of the year. All arthropod taxa found in this study will contribute to an overall inventory of arthropods at Bandelier.

Methods

Arthropod pitfall traps were located in association with small mammal trapping webs at five plots (webs) at a pinon/juniper woodland site, and at five plots in mixed-conifer forest site, in the early summer of 1992. Locations of the plots at each site are plotted on the maps provided by Craig Allen in Appendix 1. Six traps located in a line at approximately 5 meter intervals were installed at the five web locations, for a total of 30 traps at each of the two sites. An additional set of 30 traps were established in a ponderosa pine site in the summer of 1993. An additional mixed-conifer site (site F) was also established during the summer of 1993 to specifically examine the effects of prescribed burn forest fire on ground-dwelling ant populations.

Each pitfall trap consists of one 3X4.5 inch steel can buried in the ground, with the open top of the can level with the ground surface. A plastic cup was placed in each can and filled half full with propylene glycol. A 6X6X3/8 inch plywood cover supported on 3.5 inch nails was placed over each pitfall trap. Native rocks were later used for covers at the mixed- conifer sites to discourage elk.

The pitfall traps were sampled every six to eight weeks by Park Service personnel. The contents of each pitfall cup was emptied into a small wire strainer, and the arthropods were transferred into glass storage vials with alcohol. Each vial was labelled by site, plot, pitfall number, and date. Vials containing the arthropod samples were sent to the University of New Mexico to be sorted and tabulated.

Only arthropod groups that are truly ground-dwelling, and appropriately sampled by pitfall traps are considered in this study. These "target" groups include ground-dwelling spiders, centipedes, millipedes, beetles, crickets, and others. Other "non-target" arthropods also fall into pitfall traps. These include arthropods that are not typically ground dwelling, but are attracted to the open trap, and typically ground-dwelling arthropods that are not appropriately sampled by pitfall traps. Flies are examples of arthropods that do not live on the ground but are attracted to pitfall traps, and large numbers are often caught in pitfall traps. Representative specimens of non-target arthropods are retained and placed in the general Bandelier arthropod collection, as contributions to an inventory of arthropods at Bandelier.

Ground-dwelling arthropods were sorted and counted from each sample vial. Arthropods were sorted to the species level, however the actual names of most taxa are not yet known. Arthropods were thus assigned to Operational Taxonomic Units (OTU's) based on obvious differences in morphological features. Each OTU was given an alphanumeric code that corresponds to the taxonomic classification of each OTU. Each code consists of two characters for the classification levels of order, family, genus, and species. If known, the first two letters of the taxonomic name for each level were used for the code. Numeric characters were used if the level names were not known. For example, the code for the grasshopper *Trimerotropis*

pallidipennis is: ORACTRPA, from Order: Orthoptera, Family: Acrididae, Genus: *Trimerotropis*, and Species: *pallidipennis*. The code for an unidentified genus and species of wolf spider would be: ARLY0101, from Order: Aranea, Family Lycosidae, Genus: 01, and Species: 01. Note that many of the initial OTU designations are tentative, and will need to be confirmed by taxonomic experts.

Taxonomic classification of insects to the order and family level corresponds to Arnett, 1985 (American insects: A handbook of the insects of America north of Mexico. Van Nostrand Reinhold Co., New York, NY). Taxonomic classification of non-insect arthropods to the class, order and family levels, corresponds to Borror, De Long and Triplehorn, 1981 (An introduction to the study of insects, 5th. edition. Saunders College Publ., Philadelphia, PA).

All pitfall trap data were recorded in two types of data books. One book, "Arthropod Taxa Code Listings," is a listing of all OTU codes and corresponding taxonomic names, if known. The other books, "Pitfall Trap Data," contain records of all OTU's and numbers of individuals from each pitfall trap.

Data from the "Pitfall Trap Data" and the "Arthropod Taxa Code Listings" books were entered into computer database files. Data were initially entered as Quattro Pro v.3 spreadsheet files on an MS-DOS based computer. Quattro Pro provides excellent data entry and data matrix manipulation capabilities. These files may be readily converted into ASCII format, and then imported into other hardware and software environments for the Sevilleta Information Management System (SIMS) or the National Biological Service databases.

Summary statistics were produced by data analysis with SAS (Statistical Analysis Systems) on the SIMS UNIX system. Repeated measures analysis of variance were performed for ant data to test for differences in ant abundance between the different mixed conifer sites, and over time.

