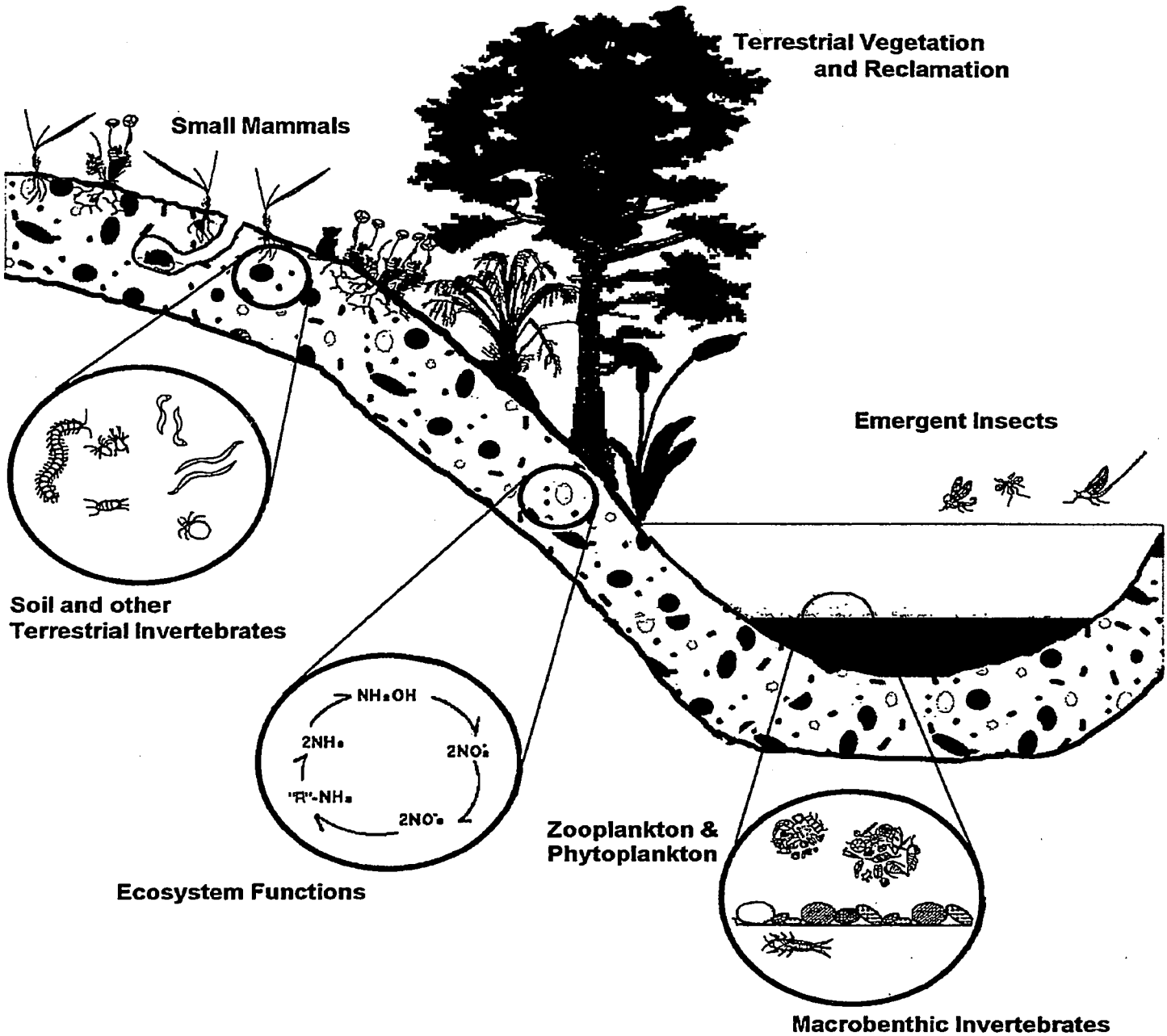
Rocky Flats Environmental Technology Site
Ecological Monitoring Program
1995 Annual Report



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EXECUTIVE SUMMARY

The Ecological Monitoring Program (EcMP) was established at the Rocky Flats Environmental Technology Site (Site) in September, 1992. At that time, EcMP staff developed a Program Plan that was peer-reviewed by scientists from western universities before submittal to DOE RFFO in January, 1993.

The intent of the program is to measure several quantitative variables at different ecological scales in order to characterize the Rocky Flats ecosystem. This information is necessary to document ecological conditions at the Site in impacted and nonimpacted areas to determine if Site practices have had ecological impacts, either positive or negative. This information can be used by managers interested in future use scenarios and CERCLA activities. Others interested in impact analysis may also find the information useful. In addition, these measurements are entered into a database which will serve as a long-term information repository that will document long-term trends and potential future changes to the Site, both natural and anthropogenic.

Because ecological data may be extremely variable, it is often difficult to determine departures from "normal" or "natural" conditions from those that may be due to various activities at the Site. Every effort has been made to summarize the range and variability associated with important ecological variables to enhance their utility in as many practical situations as possible. Managers needing quick information on representative sites and community types will be able to refer to tables presented in this document.

All terrestrial sampling (ecosystem functions, terrestrial vegetation, small mammals, soil invertebrates, and terrestrial arthropods) has been based on the designation of four community groups or types: xeric mixed grasslands, mesic mixed grasslands, reclaimed grasslands, and riparian complexes. Aquatic sampling has been based on individual sampling units of ponds, streams, and seeps after earlier data analyses showed that variability in measurements prevented grouping of sample units into broader types. Staff are continually refining ideas of community types and variability within types; this has particular relevance in the selection of proper reference areas for comparison to impacted sites.

The majority of the terrestrial sampling has taken place at twelve sites in the four community types mentioned above. These sites are in nonimpacted areas and will serve to provide baseline ecological information needed for ecological risk assessments, determination of Natural Resource Damage injuries, and guidance for future use. Other terrestrial areas sampled were in Operable Unit 11, to support the Environmental Evaluation conducted there. Aquatic sites sampled include a variety of nonimpacted and impacted Site ponds and streams, and offsite stream areas.

Ecological Monitoring Program staff completed the second year of data collection at the Site in September, 1994. This report includes analyses and interpretation of these data, as well as selected data collected in 1993 that were not available until recently. The majority of these data were collected from sites in the Buffer Zone, although 1993 activities in Operable Unit 11 are also reported in a separate appendix. Data were collected from the following technical modules: ecosystem functions, terrestrial vegetation, small mammals, aquatic ecology, soil invertebrates, reclamation monitoring, and terrestrial arthropods. Collectively, these technical areas represent population, community, and ecosystem levels of ecological organization at Rocky Flats and provide "the big picture" of the ecological health of the site. Each of these modules is briefly summarized in the following paragraphs.

Ecosystem functions were measured at three sites in each of the four community types. None of the sites are known to have been contaminated or otherwise disturbed. Of the variables measured, microbial biomass, potential respiration, potential nitrogen mineralization, and fine particulate organic matter are of most interest. Total soil organic carbon and nitrogen were measured on each sample so that differences in soil organic matter quality as well as concentrations could be estimated. The most obvious finding for total organic matter and microbial biomass concentrations was that differences between sites exceeded the differences between communities. The same was true for respirable carbon. Mineralizable nitrogen concentrations were the highest in xeric community types and lowest in reclaimed types. The fraction of

total organic carbon in microbial biomass was lowest in xeric, but highest in reclaimed community types. In contrast, the fraction of total organic nitrogen in mineralizable forms was similar among undisturbed sites, but was much lower in the reclaimed community. Reclaimed community sites had microbial biomass concentrations similar to all other sites, even though total carbon concentrations were lower. That biomass was, however, much less able to mineralize organic nitrogen. It appears that these measurements provide a very sensitive indication of ecosystem disturbance. Perhaps they will be sensitive enough to allow clear demonstrations that no effects have accrued from contamination or disturbances in unaffected areas; a concept which has been very difficult to establish to the regulators' satisfaction.

During 1994, EcMP personnel measured terrestrial vegetation parameters at 12 permanent monitoring sites. Species richness and cover were measured using belt transects and point-intercept transects at 60 permanent transects (5 transects per site). In addition, biomass production was measured in 225 production plots at 45 transects at all 9 of the grassland sites. A total of 271 species in 51 families and 73 genera were recorded from the EcMP sites. Species richness increased along the hydrologic gradient from xeric (dry), to mesic (moderate), to riparian (wet) communities (excluding reclaimed). Significant differences were found in the percent cover for different cover classes and biomass amounts between sites and between communities. Plant associations were determined for sites based on basal vegetation cover. Results of ordination and classification analyses based on species presence/absence data revealed differences in the community types studied by EcMP staff. The success of these analyses in distinguishing differences between the EcMP sites demonstrated the applicability of the analyses to remediation and revegetation efforts on Site.

Small mammal populations were monitored at the 12 permanent terrestrial sites during 2 trapping sessions: one in the spring and one in the fall. Four-hundred and twenty-three individuals of 9 species were recorded during the spring session and 661 individuals of 11 species were recorded during the fall session. Two new species were documented for the Site, the Plains Pocket Mouse (*Perognathus flavescens*) and the House Mouse (*Mus musculus*). The Deer Mouse (*Peromyscus maniculatus*) was the most common small mammal in all habitat types and during both trapping sessions. The highest small mammal populations were recorded in riparian complex communities and the lowest populations were recorded in reclaimed communities. Habitat characterization of successful and unsuccessful trap sites was conducted to determine habitat preferences of the Site's small mammal populations. Habitat data were collected at 233 trap stations. A special study designed to determine the status of the Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) was conducted during the summer of 1994 in areas that this mouse is most likely to occupy. Thirty-four captures of 23 individuals were recorded during this effort.

Biotic analyses of aquatic communities revealed that there is much inter- as well as intra-community variability in Site ponds and streams. Variation in the numbers and kinds of biological receptors is due not only to the presence/absence of contaminants, but also to the "natural" biological/physical conditions at each site. No group of ponds shared more than 45% of any of the biota sampled (zooplankton, phytoplankton, macrobenthic invertebrates, emergent insects), indicating that these systems are so biologically diverse that the selection of reference sites must be done on a case-by-case basis. The most biologically diverse OU site for overall biotic community composition is Pond A-2 (mean of 57.4 biotic taxa sampled). The most diverse reference (unimpacted) site is Pond D-2 (mean of 53 biotic taxa). Biological data summaries are now available for all Site ponds, as well as selected offsite stream areas.

Analysis of soil invertebrates showed that reclaimed grassland and riparian vegetation community types have distinct populations of selected soil invertebrate groups and that these community types can be distinguished from other community types at the Site. Thus, if similar communities are suspected of being injured by activities at the Site, a biological baseline of a sensitive invertebrate receptor can be used to determine if injury and damage have occurred. Other grassland community types were difficult to distinguish using these methods, but future analyses and new sampling techniques may elucidate additional community differences.

Revegetation efforts on the 881 Hillside (Hillside) were monitored by EcMP personnel in late fall of 1994. The results reveal that the success of the revegetation effort thus far has been poor. Of the 13 species seeded on the Hillside, only six were recorded during the 1994 sampling and these provide only 3.5% of the cover on the Hillside. The Hillside is dominated by non-native, annual species and 63% of the species recorded there are considered "weeds." Vegetation cover, although having increased from 1993, is still less than half that found in reference areas on the Site. The significance of the problem should not be underestimated. With no action, the domination of the Hillside by non-native, annual species will continue to persist and provides the potential to spread throughout the Woman Creek drainage, downstream and downwind. Other studies have shown that the competitive influences of plant communities dominated by annual species prevent the reestablishment of native plant communities and often lead to lower quality watersheds by increasing the potential for erosion and typically increasing the frequency of wildfires. It is recommended that additional reseeding of the Hillside be commenced as soon as possible with a seed mixture of native, perennial grass and forb species like those found in the reference areas of the mesic grassland community at the Site.

Terrestrial arthropod communities were sampled for the first time under EcMP in August 1994. The objective of this module is to characterize the diversity and biomass of above-ground arthropods. Arthropods were collected from all 12 permanent monitoring sites along vegetation transects using a variety of methods. Results of taxonomic analyses measuring taxon richness and abundance are expected from the laboratory subcontractor after the delivery of this report. Biomass was inadequate as a measurement endpoint due to the dry weather of the 1994 summer. Three sampling sessions are planned for the spring and summer of 1995.

The EcMP Database has been designed and developed as a tool for entering, assuring the quality of, and storing data collected under the EcMP. Database development began with the objective of capturing the data collected for the terrestrial vegetation module. The database was initially designed and created in the spring of 1993 and was extensively revised and updated in summer and fall of 1994 to increase efficiency and accommodate other EcMP modules. The revised code uses approximately 13% of the disk space that the original code occupied and is composed of about 100 fewer files. Ecology and Watershed Management (EWM) was asked by the Environmental Restoration Program Division (ERPD) in October, 1994 to create a Sitewide Ecological Database (SED) for the Site. The purpose of the SED is to support environmental management and remediation efforts for the Site. The SED is expected to be complete by August, 1995.

PROGRAM/TECHNICAL SUMMARY

INTRODUCTION

The Ecological Monitoring Program (EcMP) finished the second full year of data collection at the close of 1994, and this report contains analyses and interpretations of those data.

The program was established for a variety of reasons, some of which are:

- to collect, analyze, and interpret baseline ecological data against which changes can be measured;
- to describe and better understand Site natural resources so that informed management decisions can be made;
- to assess potential impacts to ecological receptors, and;
- to provide biological/ecological expertise on special projects.

Terrestrial sampling occurred at 12 permanent sites, where observational data were recorded and soil, vegetation, invertebrate, and other biotic samples were collected and sent to laboratories for analysis (see Figure 1).

Aquatic sampling occurred at a variety of Rocky Flats Technology Site (Site) pond and stream habitats, and a few offsite locations (Figure 2 and 2A). Water and a variety of biota samples were collected from these areas and shipped to laboratories for analysis.

In addition to the monitoring activities described above, EcMP personnel were involved in a number of special projects. These are briefly described below.

- Extensive trapping surveys for the Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) (PMJM), were conducted on the Site. This animal is a Colorado species of special concern, for which a petition has been submitted to the U.S. Fish and Wildlife Service to list the species under the Endangered Species Act. Traps were placed at riparian sites which were believed to contain good PMJM habitat as well as at sites where PMJM had been captured historically. Prior to the onset of this study, it was believed that the Western Jumping Mouse (*Zapus princeps*) also occupied the drainages within Rocky Flats. However, after study of two specimens collected from the Site (one assigned to *Z.h. preblei* and the other to *Z. princeps*), it was determined that both specimens should be assigned to *Z.h. preblei*. Additionally, only PMJM were trapped at the Site during 1994. All sites where a PMJM had been captured onsite, both prior to and during 1994, were characterized in order to obtain an understanding of PMJM habitat requirements.
- An EcMP team member assisted in the development of a current vegetation map utilizing multispectral imagery data. Previous vegetation maps were developed several years ago and are no longer accurate. An effort was made to assign a vegetation classification scheme to the images. It was determined that either color resolution was not high enough in the imagery for discriminating general habitat types or the combined images were too complex to be of use without more colors for resolution.
- Information was provided to the Safety Analysis group on metal contents of Rocky Flats vegetation and litter. This information was needed to estimate airborne releases of these metals in the event of a wildfire at the Site.