Analysis of ground-dwelling arthropods for this report focused on the those taxonomic groups that contributed the greatest numbers of individuals and species of ground-dwelling arthropods in traps. Arthropod groups chosen for analysis were also those groups that can be relatively easily identified to the species level. Those groups included spiders (Arachnida: Araneae), bristletails (Thysanura: Microcoryphia), crickets (Orthoptera: Gryllidae and Gryllacrididae), darkling beetles (Coleoptera: Tenebrionidae), and ground beetles (Coleoptera: Carabidae). A detailed analysis of ants from the mixed-conifer sites was also done in an effort to provide comparisons of the ant faunas of all mixed conifer sites in anticipation of future prescribed burns that will be used to examine the effects of forest fire on the Jemez Mountain salamander, and the ants which are an important food resource for the salamanders.

Arthropod data from 1994 is also compared to data from 1992 and 1993, to begin examining long-term trends in surface active arthropod populations across the elevation gradient at Bandelier National Monument. Precipitation data obtained from a high elevation weather

station (Quezamon Snotel), and from a low elevation weather station (Fire Tower) are used to compare precipitation amounts to the arthropod data over time.

In order to make meaningful interpretations of arthropod abundances over time, the bi-monthly collection samples were pooled into three principal seasons that correspond to natural seasonal weather patterns, arthropod activity periods, and actual trap collection times. The three seasons chosen were 1) spring, which includes winter and spring. The spring sampling period included late November or early December samples from the previous year, to late April or early May samples of the current year. The spring sampling season includes winter because traps from the mixed conifer sites are typically not sampled for this entire time period because of snow on the ground. 2) summer, which included late May or early June through late August or early September. 3) autumn, which included mid-late September through mid-November samples. Note that arthropod sampling in the low-elevation pinyon/juniper zone and the high-elevation mixed-conifer zone began in the summer of 1992. Arthropod sampling in the mid-elevation ponderosa pine zone did not begin until the summer of 1993. Monthly precipitation totals were summed over the same seasonal periods as arthropod trap collections for comparison.

Results and Discussion

Accomplishments in 1994-1995

All arthropod pitfall trap samples collected during the spring, summer, and autumn of 1994 were sorted, and count data for all taxa tabulated in data books. Additional voucher specimens were added to the reference collection as needed. All data tabulated in data books were entered into a spread-sheet computer database file and error checked. The database file was transferred to the Sevilleta Information Management System UNIX computer. Summary and statistical analyses were performed on the data using SAS statistical software. The results of those analyses are given below. The raw tabulated arthropod count data are presented on hard-copy in Appendix 2 (data file name: BNDEBUG94.DAT), and provided on a computer disk in ASCII format, which is enclosed with this report. A separate data file for ants from 1993 at the mixed-conifer sites (data file name: BNDANT93.DAT) is also provided on hard copy (Appendix 2) and on a computer disk in ASCII format. Ant data for 1994 samples are included in the 1994 arthropod pitfall trap data file (BNDEBUG94.DAT).

Rainfall Data: 1992-1994

Examination of precipitation data from the high-elevation Quemazon Snotel, and the low-elevation Fire Tower weather stations (Figures 1 & 2) reveals that overall precipitation was greatest at the higher elevations, and that most of the precipitation tended to fall during the summer seasons at both elevations. 1992 and 1993 were El Nino years, with higher than average spring precipitation in New Mexico, and at both of the Bandelier weather stations. 1992 Summer and 1993 winter/spring precipitation were greater during 1992 and 1993 than the long-term average at the high elevation station, but 1993 summer precipitation was lower than the long term average. 1992 precipitation was lower than the long-term average at the low-elevation weather station. 1993 spring and summer precipitation were considerably greater than the long-term average at the low-elevation site. 1994 precipitation was close to the long term average at the high-elevation station, and below average for the low elevation station (except for autumn). These figures reveal that the high and low elevations at Bandelier not only received different total amounts of annual rainfall, but also that seasonal patterns were not consistent between high and low elevation sites.

Ground-Dwelling Arthropods

Total arthropod abundances (all individuals of all target arthropod groups) varied considerably among the three elevation zones, and between seasons and years (Figure 3). The greatest arthropod abundances were typically from the pinyon/juniper sites during the summer period. The high-elevation mixed-conifer sites tended to support the second greatest abundances, and the mid-elevation ponderosa pine sites supported the lowest arthropod abundances. Across all elevation zones, arthropod abundances were greatest during the summer period, and lowest in the winter/spring period. Overall abundances were higher in 1992 and 1993 than in 1994.