The goal of complete internalization of field work was achieved during 1994. All 1994 EcMP field data were collected by the following personnel:

Mark Bakeman, Ph.D, Soil edaphic relations, nutrient cycling; M.S., Forest Science; B.S. Resource Management
Mark D'Agostino, B.S., Forestry
Alison Deans, M.S., Mineral Resources Ecology; B.A., Environmental, Population, and Organismic Biology and Geological Sciences
Michelle Fink, M.S., Ecology (landscape speciality); B.S., Wildlife Biology
William Freeman, M.S., Biology; B.S., Biology
June Haines, M.S., Natural Science, B.S., Botany, A.A., Math Education
Fred Harrington, Ph.D, Wildlife Biology; M.S.,Natural Resource Administration; B.S., Wildlife Biology
Jody Nelson, M.A., Biology; B.A., Biology; A.A., Photography
Tom Ryon, M.S., Environmental Science (in progress); B.S., Wildlife Biology
Lawrence Woods, Certified Sr. Ecologist, Ph.D, Soil Ecology; M.S., Soil Science; B.S., Biology

Additionally, some staff were matrixed in on an as-needed basis:

Marcia Murdock, M.A., Zoology and Botany

Frank Vertucci, Certified Sr. Ecologist, Ph.D, Aquatic Ecology; M.S., Soil Science; B.S., Biology and Science Education

Not all data used in the EcMP were generated from field work. Some modules required the services of offsite laboratories to provide the data presented in this document. These laboratories are:

- Natural Resource Ecology Laboratory, Colorado State University, Ecosystem Functions
- SECA Inc., University of Northern Colorado, Soil Invertebrates
- Global Geochemistry, Water Chemistry
- Ecosystem Testing and Design, Aquatic Biology
- Entomology Department, Colorado State University, Terrestrial Arthropods

Each of the technical modules has been briefly summarized in the following pages to provide an outline on module activities and accomplishments. The Appendices which follow this section contain detailed module information for readers desiring a more complete explanation of technical activities. References cited in the following paragraphs may be found in the corresponding Appendix.

A) ECOSYSTEM FUNCTIONS

Ecosystems comprise biotic (individuals, populations and communities) and abiotic (soil minerals, water, soil organic matter) components. Ecosystem studies generally discuss either biotic components or ecosystem processes, but not both. Ecosystem processes, called functions in this report, include energy transformations, nutrient cycling, soil development and organic matter turnover. Ecosystem functions are included in the EcMP to balance the population and community approaches of the other modules and because processes can be sensitive indicators of subtle changes not reflected in populations and communities. Ecosystem functions also integrate all the changes in individuals, populations and communities because every individual participates in some way in each process.

Objectives for this study are to establish baseline concentrations for undisturbed areas, to describe natural differences between biotic communities, locations, seasons and years, and to provide benchmarks to assess revegetated areas when remediation and restoration are completed. A related goal is to evaluate the potential of ecosystem function measurements, which are inexpensive and sensitive, to be indicators of ecosystem health.

Other EcMP modules measure populations, communities and selected abiotic factors. Responses to perturbations, either natural or anthropogenic, must be evaluated consistent with their normal variations in time and space. We believe that these ecosystem-level measurements, together with concurrent studies at lower levels of organization, will allow us to interpret ecological patterns at RFETS.

The 12 EcMP permanent sites (TR01-TR12) were sampled. One sample was collected at each of five permanent transects within each site. Each sample consisted of five subsamples.

Results presented in this report include particle size distribution, total organic carbon (C) and nitrogen (N), microbial biomass carbon and nitrogen, potentially mineralizable carbon and nitrogen, fine particulate organic carbon and nitrogen, and some associated abiotic parameters. Results obtained, but not yet completely analyzed, included estimates of denitrification, dinitrogen fixation and rates of carbon dioxide and methane production under both anaerobic and aerobic incubation.

All data represent the top 10 cm (4 inches) of soil only. Characteristics of deeper soil layers are important to plant growth, water and soluble contaminant movement and other aspects of ecosystem processes. Nevertheless, attention is focussed where most of the soil organic matter is found, and where most of the N mineralization, soil respiration, decomposition and other biological processing are concentrated. Most contaminants, where they are of concern, are spilled on the soil surface. Knowledge of populations, microbial biomass and processes in the surface soil layer is essential to monitoring any ecosystem.

Soil texture (particle size distribution of the particles smaller than 2 mm) controls many ecosystem functions: plant growth, organic matter decomposition, microbial biomass, soil respiration. Soil texture tended to become finer moving from xeric to mesic to riparian to reclaimed sites. This trend also moves downslope and away from the mountains. All of the soils contained a significant volume of coarse fragments. Because these fragments prevented measurement of bulk densities, only the most general extrapolations from concentration to unit area can be made.

Soil organic C and N are the largest reservoirs of C and N in any ecosystem. These measurements include all of the active pools and the less-active organic matter. Rough calculations suggest that soil organic C ranges from 20 Mg per hectare (10 tons per acre) in riparian sites to 50 Mg per hectare (25 tons per acre) in xeric sites. Soil organic N ranges from 2000 kg per hectare (1 ton per acre) to 5000 kg per hectare (2.5 tons per acre). This is sufficient organic matter to sustain healthy ecosystem functions in all communities and to provide the nutrients for the plant community. Often, there were greater differences between sites or between watersheds than between communities. Spatial heterogeneity between field sites is substantial, but was not explicitly addressed by the current sampling design.

Microbial biomass C and N concentrations also reflected spatial heterogeneity. In xeric sites, the differences between Walnut Creek and Rock Creek were greater than any differences between communities in any watershed, or between average concentrations of any two communities. On average, based on rough estimates of bulk density, the top 10 cm of soil contained about 2000 kg per hectare (1 ton per acre) of microbial biomass. These sites were chosen to avoid any potential effects from Site activities. Individual locations can be quite different from each other, but all EcMP sites appear to contain healthy amounts of microbial biomass.

Potential C and N mineralization were measured in the laboratory after a 1-week preincubation. Like total organic C and N concentrations, respirable C concentrations varied substantially between sites. Communities in Walnut Creek differed more from each other than those in Rock Creek. Communities were most similar to each other in Woman Creek. Average mineralizable N concentrations were higher in Rock Creek than in Walnut Creek because of spatial heterogeneity. Xeric sites had higher concentrations of mineralizable N than mesic or riparian sites. Mineralizable N concentrations, but not respirable C concentrations were much lower in reclaimed sites. Reclaimed sites appear to have qualitatively different soil organic matter even after 20 years in grass.

Fine particulate organic C and N are the total organic C and N in sand-sized particles. Sand-sized particles are larger than 53 μm but smaller than 2 mm. This part of the soil organic matter is thought to be quite decomposable. Differences between communities and between native soil and previously farmed soil (reclaimed) might be principally in this size fraction. Our results show than xeric sites had the highest concentrations and reclaimed sites had the lowest, but differences were not dramatic. These data also show a high degree of spatial heterogeneity.

To find out if differences in concentrations of active organic matter represented qualitative differences, active fractions of total organic C and N were calculated. The only active fraction that had a community-by-watershed interaction effect significant at less than $\alpha=0.05$ was Respirable C. This interaction resulted from Walnut Creek riparian sites having more total organic C in respirable C fractions than any other community in any other watershed, except mesic sites in Woman Creek.

Communities differed from each other significantly in the fractions of their organic matter that occurred as microbial biomass C, but not microbial biomass N; and in mineralizable N, but not respirable C. Watersheds differed significantly in the fractions of their organic matter that occurred as microbial biomass C and N; and in respirable C, but not mineralizable N. The biological significance of the statistically significant differences between watersheds is not clear. They apparently resulted from inherent spatial variability.

Organic matter in reclaimed soil might be qualitatively different from soil in the other treatments, although it has been a grassland for 20 years. A larger fraction of its total organic C is found in microbial biomass, but a smaller fraction is in fine particulate organic matter. A smaller fraction of the total N was mineralized in laboratory incubations in reclaimed sites than in any other sites.

Reclaimed sites were probably similar to the mesic grassland sites before they were plowed and planted to small grains. They have similar slope positions, aspect and general soil properties. If the soils were initially similar, they were fundamentally changed by agricultural activities and have not returned to their original state after 20 years in grass. The changes apparently do not reduce the ability of the ecosystem to support plant and animal life or to prevent wind and water erosion.

It is encouraging to think that these measurements can provide a very sensitive indication of ecosystem disturbance. Perhaps they will be sensitive enough to allow clear demonstrations of no effects from disturbances or contaminants. This has been a very difficult thing to establish for relatively clean sites, which are common at the Site.

B) TERRESTRIAL VEGETATION

The diversity of plant communities associated with the Site are a result of the ecotonal effect found along the Front Range of Colorado. The mixing of prairie and foothills species in the diverse habitats provided by the varied physical environment has resulted in a vegetational mosaic which is rapidly disappearing as human encroachment along the Front Range continues.

Plant distribution, composition, and abundance are influenced by many environmental factors. Local climate, topography, and geology affect abiotic factors such as light, temperature, moisture, and nutrients, which in turn directly affect plant growth. In addition, biotic factors such as competition, herbivory, availability of pollinators, and nitrogen fixation by bacteria, interact with the abiotic factors to create habitats. Plant survival in these habitats depends upon the availability of natural resources necessary for them to grow and reproduce. The spatial and temporal variation of biotic and abiotic factors found at the Site allow for the diversity of distinct plant communities found here. Additionally, the human impact at the Site, involving physical disturbance and/or contamination of soils and groundwater, interacts with the pre-existing biotic and abiotic factors to modify plant habitats in measurable ways.

The objective of this study is to characterize and monitor changes in the composition, distribution, and production of plant species within the major plant communities located at the Site. In addition, the information gathered can be used to assess qualitative and quantitative changes in the vegetation resulting from human activities and/or natural disturbances and processes occurring at the Site.

During the 1994 field season, EcMP personnel collected terrestrial vegetation data during two sampling sessions. The first occurred in the spring, from May 3 through May 25. The second sampling session ran from August 8 through October 4. Twelve permanent sites, each with five 50-m long permanent transects were sampled. At the riparian sites, these transects were halved, with one half on each side of the stream channel. Three different sampling methods were employed during 1994. The spring sampling consisted of only belt transect sampling for species richness at all 12 EcMP sites. For the late summer sampling, three different methods were used at the nine grassland study sites: belt transect, point-intercept transect, and production plot. This provided data on species richness, cover, and biomass production. Sampling at the three riparian sites during the late summer differed from the grasslands in that no production plot data were taken. Data were entered into electronic files and quality assured for accuracy and then reduced and analyzed.

A total of 271 plant species in 51 families and 73 genera were recorded from the 12 EcMP sites in 1994. Twenty-one previously unreported species from the Site were documented for the Site in 1994. Results showed that differences in species richness occur between the sites and communities sampled. Species richness increases along a hydrologic gradient from xeric to mesic to hydric. Associated with this increase in species richness however, is a decrease in the percentage of native species along the same hydrologic gradient. Significant differences (α=0.05 level) were found for vegetation, rock, and bare ground cover between sites. A mesic site, TR04, had the highest vegetation cover of all the sites. Significant differences (α=0.05 level) were also found for vegetation, litter, rock, and bare ground cover between communities. Vegetation cover was highest in the mesic community and least in the reclaimed community. Significant differences (α=0.05 level) were also found between sites for current year production and litter amounts. Current year production between the mesic and reclaimed communities was also found to differ significantly (α=0.05 level), with the reclaimed community having the higher mean production values. No significant differences (α=0.05 level) were found between communities for litter mass.

The xeric community had the highest native species richness and the highest biomass value produced by native species. The data also revealed that two plant associations make up the xeric community as studied by EcMP personnel. An *Andropogon scoparius* association best describes TR01 and a *Stipa comata-Bouteloua gracilis* association best describes TR06. TR12 seems to be intermediate between the two. The larger presence of Pleistocene tallgrass prairie relict species (*Andropogon scoparius,*

Andropogon gerardii, Sorghastrum nutans, Sporobolus heterolepis) found on the Rocky Flats Alluvium at the western edge of the Site suggests that there is a greater moisture availability for plant use there than on the eastern edge of the alluvial deposits. The eastern edge of the alluvium has very little of the tallgrass species and an abundance of *Yucca glauca*. The presence of the tallgrass prairie relict on the Site, which has been identified as a habitat of special concern in the state due to its rarity, warrants its protection from disturbance as much as possible.

The mesic community is more uniform than the xeric community, being predominantly an *Agropyron smithii-Bouteloua gracilis* association. Although this association is present, its quality varies considerably across the Site. Cover and biomass amounts in the mesic community have become dominated at some sites by *Bromus japonicus*, an annual cheatgrass, along with large amounts of other non-native species. Only 63% of the total biomass produced in the mesic community is from native species. The competitive influences of the non-native species present suggests that continuing study is necessary to determine if these species are expanding their ranges and displacing native species.

The reclaimed community, formerly agricultural land, is an artificial community which remains dominated by the non-native, planted perennial grasses, *Bromus inermis* and *Agropyron intermedium*. These two species account for 80-100% of the vegetation cover and 95% of the current year production biomass at these sites. The reclaimed community has the least amount of basal vegetation cover of all the communities studied. Attempts could be made to convert this community back to a more native, mesic mixed grassland by seeding with native species or to evaluate successional trends.

The riparian community is the only community with any real vertical stratification monitored at the Site. The canopy is primarily *Populus deltoides-Salix amygdaloides* with a shrub layer of *Salix exigua* and *Amorpha fruiticosa*. The herbaceous layer is primarily *Juncus balticus*, with locally high amounts of *Carex nebraskensis* and *Poa pratensis*. It has the highest species richness of all the communities, but also has the lowest percentage of native species (excluding the reclaimed community).

Results of the ordinations and classification analyses based on species presence/absence data, reveal differences in the community types studied by EcMP. The individual communities were shown to cluster individually. Variations within the communities were also detected. Most noticeably was the association of TR06 (a xeric site) with the mesic community. The success of these analyses in distinguishing differences between the EcMP sites, demonstrates the applicability of the analyses to remediation and revegetation efforts on Site. The analyses will be able to associate remediation areas to reference sites, providing information for remediation seed mixes and other information pertinent to successful revegetation, as well as providing continuing information on the success and progress of remediation activities.

C) SMALL MAMMALS

The primary objective of the Small Mammal study module is to assess the dynamics of small mammal populations at the Site and the relationship of these populations to specific habitat characteristics in order to determine if populations have been affected by Site activities and to provide guidelines for reclaiming sites which have been disturbed. The Small Mammal report is broken into three sections: small mammal capture, habitat characterization, and Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) (PMJM) studies (including PMJM habitat characterization). Capture information is used to determine the diversity, abundance, and distribution of small mammals at the Site. Small mammals can be good indicators of contaminants because they occupy small home ranges, live in close contact with the soil, and consume a variety of foods. They are also a primary food source for predators. Habitat characterization of successful and unsuccessful trapsites was conducted to determine habitat preferences of the Site's small mammal populations. The PMJM is a state species of special concern and a petition to list it as threatened or endangered under the Endangered Species Act was submitted to the U.S. Fish and Wildlife Service in the Fall of 1994. The PMJM study was implemented to determine if sympatry exists between

PMJM and *Zapus princeps* (Western Jumping Mouse) and to perform a status survey of PMJM on the Site.

Small mammal trapping occurred from April 19, 1994 to May 5, 1994 and from October 4, 1994 to October 20, 1994. Both sampling sessions followed the procedures presented in the EcMP Program Management/Technical Performance Report, 1993, Appendix 16, and occurred on all 12 permanent terrestrial sites. Longworth live traps were used during both sessions making the 1994 data comparable to the Fall 1993 data. The Spring 1993 data were collected from 9 of the 12 sites using Sherman live traps which do not capture as many species or as many individuals as the Longworth traps (EcMP 1994 Report). Habitat data were collected from stations where only the Deer Mouse (*Peromyscus maniculatus*) were captured and were compared to trapsites where no small mammal was captured. All data were collected by EcMP personnel. Four-hundred and twenty-three individuals of 9 species were recorded during the Spring session and 661 individuals of 11 species were recorded during the Fall session. Habitat data were collected at 233 trap stations. Two new species were documented for the Site, the Plains Pocket Mouse (*Perognathus flavescens*) and the House Mouse (*Mus musculus*). The Deer Mouse (*Peromyscus maniculatus*) was the most common small mammal in all habitat types and during both trapping sessions. It was the only species present in high enough numbers for age and sex ratio calculations. The highest small mammal populations were found in riparian community complex sites and the lowest were found at reclaimed grassland sites. Higher populations were found in the Fall than in the Spring. The difference in number of individuals captured in 1993 and 1994 was not statistically significant.

Several statistical analyses were performed on the Habitat Characterization data to determine if any statistical differences between successful and unsuccessful trap stations occurred. A variety of plant species showed an association with either successful or unsuccessful trap stations but these species had little in common and the associations appeared to be purely random. This is probably because the Deer Mouse, the only small mammal species for which habitat characterization was performed, is a generalist and is capable of exploiting nearly every habitat in the Site's Buffer Zone. Significant correlations emerged between three of the physical characteristics measured at each trap station, distance to canopy edge, slope angle and slope aspect, indicating that they may be redundant measurements.

During the summer of 1994, 34 captures of 23 PMJM individuals were recorded. All of these captures were recorded during a study which focused on capturing PMJM by placing a fairly high density of traps in areas of prime habitat. The data indicated a preference of PMJM for areas near streams which have abundant *Salix exigua* and *Symphoricarpos occidentalis* and in the vicinity of mesic mixed grassland vegetation. The data also suggest that PMJM are not discouraged by the presence of weeds such as Canadian thistle (*Cirsium arvense*) and Japanese brome (*Bromus japonicus*) and may even have an affinity toward them.

D) AQUATIC ECOLOGY

The EcMP Aquatic Ecology Module had three main objectives for the 1994 season: 1) long-term ecological monitoring, 2) bioassessment of Walnut Creek, and 3) tissue sampling for the Woman and Walnut Creek Drainages and offsite reservoirs. This section is devoted primarily to the reporting and discussion of the aquatic ecological monitoring program. Results and discussion of the bioassessment are available in Wright Water Engineers, Inc. (1995). Results and discussion of the tissue sampling study are available in EG&G (1994).

Four major biological components of aquatic systems were sampled; macrobenthic invertebrates (insect nymph and larvae), phytoplankton (algae), zooplankton (diatoms and other microscopic animals), and emergent insect (adult mayflies, mosquitoes, etc.) populations. Abundance, taxonomic composition, and taxonomic richness were the main parameters measured from each. The sampling season was from April through September, 1994. A total of 346 biological samples were taken.

For macrobenthic invertebrates overall, sites differed in the number of macrobenthic families collected regardless of sampling method ($p = 0.0001$) and no sampling method stood out from the others in capturing more or less macrobenthic families.

Analysis of phytoplankton samples shows that community composition and relative abundance of algae varies widely between ponds, even those ponds closely in series to one another. No two ponds are more than 65% alike in the composition of algal genera. Overall, Cyanophytes were the most abundant algae on the Site, making up 47.1% of the algae sampled.

There was a highly significant difference in zooplankton taxonomic richness and emergent insect taxonomic richness between sites ($p=0.0000$). Pond D-2 was significantly greater than most other sites in zooplankton richness.

In the A-Pond series, there was a statistically significant decline in macrobenthos richness from Pond A-1 (upstream) to Pond A-4 (terminal pond), as determined by the core method. This trend was not observed in any other pond series or with any other biotic community. The core method proved to be the most reliable and sensitive sampling method of several methods tested. The surber and the drift net method are both dependent on flowing water and would therefore be limited to sampling in streams. The hand-picked dip net method is designed to be a surface sweeper and would not accurately sample mud and gravel bottoms. There could be any number of reasons for the decline of macrobenthic invertebrates in the A-series ponds. Pond A-1 is partly fed by a seep that could account for a healthier aquatic environment. A limiting factor to macrobenthic invertebrate taxonomic richness may be industrial practices that progressively degrade the ponds. Further analysis of this trend is warranted.

A survey of the macrobenthic invertebrate taxa sampled from Pond D-2 showed that approximately 60% were pollution intolerant and only 30% were facultatively intolerant (EPA, 1973). A survey of the macrobenthic taxa sampled from Pond A-2 showed that equal numbers (33% each of the total taxa collected) were pollution intolerant and facultatively intolerant (EPA, 1973). A facultatively intolerant organism has inherent characteristics or demonstrates a facility for tolerance to pollutants under certain conditions such as water temperature, dissolved oxygen level or the presence of the pollutant at a particular point in the life cycle. An intolerant organism is sensitive to pollution and shows no facility to tolerate the contamination under most circumstances.

The composition and enumeration of emergent insects were studied from Site ponds. The sum of all individuals within the orders Ephemeroptera, Plecoptera, and Tricoptera was divided by the sum of individuals within the Chironomidae family to create the biotic EPT/C index. The EPT/C index was calculated for every sample taken as a representation of aquatic ecosystem health. Pond D-2 is a potential reference pond for aquatic ecological studies. It has the highest mean value for the EPT/C index (2.172) of all the ponds, which is directly correlated to the presence of all four target taxa (Ephemeroptera, Plecoptera, and Tricoptera orders and the Chironomidae family). Although D-2 does not show the highest value for macrobenthic invertebrate family richness (13.4), an analysis of the taxonomic composition of families reveals a comparatively well balanced ecosystem.

Site phytoplankton (algae) were analyzed for composition and abundance. Cyanophytes decreased in A-4, B-5, and D-1 from 1993 to 1994, while Chlorophytes increased in D-1, Chrysophytes increased in B-5, and Euglenophytes increased in A-4. Chlorophytes replaced Cyanophytes in D-1. Seasonal algal fluctuations called blooms are dependent upon nutrient availability (nitrates, phosphates) and other limiting factors such as pH, temperature and available sunlight. An increase in the frequency of sampling at different times of the growth season is necessary to understand what limiting factors are primary in seasonal taxonomic richness.

The most diverse OU site for overall biotic community composition is Pond A-2 (mean of 57.4 biotic taxa sampled). The most diverse reference site is Pond D-2 (53 biotic taxa). The least diverse OU site is B-4 (25.2 taxa). The fact that an OU site is slightly more diverse than a reference site would seem to indicate

that the effects of contamination in the OU ponds are not a major consideration. However, this is probably more a reflection of the many variables that affect biotic community composition and indicates the difficulty in determining the extent of damages to biotic communities from Site activities.

EcMP's use of the EPT/C index is to compare this metric with other indicators and to perform analyses of a composite of the Site's aquatic profile. A ranking can be derived from the ratio of the target site EPT/C index value to a reference site EPT/C value and then multiplying the ratio by 100 (EPA, 1989). To receive a top score of 6 the result must be >90%. To receive a minimum score of 3 the result must be between 70% - 90%. Any result <70% is scored 0. When using Pond D-2 as the reference site, Pond B-1 was the only pond to receive the minimum score of 3 with a ratio of 86.37% (Table D-14). Pond B-2 was only 10.13%, followed by A-1(3.6%), B-3 (0.46%), B-4 (0.32%), A-2 (0.14%) and A-3 (0.09%). To test the integrity of this method, the ratios were re-calculated by alternately using ponds A-2, B-1, and streamsite BD1 (as the designated reference site). With Pond A-2 (the most diverse pond onsite) and Pond B-1 as the reference sites, all scoring results were either 0 or non-applicable. Pond A-3 (with a 66.7% ratio) came the closest to a non-zero score when compared with A-2. When site BD2 was used as the reference site, site GW3 had a score of 3; other streamsites scored 0. This calculated ratio method was used in Wright Water Engineers (1995) bioassessment study. Results from that paper and from the above ratio calculations indicate that this ratio method is most effective as a bioassessment value when used strictly on streamsites, and not ponds. The EPT/C index value by itself seems to be a good overall indicator of aquatic ecosystem health when used in conjunction with other analyses, such as ANOVAs, T-tests, Jaccard coefficient of similarity, and Pearson's correlation coefficient. However, the use of this index to calculate a ranking value is probably not appropriate for the Site, due to the nonrepresentative status of the reference sites.

For remediation purposes, EcMP staff can provide DOE and regulatory agencies with information on the spatial and temporal variability of Rocky Flats biotic aquatic systems and how these resources will respond to present or future stressors, either natural or anthropogenic. Following remediation, monitoring efforts could focus on the aquatic community successional changes of the pond ecosystems.

E) SOIL INVERTEBRATES

Soil invertebrates are common, numerous, and massive components of terrestrial ecosystems, and play several important roles. They affect biological, chemical, and physical soil properties, primarily by their relationships with bacterial and fungal communities, litter comminution, and maintenance of soil structure (Dindal, 1990). Soil invertebrates include earthworms, mites, insects, protozoa, nematodes, flatworms, and several other forms. They range in size from microns to centimeters in length, and numbers may run from a few to millions per gram of soil. They are particularly useful organisms for biologic monitoring purposes because their abundances are relatively easy to measure, they are in intimate contact with soil particles, soil water and contaminants, and they exhibit a wide range of trophic groups that are affected by soil perturbations.

The objectives of this study included:

1) To characterize the taxa and functional groups of soil invertebrates from several terrestrial vegetation communities and determine sources of variation that affect seasonal, annual, and long- term changes in each community. This information can be used to assess the structure of invertebrate communities associated with native vegetation and anthropogenically disturbed sites. At this time, data are only available to assess differences in community structure. Annual and long-term variations will be determined as more data are collected and analyzed.

2) To determine if the Site has a unique soil fauna when compared to other offsite areas. It is anticipated that offsite data will not be collected until summer 1995, at the earliest.

3) To determine if soil faunal community structure can be correlated with other biological indices, such as ecosystem functional measurements and vegetation species diversity. In this way a conceptual model of the Rocky Flats ecosystem can be refined, and the relationships between populations, communities, and processes clarified.

Invertebrates were collected from three major taxonomic groups: protozoa, nematodes (roundworms), and arthropods.

Soil invertebrate samples were collected from 12 terrestrial sites (Figure 1) in August and September of 1993. Three-hundred forty soil invertebrate samples were collected from the 12 EcMP sites. The sampling at a single site consisted of a separate arthropod sample at two different depths and a protozoa + nematode sample at both depths; samples were composited from five transect locations on the EcMP terrestrial sites. The north and south sides of riparian areas were sampled separately because all variables measured were expected to have greater variation than grassland sites. Living organisms were extracted from samples, identified, and enumerated. Laboratory data for the 1993 session became available in late 1994 and early 1995.

Protozoa samples were identified and enumerated to three phyla or subphyla: ciliates, flagellates, and amoebae. Organisms were plated in a dilution series and enumerated by a most probable number technique.

Nematodes were dynamically extracted, enumerated, and classified into four functional groups: bacterial feeders, fungal feeders, omnivore/predators, and plant parasites.

Soil arthropods were also dynamically extracted, enumerated and identified into several functional groups and taxa divisions. Analyses were conducted primarily on the functional groups.

Statistical tests were conducted to determine if there were significant differences between invertebrate counts in: 1) terrestrial community types (mesic mixed grassland, xeric mixed grassland, reclaimed grassland, riparian north, and riparian south); 2) the EcMP sites, and; 3) the two sample depths (0-5 and 5-10 cm).

For protozoa, surface horizons are dominated by amoebae and flagellates, with mean values of 6799 and 6776 organisms g^{-1} soil, respectively (all samples). Ciliates are much less abundant, with a mean of 34 ciliates g^{-1} soil. These data are extremely variable, especially the amoebae and flagellate data, with ranges from a few dozen to values in the tens of thousands. These same general relationships hold for the subsurface horizon, except that all counts are less than the surface horizon (5126 amoebae g^{-1} soil, 5269 flagellates g^{-1} soil, and 14 ciliates g^{-1} soil, all samples).

Surface horizon mean nematode numbers were dominated by the bacterial and fungal feeder functional groups (4846 and 4264 nematodes g^{-1} soil, respectively, all samples). Mean plant parasite counts were ranked next highest (988 g^{-1} soil), followed by omnivore/predators (803 g^{-1} soil). On the average, a single gram of dry soil (0-5 cm depth) harbors approximately 10,901 nematodes. Average subsurface nematode functional group distribution follows the same general trend, except that bacterial feeder, fungal feeder, and plant parasite numbers all diminish with depth; omnivore/predator counts are relatively insensitive to depth. Subsurface means are 3848 bacterial feeders g^{-1} soil, 3147 fungal feeders g^{-1} soil, 485 omnivore/predators g^{-1} soil, and 982 plant parasites g^{-1} soil.

Surface horizon mean functional group arthropod numbers were dominated by the total fungivore group, with 3645 fungivores m^{-2}, all samples. Small detritivores (detritivore 1) were the fewest in number (mean 140 m^{-2}), but total detritivores were numerous (mean 1704 m^{-2}). Total predators were the fewest of these three functional groups (mean 874 m^{-2}), as expected. Within surface horizon mite taxa, the Prostigmata were the most numerous (mean 3209 m^{-2}), and the Astigmata the least (207 m^{-2}). These same relative

relationships hold for the subsurface horizon, but all functional group and taxa counts were fewer than the surface horizon.