Total arthropod species richness showed similar patterns to abundance (Figure 4). In general the pinyon/juniper zone supported the greatest number of species. Species richness in the pinyon/juniper zone was especially high in the summer of 1992, an El Nino year with high rainfall. However, during the summer of 1993, species richness was low among traps in the pinyon/juniper zone, and highest from traps in the mixed-conifer zone. Species richness patterns remained relatively constant over the years, changing less than individual abundances.

Spiders were very abundant in traps in the pinyon/juniper zone during the summer of 1992, and then dropped off in abundance through 1993 and 1994 (Figure 5). Starting in autumn of 1992, spider abundance has been consistently highest in the mixed-conifer zone, and lowest in the pinyon/juniper zone. Spider abundance was highest during the summer seasons. The most abundant spider species were several as yet unidentified species of wolf spiders (Lycosidae: *Lycosa*, *Schizocosa*, *Pardosa*, and *Varacosa* spp.), and several wandering spiders (Gnaphosidae: *Drassyllus*, *Geryllus*, *Micaria*, and *Zelotes* spp.).

Bristletails were very abundant detritivores (averaging near 100 per trap), but found almost exclusively in the pinyon/juniper zone, and primarily only during the summer period (Figure 6). Some individuals were collected in pitfall traps at the mid-elevation ponderosa pine zone, but bristletails are clearly most prevalent in the low-elevation pinyon/juniper zone. *Machilinus aurdntidcus* was the common species of bristletail.

Crickets were most abundant in the pinyon/juniper zone in 1992, but from 1993 through 1994 were most abundant in the mixed-conifer zone, followed by the ponderosa pine zone, and least abundant in the pinyon/juniper zone (Figure 7). The dominant cricket species in the pinyon/juniper zone were the camel crickets *Ceuthophilus utahensis* and *Ceuthophilus pallidus*, and the field cricket *Gryllus* sp. (undescribed taxon). The dominant cricket species at all elevation zones was the camel cricket *Ceuthophilus utahensis*. The increase in cricket abundances at all elevation zones in 1993 and 1994 resulted from an increase in the abundance of *Ceuthophilus utahensis*.

Darkling beetles are a major group of detritivores, and were prevalent in the pinyon/juniper, but not ponderosa pine or mixed-conifer zones (Figure 8). Darkling beetles were particularly abundant in the pinyon/juniper zone during the summer of 1992, then declined to lower abundances in 1993 and 1994. The dominant species of darkling beetles in the pinyon/juniper zone were *Eleodes extricatus*, *Eleodes obscurus*, and *Eleodes hoppingi*.

In contrast to darkling beetles, ground beetles were abundant only in the mixed-conifer zone, and uncommon in the pinyon/juniper and ponderosa pine zones (Figure 9). Ground beetle abundances varied seasonally from being highest during the summer of 1992, to being highest in the autumn of 1993, then highest again in the summer of 1994. Ground beetle abundances were high during the summer-autumn of 1992 and 1993, then dropped off during the same seasons in 1994. The most abundant species of ground beetles were *Pterostichus luscus*, *Pterostichus adstrictes*, *Cymindis cribricollis*, *Cymindus puvctigera*, *Carabus taedatus*, and *Rhadine umbra*.

More detailed analysis of individual species abundance patterns across the three elevation zones and over time are presented here for the crickets and darkling beetles to illustrate differences in habitat preferences and changes in abundances over time for species within a group.

Ceuthophilus utahensis was by far the most abundant cricket found at all sites, but is clearly most abundant at the high-elevation mixed-conifer sites, and becoming less abundant at the ponderosa, and pinyon/juniper sites (Figure 10). At all sites, *Ceuthophilus utahensis* showed a great increase in abundance in 1993.

Ceuthophilus pallidus was less common, and restricted to the pinyon/juniper zone (Figure 11). *Ceuthophilus pallidus* was common in 1992, but declined to no captures in 1993 and 1994, an opposite trend to that seen in *Ceuthophilus utahensis*.