Seventeen separate functional group variables were analyzed for community differences. Eleven of the 17 variables showed a significant community effect; 3 of the 11 significant variables also showed a significant depth by community interaction, so that statements regarding the main effect of community cannot be made about those three analyses. Significant community effects were found for amoebae, flagellates, and six arthropod functional groups (none of the nematode functional groups showed a significant community effect). The reclaimed grassland community type showed surprisingly high arthropod predator and herbivore means, being statistically different at the $\alpha = 0.10$ level than almost all other community types. It appears that this community type can be distinguished from all others by these variables. The riparian North community type had the highest mean protozoa counts; the flagellate riparian North type was significantly different than mesic and xeric grassland types, and the amoebae riparian North type was significantly different than the mesic type. Riparian community types were also higher for all arthropod detritivore functional group means than the other community types. The riparian South type could be distinguished from all grassland types by Detritivore 1 and Total Detritivore functional groups. Several other arthropod functional groups that did not show a statistically significant community effect also had the highest mean counts in these types (fungal feeders 1, total fungivores, and general predators). Thus, it appears that in general, riparian community types often have the highest protozoa and arthropod populations, which are statistically different in some cases from all grassland community types.

Site was explored as a factor to determine if the 12 EcMP sites could be distinguished from one another through several functional variables. Seventeen functional group analyses were conducted for these taxa; 13 showed a significant site effect at an $\alpha = 0.10$ level. This included two of the three protozoa, four of four nematode functional groups, and seven of the ten arthropod functional groups. Both Cryptostigmatid and Prostigmatid mite richness values also showed significant site differences. Protozoa showed a general site trend, with highest mean counts of amoebae and flagella in the TR05 sites (Walnut Creek), and the remaining sites clustered together. The TR05N site was significantly higher in flagellate counts than all grassland sites.

Nematode site means generally fell into two site groupings; group one consisted of a few sites that were significantly greater than all other sites, which constituted group 2. A riparian site functional group mean was always ranked as one of the greatest 3 out of 15 possible site means for the 4 functional groups, and was also ranked as one of the lowest three mean values for 3 functional groups. Omnivore/predators were the only functional group that did not have any significant differences between any of the grassland sites. For fungal feeders, TR11 (a mesic community type) was significantly greater than TR01, TR02, TR03N and S, TR07, TR10N and S, and TR12. A very similar relationship existed between TR11 and the other site means for bacterial feeders. Site TR07 mean plant parasitic nematode counts were significantly greater than most other grassland sites and two of the riparian sites as well. These data illustrate that sites within a particular community type can have significant differences in functional group counts, and that variation between sites within a community type may exceed sites between community types.

Arthropod functional groups had more consistent site differences than did nematode functional groups. Site differences were often due to one or more riparian sites that had higher mean values that were significantly different than all other sites. Arthropod predators were the only functional group that had a significant difference between grassland sites (TR07 was significantly greater than four other grassland sites).

These data have applicability for activities at the Site in several ways. The most obvious application is to determine if adverse ecological effects have occurred as a result of Site activities, such as construction, remediation, or accidental contamination. In the injury definition section of Natural Resource Damage Assessment guidelines (43 CFR 11.62), "concentrations in the soil of substances sufficient to cause a toxic response to soil invertebrates" are specifically mentioned. These data are the beginning of the baseline information that is necessary to determine if injury has occurred.

Means and 90% confidence intervals of several soil invertebrate functional group variables are available for some community types. For other community types where this resolution is not yet available, ranges and variabilities have been established that can guide interpretation of potential injury. For instance, if an area is damaged in some way where injury to ecological receptors is suspected (or claimed by Natural Resource Trustees), soil invertebrate measurements of the area may be taken. If the appropriate organism counts are below the known range of values for the Site, then injury may have occurred. If values fall within the Site range, ecologists may determine if comparisons to appropriate sites are available.

F) RECLAMATION MONITORING

Human disturbance of the landscape often results in removal of the native vegetation, either leaving the soil exposed to erosion or replaced by non-native, exotic species. This has resulted in large scale alterations to native ecosystems which were once present and often leads to the extinction of some components of localized floras. Environmental regulations and laws have become necessary to provide for revegetation of areas disturbed by mining, logging, and other activities which result in the loss of vegetation from the land. At the Site, a variety of activities occur which require remediation for disturbance and loss of the native vegetation.

The 881 Hillside is a southfacing slope in the Woman Creek watershed on the south side of the industrial complex at the Site. During 1991-1992, much of the Hillside was disturbed during the construction of the French Drain. As a result, a revegetation program was initiated to provide ground cover to stabilize the soil on the Hillside and reduce the potential for erosion. The objective of this module is to monitor the revegetation of the 881 Hillside (Hillside) since the area was disturbed by the construction of the French Drain.

During the 1994 field season, data were collected by EcMP personnel on the 881 Hillside from November 30 through December 22, 1994. Twenty-five, 50m transects placed end to end were sampled across the Hillside in an east-west direction with the transects located generally perpendicular to the slope angle. Two different types of measurements were taken at the 25 transects: species richness and basal cover. The data were entered into electronic files and reviewed for accuracy. Data reduction, analysis, and interpretation were then done to determine the effectiveness of the revegetation effort.

The success of the revegetation effort thus far has been rather dismal. Of the 13 species seeded on the Hillside, only 6 were reported during the 1994 sampling and these only provided 3.5% of the cover on the Hillside. A total of 68 species from 19 families were reported from the Hillside, however only 48% of these were native species. Annual species represented 29% of the total Hillside species richness. Basal vegetation cover was only 14%, up from 4.7% in 1993. Litter provided the greatest amount of cover (58.9%). Native species accounted for only 4.3% of the total vegetation cover on the Hillside. Annual species accounted for 91.6% of the Hillside's vegetation cover. The Hillside is dominated by two non-native, annual species - *Bromus tectorum* and *Alyssum minus*. In addition, 63% of the species found on the Hillside are considered "weeds" and six species are considered to be either prohibited or restricted noxious weed seed producers by Colorado state law.

The mesic mixed grassland which provides a reference area for comparison of the Hillside data reveals that the Hillside has less than half the vegetation cover (14%) than is found in the mesic grassland community (29%). Bare ground on the Hillside (19.4%) is 11 times that found in the mesic community (1.7%). Species richness on the Hillside (68 species) is much less than that found in the mesic community (combined richness=143 species or mean richness=102 species).

The domination of the Hillside by annual species and the lack of success of the seeded species is a significant problem not to be underestimated. If this situation is not rectified, the Hillside will act as a weed seed source, spreading weed seed potentially downstream and downwind into the Woman Creek

drainage. Studies have shown that the competitive influences of weedy annuals such as are present on the Hillside may prevent the natural recovery of native species and require extensive controls and management for the establishment of other native species. Dominance by annuals has also been shown to alter ecosystem functions. The conversion of sites to annual communities usually results in lower quality watersheds by increasing the potential for soil erosion and, typically, increasing the frequency of wildfires. One of the primary concerns on the Site is to limit the potential movement of plutonium in contaminated soils. The chief mechanism on Site for this has been identified as wind erosion. So it is important to maintain a good vegetation cover on the soils. The present state of the 881 Hillside compromises that position and should be dealt with in a timely manner. It is recommended that the Hillside be reseeded as soon as possible with a mixture of native, perennial grasses and forbs, similar to what are found elsewhere in the mesic grassland community on the Site.

G) TERRESTRIAL ARTHROPOD MODULE

The Terrestrial Arthropod Module was established in June, 1994 with the delivery of the *Ecological Monitoring Program Final Terrestrial Arthropod Field Procedure*, DOE (deliverable #61405206-E). The first sample collections were conducted in August and September of 1994. A laboratory contract with Colorado State University was established in January, 1995 to provide expertise in the identification and enumeration of arthropods.

The objective of this study is to characterize the diversity and biomass of insects, spiders, and other above-ground terrestrial arthropods, collectively called terrestrial arthropods. Characterization of arthropods is conducted within and among vegetation communities. Data will be used to establish the natural variation in arthropod diversity among vegetation communities, document taxa richness by community types, and develop a listing of arthropod taxa present at Rocky Flats. A number of methods were tested to determine the most effective methodologies and equipment to conduct sampling.

Methods used to date have been sweep netting, beating trays, pitfall traps, and Malaise traps. All methods, with the exception of the beating trays, have worked well in gathering samples for taxonomic information (richness and diversity). Sweep netting methods have not provided adequate biomass samples, however. This may be due to the area sampled or the lack of moisture during the growing season (i.e., 1994 had below average rainfall). A new method for sampling biomass is being devised. It includes using D-vac samplers or a direct current insect vacuum, whichever is most effective and economical. This methodology is considered superior to sweep netting in that it samples a well-defined area, is easily replicated, and captures arthropods more completely when used properly. The deterring factor may be cost, however. Sweep netting is considerably less expensive, samples a larger area and collects a sample in less time. Field trials in 1995 (late summer) will determine the best method.

A total of 24 sweep net samples, 4 pitfall samples, and 4 malaise trap samples were collected from the 12 EcMP permanent sampling sites. Communities where arthropods were sampled were xeric, mesic, and reclaimed mixed grasslands, and riparian areas. All sampling was conducted adjacent to the permanent vegetation transects, previously described in the terrestrial vegetation section.

The laboratory contract requires samples to be delivered no later than June 16, 1995. Data from 13 samples were recently delivered, and are undergoing data quality control measures. Therefore, results from the 1994 field season will be reported at a later date.

Three sampling sessions are planned for 1995. During all three sessions, 32 samples will be collected for taxonomic analysis. A session will include 24 sweep net samples, 4 pitfall trap samples, and 4 Malaise trap samples. Sessions are planned for the following time frames:

- Session 1 - May/June (3-week period including a training day)
- Session 2 - July/August (2-week period)
- Session 3 - August/September (3-week period)

Additionally, the third sampling session will include the collection of 24 biomass samples. The results from this effort will determine if biomass is a viable measurement for terrestrial arthropods at the Site.

H) EcMP DATABASE

The EcMP Database has been designed and developed as a tool for entering, assuring the quality of, and storing data collected under the EcMP. In addition, the database provides the flexibility to export data into software applications, such as FoxPro, StatGraphics, and Excel, for statistical analysis and manipulation. The software platform is dBASE IV[1], version 2.0. This software runs on IBM and IBM compatible PCs. Database development began with the objective of capturing the data collected for the Terrestrial Vegetation Module. The database was initially designed and created in the spring of 1993 and was extensively revised and updated in summer and fall of 1994 to increase efficiency and accommodate other EcMP modules.

The data entry screens have been designed to minimize keystrokes, automatically input default values (either system or user-defined), and to limit entry choices to valid parameter values. Before, during, and after data entry, data undergo Quality Assurance/Quality Control (QA/QC) to identify missing, incorrect, and inconsistent data. Data entry is menu driven, so that the user need not be familiar with dBASE IV to input data. The database is divided into discrete modules, or sections, that reflect the technical modules of the EcMP. Each database module contains one or more files that use a standardized set of data fields which store the information for that module. These fields are defined in a glossary that is distributed to all users and updated as necessary. Leads for each of the EcMP technical modules are responsible for adhering to the glossary when deciding on the content of new data files. All data files contain one or more standard fields that identify and describe the informational content of the file, such as date, location, and type of study. This consistency of data file design creates what is known as a relational database, allowing cross-referencing and dynamic retrieval of data for integrated analysis and reporting.

In 1994, the existing program code was simplified to improve the user interface and to conserve space on the computers. The revised code uses approximately 13% of the disk space that the original code occupied and is composed of about 100 fewer files. One reason for the dramatic difference between the old and new code is that both working and compiled program files of the old code were kept on the data entry computers, which doubles the number of files and approximately doubles the kilobytes used. In the interest of space and neatness, only compiled program files of the revised code were put in the data entry computers and all old program files were removed.

To accommodate changes in code, changes in field methods, and in the spirit of simplification, most of the existing data file structures were also revised. Several unnecessary fields were removed, some fields changed definition, and a few fields were added. This revision did not affect files containing data from previous sampling sessions, only subsequent data files reflect the change. Revisions do not affect data integrity and most improve Quality Assurance.

Documentation for the new code and file structures was begun in late 1994, and was completed in February, 1995. Documentation includes a revised User's Guide; hard copy printouts of all file structures, all program code, an updated field glossary, and a printout of program files involved and their interrelations.

After the code was modified for the existing database modules, Terrestrial Vegetation and Small Mammal modules, additional modules were added to accommodate other EcMP data. Reclamation Monitoring data and program files were added, Ecosystem Functions and Soil Physical/Chemical data files were added, and a weather data submodule to the Small Mammal module was added.

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[1]dBASE and dBASE IV are registered trademarks of Borland International, Inc.

Ecology and Watershed Management (EWM) was assigned a Computer Systems Security Officer (CSSO) in August to comply with EG&G Computer Security Policy. The CSSO classified the EcMP database archive computer as "Mission-essential" because it is the sole location for the complete EcMP database. Mission-essential is defined as data and/or data systems that are determined to have a high importance related to accomplishing a DOE mission and therefore requires a greater degree of protection than non-essential systems (EG&G, 1994). Loss or corruption of all or part of the EcMP database could adversely affect EG&G's ability to comply with DOE Order 5400.1.

Security measures taken to protect the EcMP database are documented on the Certification for Level 1 Unclassified Sensitive Systems form for this system. These basic security measures are deemed sufficient as the data contained within the EcMP database are considered Unclassified Non-sensitive information.

Backups of the EcMP database are performed weekly. Backup copies of the database programming code, data files, and related files are sent in a compressed form via a direct connect MODEM to a subdirectory of the Rocky Flats Environmental Database System (RFEDS) computer mainframe ("Hobbes"). This subdirectory is itself stored onto tape on a weekly basis. These tapes are stored in a locked cabinet at EG&G's Interlocken offices.

EWM was asked by the Environmental Restoration Program Division (ERPD) in October, 1994 to create a Sitewide Ecological Database (SED) for the Site. The purpose of the SED is to support environmental management and remediation efforts for the Site. The goal of EWM in doing this project is to compile, organize and review the quality of relevant ecological data in order to facilitate the retrieval and analysis of these data for scientific and regulatory compliance purposes.

Much of the existing ecological data have been stored in smaller databases, individual diskettes, or only in hard copy format scattered throughout the different divisions and branches of EG&G and several subcontractors. Relevant data sources include the Environmental Evaluation (EE) studies conducted separately for each Operable Unit (OU), the "Baseline Biological Characterization of the Terrestrial and Aquatic Habitats at the Rocky Flats Plant" (hereafter referred to as "the Baseline study"), the EcMP and the Natural Resource Policy Compliance Program (NRPCP). The SED will help promote consistency between OUs, employ proper quality controls, and allow for the implementation of data usability criteria. Data will become much more readily available for retrieval and analysis by interested parties and will be securely stored within the RFEDS.

The "Rocky Flats Plant Comprehensive Risk Assessment (CRA) Scoping Document" (July 26, 1993) states that OU EE and sitewide monitoring data will serve as the primary data sources for the Comprehensive Risk Assessment (CRA). However, this document notes that OU field study methodologies are inconsistent, data gaps exist, and that retrieval of data currently in RFEDS is difficult and labor intensive. Therefore, one of the objectives of the CRA is the development of a database management system that will facilitate the recognition of data gaps, the retrieval of existing data, and the consistency of future measurements. The SED will fulfill this objective in regards to ecologically relevant data.

The DOE Data Quality Investigation of the Rocky Flats Environmental Restoration Program (December, 1994) noted that there is a general deficiency in Quality Assurance (QA) implementation of the OU EEs. The creation of the SED is a direct response by ERPD to the audit. The SED will provide a level of QA/QC and format consistency previously absent among the EE data.

The Baseline Study was completed September 1992 and served as the initial comprehensive study of Rocky Flats biota and associated habitats. The EcMP and NRPCP are ongoing programs that are directed by DOE Order 5400.1 and 10 CFR Part 834. The data from the two programs are contained in two separate databases with different formats and levels of QA. Integrating these databases as well as

the data derived from the Baseline Study would greatly facilitate analysis and interpretation of the ecological state of the Site Buffer Zone.

The EcMP database coordinator has designed the structure of the SED, written the Statement of Work subcontracting data compilation and transformation to the S. M. Stoller Corp., is acting as the Contract Technical Representative (CTR) in supervising Stoller personnel, and is working in cooperation with RFEDS/Information Resources (IR) personnel in implementing the SED into the RFEDS system. Once the SED is completed, EWM may remain the point of contact for data search and retrieval requests by other groups or agencies.

Initial organization meetings were held with DOE and RFEDS/IR personnel December 7. The S. M. Stoller Corp. was awarded the contract to locate and transform existing relevant ecological data for the SED on December 6 and a kick-off meeting was held with Stoller personnel December 9. In accordance with the contract, Stoller personnel have delivered the three original deliverables, the "Prototype Data Set," the "Main Data Set," and the "Remaining Data Set." A third task, with a fourth deliverable was added to the contract on April 20, 1995. This additional task requires Stoller personnel to assimilate all existing spatial coordinates of ecological sample sites into a location look-up data file and deliver it to the EG&G CTR by June 1, 1995. The contract was extended for this task, and will now expire on May 31, 1995.

As of May, 1995, RFEDS/IR personnel, in cooperation with the EcMP database coordinator, have completed the SED Functional Requirements Document, an approved schedule for completing the SED, and initial organizational diagrams for the SED. The SED is expected to be ready to receive the data provided as deliverables from Stoller by August, 1995.

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DOE. 1994. Data Quality Investigation; Rocky Flats Environmental Restoration Program. U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, TN.

EG&G, Rocky Flats, Inc. 1993. Rocky Flats Plant Comprehensive Risk Assessment (CRA) Scoping Document. U.S. Department of Energy, Rocky Flats Plant, Golden, CO.

EG&G, Rocky Flats, Inc. 1994. Handbook For Users and CSSOs of Unclassified Computer Systems. U.S. Department of Energy, Rocky Flats Plant, Golden, CO.

I) OPERABLE UNIT 11 ECOLOGICAL EFFECTS

Between April, 1982 and October, 1985, three areas in the Rocky Flats Buffer Zone were sprayed with water from the Solar Ponds. This was done to remove excess water when the ponds became full. Because the water was contaminated, the site was identified as a hazardous waste management unit under the Resource Conservation and Recovery Act (RCRA) in 1986. Through a series of regulatory actions, the three areas were combined to create Operable Unit (OU) 11 of the Rocky Flats Interagency Agreement (IAG). Designation as an OU under the IAG required a RCRA Facility Investigation/Remedial Investigation (RFI/RI) to be carried out. an Ecological Risk Assessment (ERA) is part of that investigation.

In late summer of 1993, EcMP staff were asked by the OU 11 manager to investigate the possibility of conducting the ERA for this site. Ecology staff had contracts with several laboratories at that time whose analytical work might contribute to the assessment of ecological effects. Staff then devised a sampling program to determine ecological effects of several potential receptors.

The approach taken was to conduct a quantitative effects assessment on several potential ecological receptors, and to provide evidence from population, community, and ecosystem levels of organization as

to whether an effect(s) was present 8 years following the treatment application. If differences did persist, which ones demonstrated the clearest differences? A related purpose was to determine if these relatively inexpensive and quick tests could provide a sensitive measurement of contaminant effects. If similar trends were to emerge from this wide array of receptors, it might be possible to draw conclusions regarding the presence or absence of significant effects.

The receptors evaluated include:

A) Soil Physical and Chemical Properties
1) Total soil organic carbon
2) Total soil nitrogen
3) Soil exchangeable potassium
4) Soil extractable phosphorus
5) Soil calcium concentration
6) Soil particle size (texture)
7) Soil cation exchange capacity

Some of these properties (C and N) and other soil properties (particle size) were also measured under the ecosystem function section of this report.

B) Vegetation and Litter
1) Vegetation biomass.
2) Vegetation carbon, nitrogen, potassium and phosphorus concentrations (mg element kg^{-1} vegetation) and element contents (mg element m^{-2}).
3) Litter mass.
4) Litter carbon, nitrogen, potassium and phosphorus concentrations (mg element kg^{-1} vegetation) and element contents (mg element m^{-2}).

C) Soil Invertebrates
1) Soil invertebrate nematodes from the 0-5 and the 5-10 cm depths, classified into several functional groups.
2) Soil invertebrate arthropods from the 0-5 and the 5-10 cm depth, analyzed both taxonomically and by functional groups.

D) Ecosystem Functions
1) Extractable soil nitrate (NO_3)
2) Extractable soil ammonium (NH_4)
3) Total soil nitrogen
4) Total soil carbon
5) Fine Particulate Soil Organic Carbon
6) Fine Particulate Soil Organic Nitrogen
7) Microbial carbon concentration (direct extraction)
8) Potentially mineralizable nitrogen (10-day incubation at field capacity water content at 25^0 C followed by NO_3 and NH_4 analysis
9) Potentially respirable carbon (CO_2 analysis during a 10-day incubation at field capacity water content and 25^0 C)
10) Nitrogen fixation rate (ethylene production)
11) Denitrification rate (nitrous oxide production under 10% acetylene)

Twelve sites from OU 11 were sampled: three treatments (Sprayed, Nonsprayed and Reference), four replicate sites within each treatment, and five plots per site. Sprayed plots were exposed to high levels of nitrate. Non-sprayed plots were initially thought to not have been exposed to nitrates; but were

subsequently found to have received some spray. Reference sites were outside the spray area, just north of the McKay ditch, but were in the same soil series and vegetation community (xeric mixed grassland).

All hypotheses tested were related to significant differences between treatment means. The null hypothesis was that the treatment means of the variable in question were equal, and the alternative hypothesis was that at least two of the treatment means were significantly different at the stated alpha level.

Soil physical properties were found to be very similar among the three treatments, indicating that conditions were fairly uniform in treated and reference areas prior to the Spray treatment. Soil chemical properties were considerably more variable, and most had a statistically significant replicate within treatment effect. Soil carbon and nitrogen concentrations at 0-10 cm depth were the only elements that showed a significant elevated response to the Spray treatment.

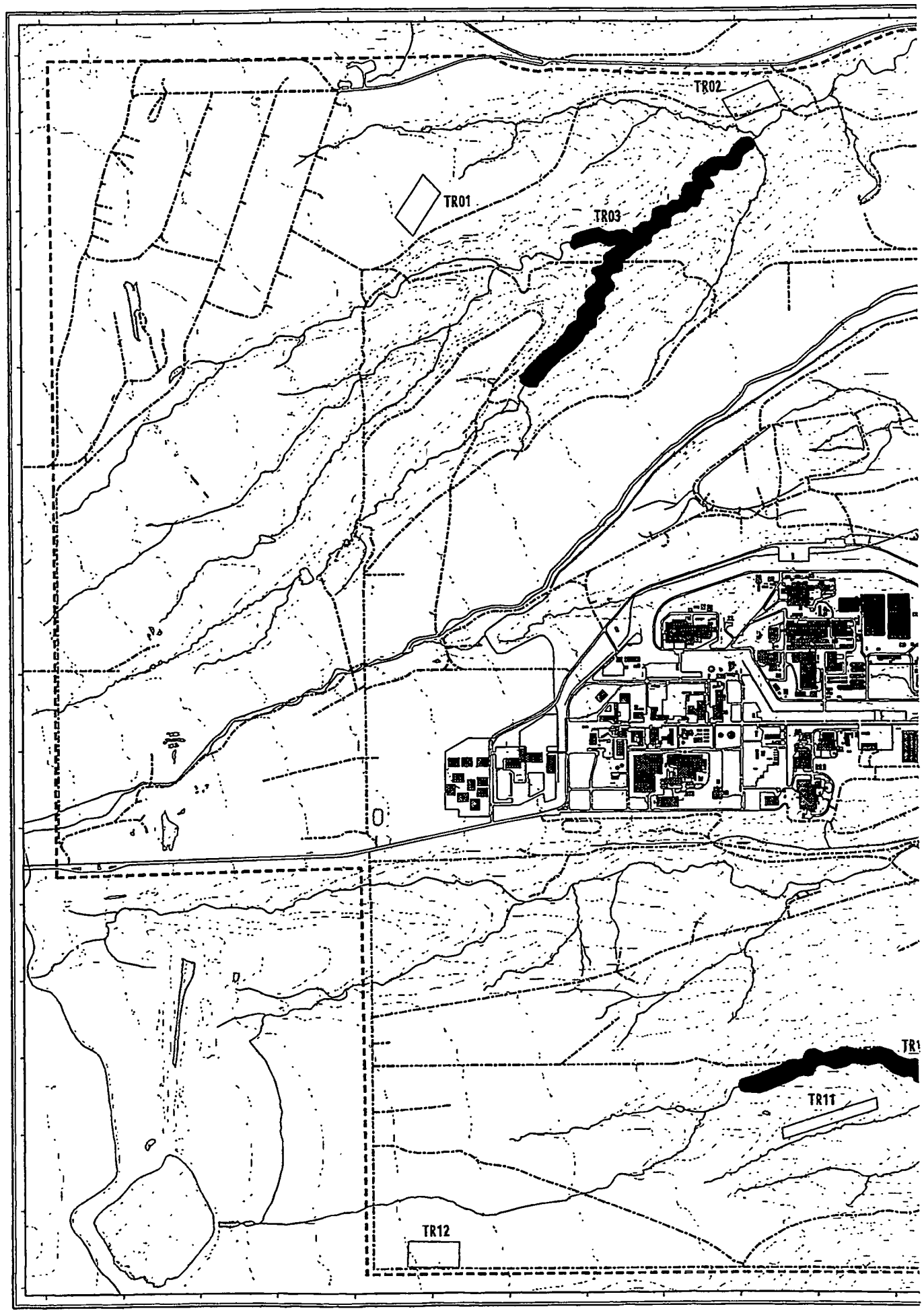
Vegetation and litter biomass did not have statistically significant treatments effects, although both of these variables were highest in the Sprayed treatment. Most element concentrations also did not show significant effects, although vegetation carbon concentration was greatest in the Non-sprayed treatment. Vegetation potassium concentration and content and phosphorus concentration were also highest in the Non-sprayed treatment; the meaning of these results is not clear.

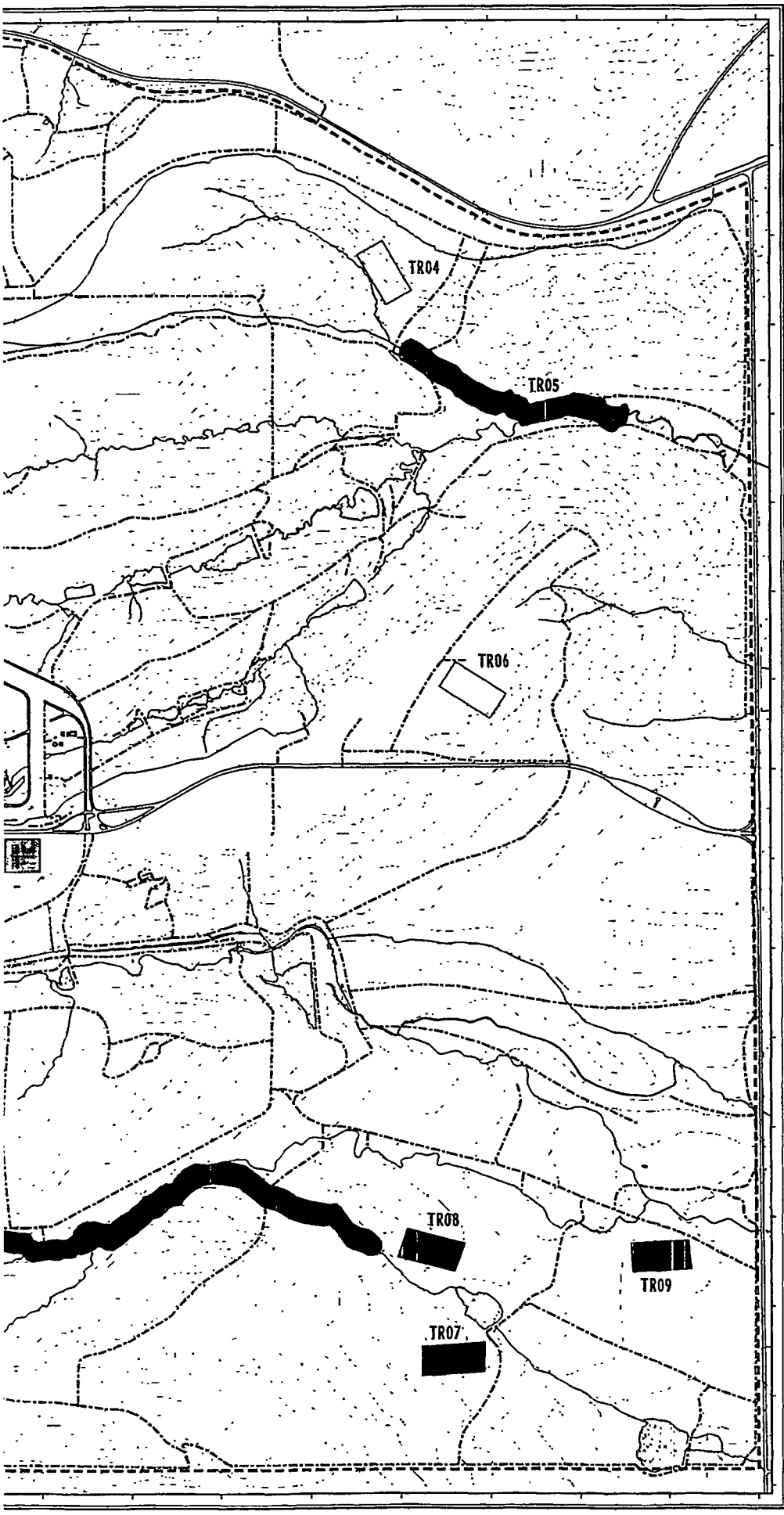
Changes in both arthropod and nematode functional groups were generally not evident as a result of the Sprayed treatment. Six of a total of 35 soil invertebrate variables had a statistically significant treatment effect. Detectable changes were only found where organisms in the Sprayed treatment were significantly more abundant than either Non-sprayed or Reference treatments. There was not a consistent ranking of treatment means in the expected order (Sprayed > Non-sprayed > Reference, or the reverse). However, it can be stated that preliminary analyses have not shown any statistically significant or dramatic (more than 10x) nematode or arthropod functional group declines in areas where the Spray treatment was thought to be heaviest.