Gryllus sp. (undescribed) showed the opposite elevation distribution pattern to *Ceuthophilus utahensis*, being most common at low-elevation pinyon/juniper sites, less common at mid-elevation ponderosa pine sites, and absent from high elevation mixed-conifer sites (Figure 12). *Gryllus* also showed opposite trends in abundance over time to *Ceuthophilus utahensis*, declining since 1992.

The most abundant darkling beetle was *Eleodes extricatus*, which was most abundant at the low elevation pinyon/juniper sites, but also found at the mid-elevation ponderosa pine and high-elevation mixed-conifer sites (Figure 13). *Eleodes extricatus* showed an overall decline in abundance from 1992 to 1994.

Eleodes obsoletus was common but restricted to the low-elevation pinyon/juniper zone (Figure 14). *Eleodes obsoletus* abundances were relatively stable from 1992-1994.

Eleodes hoppingi was found at all elevations, but clearly most abundant at the low-elevation pinyon/juniper sites (Figure 15). Unlike *Eleodes extricatus*, *Eleodes hoppingi* increased in abundance from 1992 to 1994.

Ant Abundance at the Mixed-Conifer Sites

The abundances of ants among the five mixed-conifer sites showed consistent differences among the sites over the two years (Figure 16). An unusually high number of ants from the spring of 1994 at site D resulted from several hundred ants, apparently from one colony, in one pitfall trap. Ant abundance was consistently highest at sites B and D, and relatively similar among the other sites. Repeated measures analysis of variance of log-transformed count data was used to test the null hypotheses that 1) there were no differences in ant abundances among the six sites, and 2) that there were no differences in ant abundances across the six sites over time. Results of repeated measures analysis of variance revealed that the numbers of ants were significantly different among sites, and that abundances changed significantly over time.

One-way analysis of variance tests were used to compare the six sites at each season/year. In the summer of 1993, there were no significant differences in ant abundances across the six sites. In autumn of 1993, ant abundances were not significantly different among sites D, B, F, and E, and sites A, C, E, F, and B were not significantly different from each other; traps at site D had significantly more ants than sites A and C. In spring of 1994, ant abundances at sites D, C, and A were not significantly different, and sites C, A, E, B, and F were not significantly different from each other; traps at site D had significantly more ants than sites E, B, and F. In summer of 1994, sites D, B, A, C, and E were not significantly different, and sites F, E, C, A, and B were not significantly different from each other; traps at site D had significantly more ants than traps at site F. In autumn of 1994, sites D, B, E, and F were not significantly different, sites A and C were

not significantly different, and sites E, F, and C were not significantly different from each other; traps from sites D and B had significantly more ants than site A.

In summary, traps from site D consistently had more ants than traps from any of the other sites, and patterns of ant abundance among the other five sites varied through time. The proposed prescribe burn site F, was consistently most similar to site E in terms of numbers of ants/trap, and was also similar to sites A and C. Site D consistently had significantly higher numbers of ants than site F, and site B often had significantly higher numbers of ants than site F.

The most abundant ant species at all sites were *Camponotus laevis*, *Formica densiventris*, and *Formica neogagates*.

Summary and Conclusions

Three years of pitfall trap data from sites at three different elevations/forest types, revealed distinct arthropod abundance and species distribution patterns. Different arthropod groups were typically most abundant at one elevation zone, generally dominated by one or several common species at that zone. Typically, each group was represented by several less common species that occurred in other elevation zones. Annual differences in abundance patterns were pronounced. In general, abundances of most arthropods were greatest in 1992 and 1993, corresponding to El Nino years and increased precipitation. Seasonally, arthropod abundance was highest during the summer period, and some groups and species were distinctly limited to a certain season.

The above patterns demonstrate that ground-dwelling arthropods at Bandelier National Monument provide an excellent group of organisms to monitor for examining patterns of change in species composition and abundance relative to climate change. Shifts in annual abundances, seasonal abundances, and changes in abundances of individual species across an elevation gradient can all be used as indicators of climate change. Predictive models of temporal and elevation abundance shifts can be tested using long-term monitoring data for ground-dwelling arthropods.

Appendix 1. Map locations of plots or webs and pitfall trap lines at the pinon/juniper, ponderosa pine, and mixed-conifer sites, and a map showing locations of weather stations relative to study sites. See following pages.

Appendix 2. Bandelier arthropod pitfall trap data file (BNDBUG94.DAT), and 1993 ant data file (BNDANT93.DAT). These printed copies of the data files were generated by SAS. See following pages.