Several ecosystem function measurements were found to have a significant treatment effect. Eight years after spraying ceased, soil C and N concentrations are greater in Sprayed than in non-sprayed treatments. Nitrate-N concentrations were also greater 8 years after spraying (14.0 µg/g) than in reference soil (6.4 µg/g). Concentrations of nitrate-N greater than 10 µg/g are unusually high for grassland soils, although they are common in agricultural soils. Although potentially mineralizable N concentrations were not different at α=0.05, they were significantly different at α=0.10. Sprayed soils mineralized the least N (8.9 µg/g) and reference soils the most N (13.7 µg/g). There are 7.6 µg/g more nitrate and 4.8 µg/g less mineralizable N. Possibly N that was mineralizable N in reference soil was already mineralized in sprayed soil.

Microbial biomass C was not significantly different in sprayed soils, but microbial biomass N was significantly greater. At first, this suggested that microbial populations changed, changing the microbial C:N ratio. For example, fungi have wider C:N ratios than bacteria and as fungi become relatively more abundant, microbial C:N ratios increase. There were, however, no statistical differences between treatments in microbial C:N ratio.

In conclusion, a total of 74 variables were analyzed to assess the ecological effects of a spray treatment to OU 11, and 18 variables showed statistically significant differences at the $\alpha = 0.10$ level of significance. The most biologically significant effects were the increase in soil C and N in the Sprayed treatment. This effect was also seen in elevated amounts of nitrate in the Sprayed treatment. Of seven soil invertebrate variables that were found to have a significant treatment effect, six functional or taxa groups showed increases in the Sprayed treatment areas. Variables that showed statistically significant decreases in the Sprayed treatment were not thought to have deleterious ecological effects. Although the spray treatment has altered some of the nutrient pools and cycling processes, the result has not caused any ecosystem damage.


TR02
TR01
TR03
TR11
TR12



U.S. Department of Energy

Rocky Flats Plant

Figure 1

EcMP Terrestrial Sites

Community Types

- Mesic grassland
- Xeric grassland
- Reclaimed grassland
- Riparian

N

1 inch = 500 meters

0 500 750 m.

Prepared by:

EG&G ROCKY FLATS

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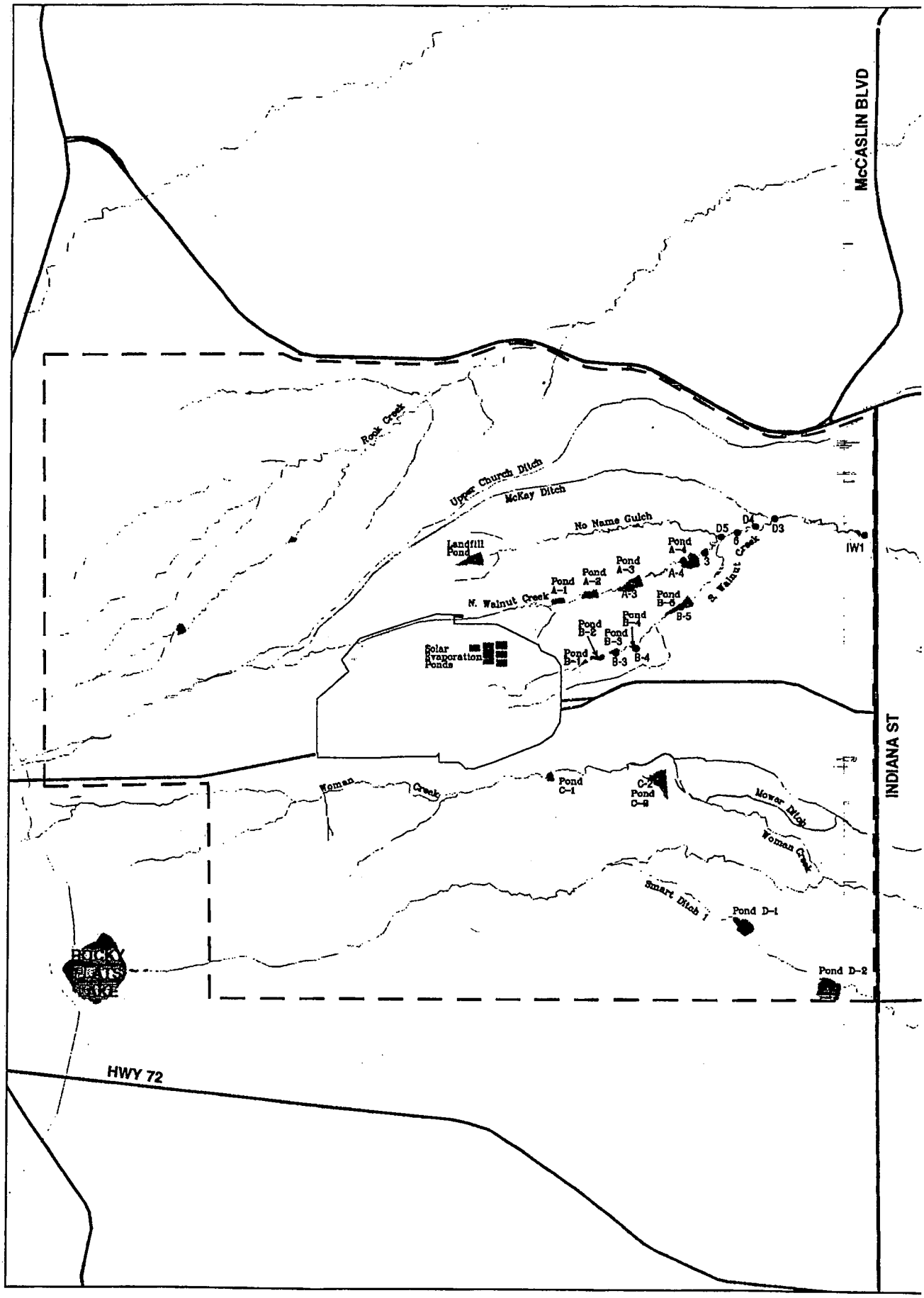
Golden, Colorado 80402-0464


McCASLIN BLVD
INDIANA ST
HWY 72
Rock Creek
Upper Church Ditch
McKay Ditch
No Name Gulch
Landfill Pond
Pond A-1
Pond A-2
Pond A-3
Pond A-4
A-3
A-4
3
D5
6
D4
D3
IW1
N. Walnut Creek
S. Walnut Creek
Pond B-6
B-5
Pond B-4
Pond B-3
Pond B-2
Pond B-1
B-3
B-4
Solar Evaporation Ponds
Woman Creek
Pond C-1
C-2
Pond C-2
Mower Ditch
Woman Creek
Smart Ditch 1
Pond D-1
Pond D-2
ROCKY FLATS LAKE

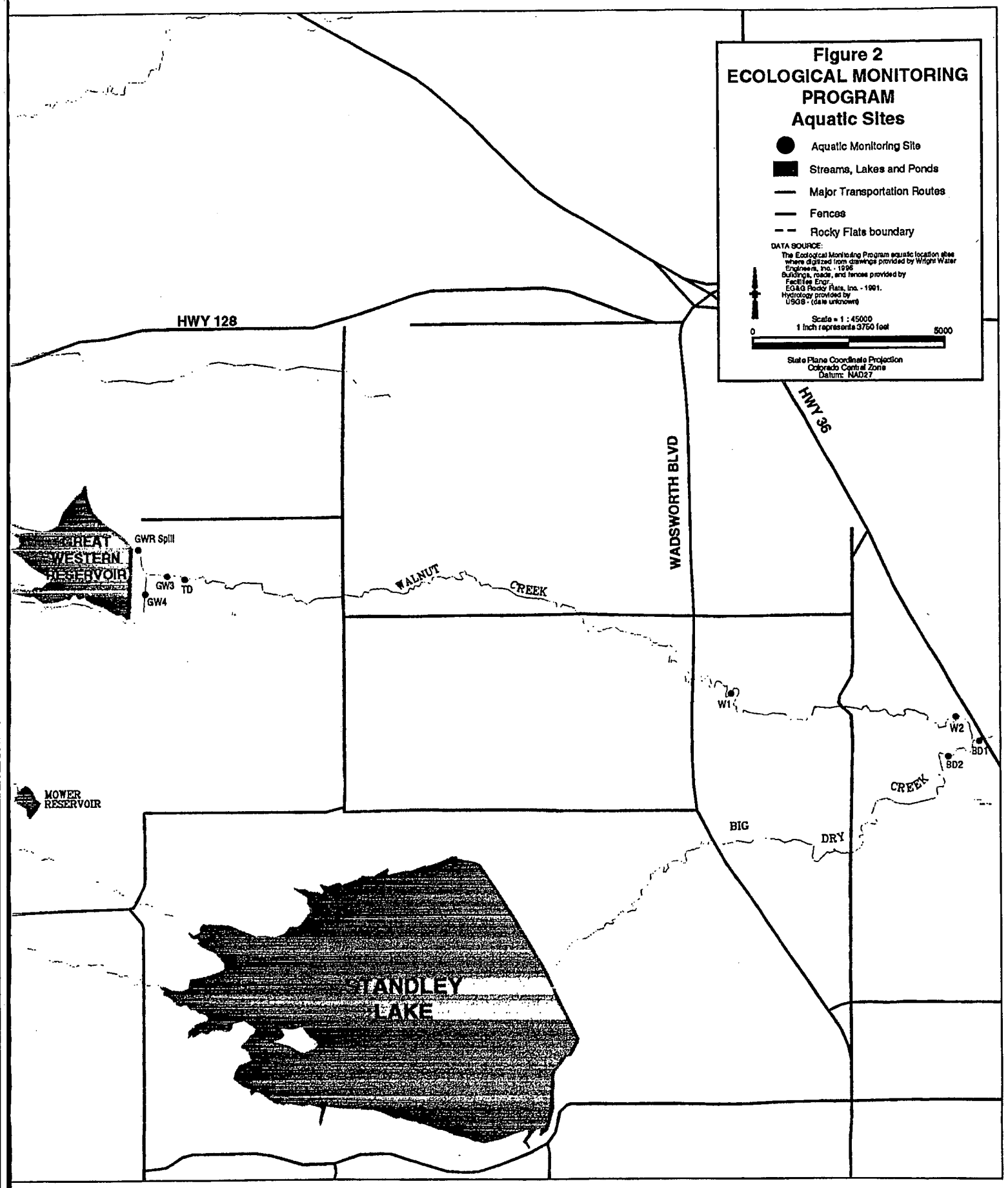


Figure 2
ECOLOGICAL MONITORING PROGRAM
Aquatic Sites
Aquatic Monitoring Site
Streams, Lakes and Ponds
Major Transportation Routes
Fences
Rocky Flats boundary
DATA SOURCE:
The Ecological Monitoring Program aquatic location sites where digitized from drawings provided by Wright Water Engineers, Inc. - 1996
Buildings, roads, and fences provided by Facilities Engr. EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)
Scale = 1 : 45000
1 inch represents 3750 feet
0
5000
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27
HWY 128
HWY 36
WADSWORTH BLVD
GREAT WESTERN RESERVOIR
GWR Spill
GW3
TD
GW4
WALNUT CREEK
W1
W2
BD1
BD2
CREEK
BIG DRY
MOWER RESERVOIR
STANDLEY LAKE

Figure 2A. Aquatic Site Descriptions.

A-1	A-1 pond, North Walnut Creek drainage
A-2	A-2 pond, North Walnut Creek drainage
A-3	A-3 pond, North Walnut Creek drainage
A-4	A-4 pond, North Walnut Creek drainage
B-1	B-1 pond, South Walnut Creek drainage
B-2	B-2 pond, South Walnut Creek drainage
B-3	B-3 pond, South Walnut Creek drainage
B-4	B-4 pond, South Walnut Creek drainage
B-5	B-5 pond, South Walnut Creek drainage
BD1	Big Dry Creek downstream of Walnut Creek confluence
BD2	Big Dry Creek upstream of Walnut Creek confluence
C-1	C-1 pond, Woman Creek drainage
C-2	C-2 pond, Woman Creek drainage
D-1	D-1 pond, Smart ditch drainage
D-2	D-2 pond, Smart ditch drainage
D3	Walnut Creek downstream of Mckay confluence
D4	Walnut Creek upstream of Mckay confluence
D5	Walnut Creek downstream of A-4 pond dam
GW1	Runoff stream from GWR located east of GWR at the service road culvert
GW2	Overflow pipe emptying into Walnut Creek east of GWR
GW3	Walnut Creek east of Great Western Reservoir (GWR), downstream of diversion ditch, upstream of GWR overflow pipe
GW4	Downstream or at the end of Walnut diversion ditch at 2 small culverts
IW1	Walnut Creek west of Indiana at the culvert just inside Rocky Flats fence boundaries
SW039	Woman Creek, surface water site
SW033	Woman Creek, surface water site
SW026	Woman Creek, east of C-2 pond, surface water site
SW05	Lindsay Pond
W1	Walnut Creek west of culvert at 105 th St. and Old Wadsworth intersection
W2	Walnut Creek upstream of confluence with Big Dry Creek

A) ECOSYSTEM FUNCTIONS

Authors: L.E. Woods and M.E. Bakeman

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BACKGROUND

Ecosystems are comprised of biotic (individuals, populations and communities) and abiotic components. Ecosystems are generally studied in either one of two ways: based on their biotic components or based on their processes. Ecosystem processes, called functions in this report, include energy transformations, nutrient cycling, soil development and organic matter turnover.

Ecosystem functions are included in the Ecological Monitoring Program (EcMP) to balance the population and community approaches of the other modules and because they may be sensitive indicators of subtle changes in ecosystems that are not reflected in measurable changes in populations and communities. Natural Resource Damage Assessment (NRDA) Regulations, a responsibility of the Ecology and Watershed Management (EWM) Branch, list two Ecosystem Function measurements as specific methods of injury determination: impeded soil microbial respiration, and reduced respiration from reduced soil microbial populations. These measurements are made in the EcMP to provide a baseline description of undisturbed soil at RFETS, including normal ranges and seasonal and annual trends.

Several other measurements related to nutrient cycling were also analyzed: soil physical and chemical properties, and estimates of vegetation and litter nutrient contents. Some of the soil variables represent baseline ecological conditions that help explain results from other analyses. Differences in vegetation and litter nutrient contents can affect other variables like soil invertebrates, and biogeochemical cycling.

OBJECTIVES

Objectives for measuring ecosystem function properties are to establish baseline concentrations for undisturbed areas, to describe natural differences between biotic communities, locations, seasons and years, and to provide benchmarks to asses revegetated areas when remediation and restoration are completed. A related goal is to evaluate the potential of ecosystem function measurements, which are inexpensive and sensitive, as indicators of ecosystem health.

Populations, communities and selected abiotic factors will be measured in other modules. Attention will be focused on indicators of nutrient cycling processes as suggested by O'Neill, et al. (1977). Responses to perturbations, either natural or anthropogenic can only be evaluated in light of their normal variations in time and space. We believe that these ecosystem-level measurements, in conjunction with concurrent studies at lower levels of organization, will allow us to interpret ecological patterns at RFETS.

HYPOTHESES

Several questions framed the hypotheses:

a) What are characteristic potential respiration rates of the four community types of terrestrial vegetation?
b) Are potential respiration rates similar in reclaimed sites and undisturbed sites?
c) Are similar fractions of the total organic matter potentially active in all communities?
d) What is the "normal" range of variation for each type of measurement?
e) Is the potential for N_2-fixation appreciable in any habitat?
f) What are the characteristic potential N mineralization rates of the four community types?
g) Is there a potential for NO_3^- to accumulate in soils in any of the community types?
h) If pools represent potential fluxes, what are the relationships between fluxes and pools?
i) Between pools and habitats?
j) Between pools and abiotic parameters?

Hypotheses related to soil physical and chemical properties include: do these properties differ by community type, and are the sample sites used to calculate community soil means a significant factor in evaluating variation in the overall statistical model used.

Specific hypotheses include:

$H1_0$: Potential soil respiration does not differ significantly between sites.
$H1_A$: Potential soil respiration differs significantly between sites.

Basis for hypothesis: Respiration represents the integration of most ecosystem functions. Locations with larger amounts of primary productivity also must have larger amounts of respiration, must have other carbon export mechanisms, or must be sites of carbon accumulation.

$H2_0$: Soil respiration rates exhibit similar seasonal patterns in all habitats.
$H2_A$: Soil respiration rates exhibit different seasonal patterns in riparian communities than in grassland communities.

Basis for hypothesis: Respiration is limited by the availability of substrate, by water and by edaphic factors. The available water will probably show much stronger seasonal trends in the grassland sites than in the riparian sites. Seasonal data are not available at this time to evaluate these trends.

$H3_0$: Potential soil respiration does not vary significantly between sites or between communities.
$H3_A$: Potential soil respiration varies by more than 100% between sites and between habitats.

Basis for hypothesis: The "normal" range of variation in respiration potential within a site is probably less than the differences between sites. Probably the greatest differences will be in the grassland sites which vary widely in water status.

$H4_0$: N_2-fixation is not significantly greater than zero at any site.
$H4_A$: N_2-fixation is greater than zero in one community type.

Basis for hypothesis: Nitrogen is the most common limiting nutrient in almost any terrestrial ecosystem. N_2-fixation depends on several edaphic and biotic factors that will probably be different in riparian areas than in grassland sites.

$H5_0$: N mineralization potentials are similar in all community types.
$H5_A$: N mineralization potentials are higher in riparian than in other community types.

Basis for hypothesis: N mineralization is limited by substrate quantity, substrate chemical characteristics, soil water, and edaphic factors. Nearly all of these factors are less limiting in the riparian zone than in the other community types.

$H6_0$: NO_3^- is not accumulating in the soils of any community.
$H6_A$: NO_3^- is either moving out of the watersheds in stream water or is accumulating in soils.

Basis for hypothesis: Increased N mineralization at the expense of immobilization indicates that ecosystem functions are disturbed. This imbalance can quickly result in increased nitrate concentrations in soil or stream water. Ecosystem function disturbances can, of course, occur without causing increased nitrate concentrations, but if nitrate concentrations do increase, something is amiss.

SAMPLING SITES

One hundred fifty one samples for Ecosystem Function parameters were taken from 24 field sites. The 12 EcMP permanent sites (TR01-TR12) sampled for vegetation production measurements were also sampled for ecosystem functions. One sample was collected at each of five transects within each site. This sample consisted of five subsamples. Additional sites were sampled to provide field replicates for quality assurance. Another 12 sites from Operable Unit (OU) 11 were sampled. Results from OU11 are discussed in Appendix 1 of this report. A total of 151 samples was sent to the Natural Resource Ecology Laboratory at Colorado State University in Fort Collins, Colorado for analysis.

Vegetation and litter data reported in this section were collected to satisfy objectives outlined in other sections of this report. These data are summarized here by community to allow comparison with the ecosystem functions data. Data were collected at grassland, but not riparian sites; and sample sizes were unequal because species were analyzed separately for plant tissue conecntrations. For plant tissue concentrations, mesic and reclaimed grassland had 20 observations each (1 site each), and xeric grassland had 7 observations (from 3 sites). For litter analysis, mesic and xeric grasslands had 35 observations each. Reclaimed grasslands had 55 observations. Litter analysis was from three sites in each grassland community.

SCHEDULE

A) Field Sampling

All samples were collected in early August or in September, 1993.

B) Laboratory Analysis

All analyses were completed on schedule. Data were delivered on schedule.

METHODS

A) Field Methods

Detailed descriptions of the soils sampling procedures have been provided in "Procedures for Sampling Soil Invertebrates and Ecosystem Function Measurements, Appendix 11 of the Ecological Monitoring Program Management/Technical Performance Report-GHS-462-93 (93-RF-11615)." Samples were collected by excavating a 10 x 10 x 10 cm cube of soil from the selected location. All samples represented the surface 10 cm. Samples were composited from the five quadrat locations on each transect adjacent to vegetation production plots. Sample collection was complicated by the large amount of coarse fragments (cobbles and stones). Large rocks were removed and weighed separately. Samples were immediately transferred to coolers containing ice (Blue Ice or its equivalent). They were maintained in coolers until they were transported to the laboratory. In the laboratory they were maintained in a 4°C cold room until analysis.

Vegetation and litter samples were collected from 0.25 m^{-2} quadrats. All current-year's growth and litter inside the quadrat frame were harvested and bagged separately. They were then dried in a forced draft oven to constant weight. Samples were weighed, then sent to the analytical laboratory.

B) Laboratory Analysis

1) Ecosystem Function Parameters

Detailed procedures for the analyses performed by the Natural Resource Ecology Laboratory are on file with EWM personnel. For initial processing at the laboratory, samples were sorted and laboratory identification numbers assigned. Five separate field bags held each sample. Their contents were mixed and coarse mineral and organic matter fragments were removed. These coarse fragments were later weighed. The soil was then sieved through a 2 mm sieve. Water content of the sieved soil at field capacity was measured.

Incubations were then initiated using sieved soil. Field nitrate and ammonium concentrations were measured. Three subsamples were prepared for each sample date. All extractions and incubations were carried out for each soil sample and for selected duplicates and three blanks. Fifty grams of soil was weighed into appropriate containers. Water was added to bring the soil to the water content at field capacity. The cups were placed into respiration chambers with several ml of water to prevent desiccation of the soil. A vial containing a known volume of 3 M NaOH (usually 1.275 ml) was place in each chamber. The chambers were sealed and incubated at 25°C. On the third, sixth and tenth days, the vials of NaOH were titrated with 1 M HCl in the presence of $BaCl_2$. The vials were replaced on the third and sixth days. On the tenth day, the soil was removed and subsampled for water content, mineralized N, and microbial biomass C and N.

Water content was measured gravimetrically. Mineralized N was measured by analyzing for ammonium and nitrate+nitrite on an auto-analyzer. Microbial biomass C and N were estimated by measuring the differences in soluble C and N between a control and a chloroform fumigated subsample of each sample. In this report, microbial biomass is presented as the difference between these subsamples. No correction was made for the efficiency of extraction. It is more common in scientific reporting to divided the difference in extractable carbon between chloroformed and unchloroformed soil by 0.41 or some other factor. That is to say, exposure to chloroform renders 41% of the microbial carbon extractable. Nitrogen is calculated by various formulae, because the extractability of nitrogen is not straightforward. Details of these corrections are not explored for this report.

Texture and Particulate Organic Carbon and Nitrogen were measured by suspending soil samples in 5% sodium hexametaphosphate. Sand sized particles are collected on a 53 µm sieve. The remaining sample is placed in 1 l sedimentation cylinders and measured by hydrometer. Particulate organic carbon and nitrogen are then measured on the sand fraction collected on the sieve.

2) Soil Physical and Chemical Properties

Soil samples for physical and chemical properties analysis were shipped to the University of Idaho Analytical Laboratory in plastic-lined sample bags provided by the laboratory. Each sample consisted of approximately 1 kg of soil. Soil samples were passed through a 2-mm sieve. Water content was determined gravimetrically. Micronutrients, such as Zn, Mn, Cu, Fe, Pb, and Cd were extracted by DTPA at pH 7.3, and analyzed on an ICP-AES. Exchangeable cations such as Ca, Mg, Na, and K, were extracted with 1.0 N ammonium acetate and analyzed on the ICP-AES. Phosphorus was extracted with 0.5 M sodium bicarbonate and then analyzed on a spectrophotometer. Soil sulfate was determined by shaking the sample with deionized water with 1 drop of concentrated HCL, filtered, and $BaCl_2$ was added to form $BaSO_4$, which was then measured on a Turbidometer. Cation exchange capacity was determined by extraction with

ammonium acetate at pH 7, followed by measurement of extractable cations by ICP. Total carbon and nitrogen concentrations were determined using an automated CHN Analyzer (McGeehan and Naylor, 1988). Quality control was ensured by the use of laboratory blanks, spikes, and certified standard materials. All laboratory procedures are on file with EcMP staff.

3) Vegetation and Litter Analyses

All vegetation samples were dried at 65°C in a forced-air drying oven until they had reached constant weight, and then weighed on a top loading balance to the nearest 0.1 g. Samples were then shipped to the University of Idaho Analytical Laboratory in paper bags for elemental analysis. All laboratory procedures are on file with EcMP staff. Dried samples were first ground in a Wiley mill, weighed (0.25 - 0.50 g of tissue), and digested in 3.0 ml of reagent grade nitric acid. Samples were centrifuged and the resulting solutions were analyzed on a Perkin Elmer P-40 ICP for cation elements, phosphorus, and sulfur. Total carbon and nitrogen concentrations were determined using an automated CHN Analyzer (McGeehan and Naylor, 1988). Quality control was ensured by the use of laboratory blanks, spikes, and certified standard materials.

4) Statistical Analyses

Statistical analyses for the ecosysem funtion parameters consisted of a two-factor Analyses of Variance; the two factors were community and watershed. The design was five communities (xeric, mesic, riparian-north side, riparian-south side and revegetated) in three watersheds (Rock, Walnut and Woman Creeks). Each community, except revegetated, was sampled at one site in each watershed. The three sites of the revegetated community were all in Woman Creek. Five samples were collected in each site. Means were separated by Tukey's Honestly Significant Differences (HSDs) at $p \leq 0.05$, where appropriate.

Statisitical analyses for soil physical and chemical data consisted of nested analyses of variance, with communities as the main effect. Sites were considered to be nested within communities. Residual sums of squares were from transects within sites. Differences for these variables were considered to be different if they were significant at $\alpha=0.10$. Vegetation and litter nutrient content data were not statistically analyzed because of diesgn imbalance and lack of communiy replicates.

DATABASE STATUS

Field formats were developed with the EcMP database coordinator. The first data were received in January, 1994, as scheduled. No field records other than field sample sheets and sample chain of custody (COC) records are used in this module. Field records were combined with laboratory results using the assigned observation number (OBSNUM) as the common variable.

RESULTS

A) Ecosystem Function Parameters

Results presented here include particle size distribution, total organic carbon and nitrogen, microbial biomass carbon and nitrogen, potentially mineralizable carbon and nitrogen, fine particulate organic carbon and nitrogen, and some associated abiotic parameters. Results obtained, but not yet completely analyzed, include estimates of denitrification, dinitrogen fixation and rates of carbon dioxide and methane production under both anaerobic and aerobic incubation. These results will be presented in future reports.

Soil textures of the surface 10 cm were different in the different community types of the EcMP: Xeric sites were generally sandier (coarser) and reclaimed sites were more clayey (finer) (Table A-1). Coarse fragment content was high. Xeric sites, for example, were in Flatirons soil, which by definition contains at least 85 % cobble or stone in the surface horizon. Because measurement difficulties associated with the abundance of coarse fragments rendered accurate determination of bulk densities impossible, concentrations but not distributions are presented.

Analysis of Variance revealed highly significant treatment by watershed interactions for total soil organic C and N (Table A-2). These interactions reflect the different patterns in the concentrations of organic C and N in the three watersheds depending on the plant community. The Xeric site in Walnut Creek has the highest organic C and N concentrations, but it has the lowest concentrations in Mesic and Riparian sites. Rock Creek has higher concentrations than Woman Creek in all communities except Riparian B (south of the creek). Organic matter concentrations were generally higher in Xeric sites than in the other communities and, not surprisingly, were lower in reclaimed sites (Figures A-1 and A-2).

Microbial biomass C and N concentrations also reflected highly statistically significant Community by Watershed interactions (Tables A-4 and A-5). Microbial biomass also responded differently to differences between communities, depending on which watershed was sampled (Figures A-3 and A-4). Although microbial biomass concentrations were, on average, greater in Xeric than in other communities, Walnut Creek alone caused most of the difference. Microbial biomass concentrations in reclaimed sites were more similar to the other communities than total organic C and N concentrations.

Potentially active C and N concentrations (Respirable C and Mineralizable N) had different patterns with community type. Respirable C demonstrated a significant Community by Watershed interaction, but Mineralizable N did not (Tables A-6 and A-7). Respirable C concentrations in Walnut Creek were highest in Xeric Sites, but by far the lowest in Mesic sites (Figure A-5). Respirable C concentrations were more similar between communities in Woman Creek than in either of the other watersheds. Mineralizable N concentrations demonstrated no significant Community by Watershed interaction or Watershed Main effect (Table A-7). Mineralizable N concentrations were considerably higher in Xeric sites and considerable lower in Reclaimed than in Mesic or Riparian sites (Figure A-6).

Fine particulate organic C and N concentrations both manifested highly significant Community by Watershed interactions (Tables A-8 and A-9). Rock Creek and Walnut Creek sites had opposite concentration patterns (Figures A-7 and A-8). Woman Creek sites were more similar across all sites except for reclaimed sites. In general, Xeric sites had higher concentrations of Fine Particulate Organic C and N than did the other sites. Reclaimed sites had the lowest concentrations.

The fractions of the total soil organic C or N in microbial biomass, in potentially mineralizable forms, or in fine particulate organic matter revealed only one treatment by watershed interaction: potentially respirable carbon (F=3.06; P=0.011)(See Tables A-10 through A-15). By inspection of Figure A-9, this interaction resulted because Walnut Creek had lower fractions of the Total Organic Carbon in Respirable forms in Xeric and Mesic communities, but much higher fractions in riparian communities.

Fractions of Total organic C and N in microbial biomass showed different patterns. Microbial C had statistically significant community effects (F=4.12; P=0.005) and watershed effects (F=11.42; P=0.000). Figure A-10 demonstrates that Reclaimed sites had a higher fraction of soil C in microbial biomass. Xeric sites had the smallest fraction. Microbial N had only significant watershed effects. Potentially mineralizable N had significant community effects (F=10.03;

P=0.000). Figure A-11 shows that this effect is caused by the very low percent of the total nitrogen that is mineralizable in reclaimed sites.

We examined the fractions of the total organic C and N in fine particulate organic matter.. This fraction of both C and N had statistically significant community effects: F=8.00; P=0.000 for C and F=12.37; P=0.000 for N. Figure A-12 shows that Xeric sites had a larger fraction and Reclaimed sites had a smaller fraction of total C in this form than Mesic or Riparian sites. Figure A-13 reveals similar relationships for N.

B) Soil Physical and Chemical Properties

Soil element concentrations and physical properties were analyzed for a significant community effect using a Nested Analysis of Variance (ANOVA) model. If this effect was statistically significant, it indicated that at least two of the community means were significantly different at the stated α level (0.10 unless otherwise stated). The same model was also used to assess if there were significant differences in the sites within each community. If this effect was significant, it indicated that there was a significant component of variation within the sites within each community.

Soil total carbon and nitrogen were analyzed and discussed with ecosystem function measurements because of their important relationships to those data. Data for phosphorus, potassium, calcium, magnesium, sulfate, sodium, and cation exchange capacity ANOVAs are given in Table A-16. Soil property means and summary statistics by community type are given in Table A-17. This table includes summary statistics for C and N, and values are generally greater than the functional analyses for these elements, due to differences in laboratory handling and sample variation.

Soil extractable phosphorus had a significant community effect (p=0.0408), with riparian north and south types having the highest mean values (19.45 and 16.46 mg kg^{-1}, respectively), and the reclaimed community having the lowest (7.82 mg kg^{-1}). The site within community effect was not significant (p=0.2540).

Soil exchangeable potassium had a significant community effect (p=0.0059), and the site within community effect was not significant (p=0.4136). Community means were ordered opposite from phosphorus means; the reclaimed community had the highest mean (1.22 mg kg^{-1}) , and the riparian north and south types having the lowest (0.825 and 0.843 mg kg^{-1}, respectively).

Soil exchangeable calcium did not have a statistically significant community effect (p=0.3533), but the site within community effect was extremely significant (p=0.000). Calcium community means did not display much variation, ranging from 11.27 mg kg^{-1} (mesic type) to 15.90 mg kg^{-1} (reclaimed type).

Soil exchangeable magnesium showed both significant community and site within community effects. Magnesium concentrations were lowest in the xeric community type (1.80 mg kg^{-1}) and highest in the reclaimed and riparian types (approximately 4.3 mg kg^{-1}).

The soil extractable sulfate community effect was significant at the α =0.1 level (p=0.0525). Mean sulfate was extremely high in the riparian north community (149.67 mg kg^{-1}), followed by the riparian south type (64.93 mg kg^{-1}). The site within community effect was not significant (p=0.6332).

Soil sodium showed a significant community effect (p=0.006), with the riparian areas having the highest concentrations (0.40 mg kg^{-1}), and the xeric type having the lowest concentration (0.11). The site within community effect was not significant (p=0.1639).

Cation exchange capacity did not show a significant community effect (p=0.1887), although the site within community effect was extremely significant (p=0.0000). Cation exchange means ranged from 19.78 cmol kg^{-1} (xeric type) to 30.23 cmol kg^{-1} (reclaimed type).

C) Vegetation and Litter

Statistical analysis was not conducted on either vegetation or litter nutrient concentrations or contents for two reasons: 1) the design was very unbalanced in multiple areas, such as unequal observations within community levels, and unequal observations between community levels, and 2) for vegetation, some community levels were not replicated, and the means presented are representative of only a single site within that community. Therefore, these results are exploratory at best. Despite these shortcomings, these data are a useful glimpse at vegetation and litter element pools and may reveal gross trends that will help in the interpretation of other relationships.

Element contents were calculated by taking tissue concentration (corrected for ash) x biomass =element content. The equation is:

(concentration in mg element kg^{-1} tissue or litter) * (tissue or litter biomass in g 0.25 m^{-2}) * (4) * 10^6 mg kg^{-1} =mg element m^{-2}.

Vegetation data for three community types are presented in Table A-18. Total estimated element pools are also estimated for each community type, based on the area of each type at RFETS. In general, the xeric type was lower in most element contents than the other types, even though biomass production did not differ significantly among the three types. Differences are expected not only because of differences in the amount of biomass produced, but also because of differences in species composition; species vary tremendously in their element concentrations. Most of the mean element pools among the community types were within 1 order of magnitude of each other, however, some of the differences are surprising. For instance, mesic mixed grasslands showed almost 5 x more total carbon and nitrogen per unit area than did the xeric type, which would not be expected based on production values.

Total mean element pools in litter were almost always higher than in the above-ground vegetation. Litter nutrient summaries are presented in Table A-19. Differences between litter and vegetation ranged from < 2x to > 20x. Again, the xeric community type often had the lowest total element pools of the three types examined. Potassium was the only element that was higher in vegetation than litter, for the mesic and reclaimed community types.

INTERPRETATION AND RECOMMENDATIONS

A) Ecosystem Function Parameters.

All data presented in this report are for the top ten cm (4 inches) of soil only. Characteristics of deeper soil layers are important to plant growth, water and soluble contaminant movement and other aspects of ecosystem processes. Nevertheless, most of the soil organic matter is found in the top few inches of the soil. Most of the N mineralization, soil respiration, decomposition and other biological processing are concentrated there. Most contaminants, where they are of concern, are spilled on the soil surface. Knowledge of populations, microbial biomass and processes in the surface soil layer is essential to monitoring any ecosystem.

Soil texture (particle size distribution of the fines) controls many ecosystem functions: plant growth, organic matter decomposition. microbial biomass, soil respiration. Clay content generally increased from xeric to mesic to riparian to reclaimed sites. This trend also moves downslope and

away from the mountains. All of the soils contained a significant volume of coarse fragments. Because these fragments prevented measurement of bulk densities, only the most general extrapolations from concentration to unit area are discussed.

Soil organic C and N are the largest reservoirs of C and N. These measurements include all of the active pools reported below and all of the less active organic matter. Rough calculations suggest that soil organic C ranges from 20 Mg per hectare (ten tons per acre) in Riparian sites to 50 Mg per hectare (25 tons per acre) in Xeric sites. Soil organic N ranges from 2000 kg per hectare (one ton per acre) to 5000 kg per hectare (2.5 tons per acre). This is sufficient organic matter to sustain healthy ecosystem functions in all communities and to provide the nutrients for the plant community. In many cases, there were greater differences between watersheds than between communities. Spatial heterogeneity between field sites is obviously substantial, but was not explicitly addressed in the current sampling design.

Microbial biomass C and N concentrations also reflected spatial heterogeneity. In Xeric sites, the differences between Walnut and Rock Creek were greater than any differences between communities in any watershed, or between average concentrations of any two communities. On average, based on rough estimates of bulk density, the top ten cm of soil contained about 2000 kg per hectare (one ton per acre) of microbial biomass. These sites were chosen to avoid any potential effects from RFETS activities. Individual locations can be quite different from each other, but all EcMP sites appear to contain healthy amounts of microbial biomass.

More direct measures of ecosystem functions include potentially mineralizable C and N concentrations. The main limiting factors for microbial activity are available water content and soil temperature. These factors fluctuate widely and frequently. Microbial activity increases dramatically and unpredictably following sample collection and soil manipulation. Therefore, potential C and N mineralization were measured in the laboratory after a one week preincubation. Again, there was substantial activity in the range expected for undisturbed grasslands. And, like total organic C and N concentrations, respirable C concentrations varied substantially between sites. Communities were more different from each other in Walnut Creek than in Rock Creek, and were most similar to each other in Woman Creek. Average mineralizable N concentrations were higher in Rock Creek than in Walnut Creek, also suggesting substantial spatial heterogeneity. Xeric sites had higher concentrations of mineralizable N than Mesic or Riparian sites. Mineralizable N concentrations, but not respirable C concentrations were much lower in Reclaimed sites. Reclaimed sites appear to have qualitatively different soil organic matter even after 20 years in smooth brome.

Fine particulate organic C and N are the soil organic C and N of sand size. Sand sized particles are larger than 53 µm but smaller than 2 mm. This part of the soil organic matter is thought to be the most decomposable. If so, differences between communities and between native soil and previously farmed soil (reclaimed) might lie principally in this fraction. Our results show than xeric sites had the highest concentrations and reclaimed sites had the lowest, but differences were not dramatic. These data too show a high degree of spatial heterogeneity.

To find out if differences in concentrations of active organic matter represented qualitative differences, active fractions of total organic C and N were calculated. The only active fraction that had a community-by-watershed interaction effect significant at less than $\alpha=0.05$ was Respirable C. This interaction resulted from Walnut Creek Riparian sites having more total organic C in respirable C fractions than any other community in any other watershed, except Mesic sites in Woman Creek.

Communities differed from each other significantly in the fractions of their organic matter that occurred as microbial biomass C, but not microbial biomass N - and in mineralizable N, but not respirable C. Watersheds differed significantly in the fractions of their organic matter that occurred as microbial biomass C and N - and in respirable C, but not mineralizable N. The biological

significance of the statistically significant differences between watersheds is not clear. They apparently resulted from inherent spatial variability.

General trends in Figures A-10, A-11, A-12 and A-13 suggest that organic matter in reclaimed soil is qualitatively different than in the other treatments even though it has been a grassland for twenty years. A larger fraction of its total organic C is found in microbial biomass, but a smaller fraction is in fine particulate organic matter. A smaller fraction of the total N was mineralized in laboratory incubations in reclaimed sites than in any other site.

The reclaimed sites were probably similar to the mesic sites before they were plowed and planted to small grains. They have similar slope positions, aspect and general soil properties. If the soils were initially similar, they were fundamentally changed by agricultural activities and have not returned to their original state after twenty years in grass. The changes are not reducing the ability of the ecosystem to support plant and animal life or to prevent wind and water erosion.

It is encouraging to think that these measurements can provide a very sensitive indication of ecosystem disturbance. Perhaps they will be sensitive enough to allow clear demonstrations of no effects from disturbances or contaminants. This has been a very difficult thing for relatively clean sites to establish.

B) Soil Physical and Chemical Properties

Many of the soil concentrations of plant nutrients had significant community effects, indicating that there are significant differences in concentration values among some of the community types. Elements that showed these differences (at α =0.10) include P, K, Mg, SO_4^{-2}, and Na.

Community types that often displayed either high or low mean values were often the reclaimed or riparian north or south types. This is not surprising, given the historical anthropogenic manipulations of the reclaimed areas (plowing, cropping, irrigation, fertilization?), and the generally finer particle size distributions than in the grassland types. Riparian types also differ from grassland types in available soil water, organic matter inputs (and vegetation composition), topographic position, and age of materials. In short, it would be surprising if effects were not found.

Reclaimed areas had higher exchangeable K and Mg concentrations than other community types. The difference between the reclaimed type and the xeric and mesic types for Mg was significant at the α =0.10 level (means 4.54, 1.80, and 3.10 mg kg^{-1} respectively). Mean potassium concentration in the reclaimed type was significantly greater than the two riparian types, but not the other grassland types.

Riparian types had significantly greater soil P concentrations than the reclaimed type, but not the other grassland types. Phosphorus is a relatively insoluble element, and riparian types are probably sinks for erosional particles that contribute P to the profile. Soil sulfate and sodium concentrations were greatest in the riparian types, and also much more variable in this community type than the others (the standard deviation in the riparian types for SO_4^{-2} was approximately 6x greater than grassland standard deviations). The trend of greatest variability in the riparian types was observed for many variables, and is not surprising given the complexity of both the physical and biological conditions in these areas.

Some of the soil analyses also showed significant site-within-community effects. This indicates considerable variation within community types. This is probably related to significant watershed x community interactions that were seen for other variables, but not analyzed for this set. Future sampling may see experimental designs change to a watershed basis, or the analysis of riparian community types separately from grassland types.

C) Vegetation and Litter

Total element pools of above-ground vegetation are factors of element concentration and biomass (or littermass) production as previously explained. By collecting tissue on an area basis and analyzing a homogenized sample for element concentrations, an integrated value for that area is obtained. The variation of this variable is considerably less than those of species nutrient concentrations, and it provides a ready estimate of each community's element pool(s). It also more closely represents the diet available for indiscriminant hervibores like cattle or bison.

A surprising amount of variation was found in element pools among the 3 community types analyzed. At this time, it is not known if these differences are real, or sampling artifacts. However, if community types have distinct element distributions, this may be used as a relatively easy tool to not only distinguish community types from one another, but to potentially assess long term changes in community element distributions.

The data do show the very consistent relationship that the majority of the element pools are in litter mass, not above-ground vegetation.

FUTURE ANALYSES

Data on gaseous transformations of C and N, specifically carbon dioxide, methane, nitrogen fixation and dentirification under both anaerobic and aerobic conditions are now available. These data are not presented here but will be analyzed for future reports.

These data represent a single year and a single season. Differences between years and between seasons are large for some other parameters of the EcMP. Ecosystem functions will be measured along with the other population measurements. If contamination effects are less than normal and natural fluctuations in the ecosystem, that needs to be known before actions are undertaken or Natural Resource Damages are assessed.

This section of the report covered only ecosystem function measurements and some auxiliary measurements. Future reports will combine these data with data from soil fauna, vegetation, small mammals and other modules and with more general soil properties. The functioning and sensitivity of the whole ecosystem to contamination and perturbation need to be understood to provide solid background data and avoid costly remediation activities where they are not needed.

Figure A-1. Soil organic C concentrations.

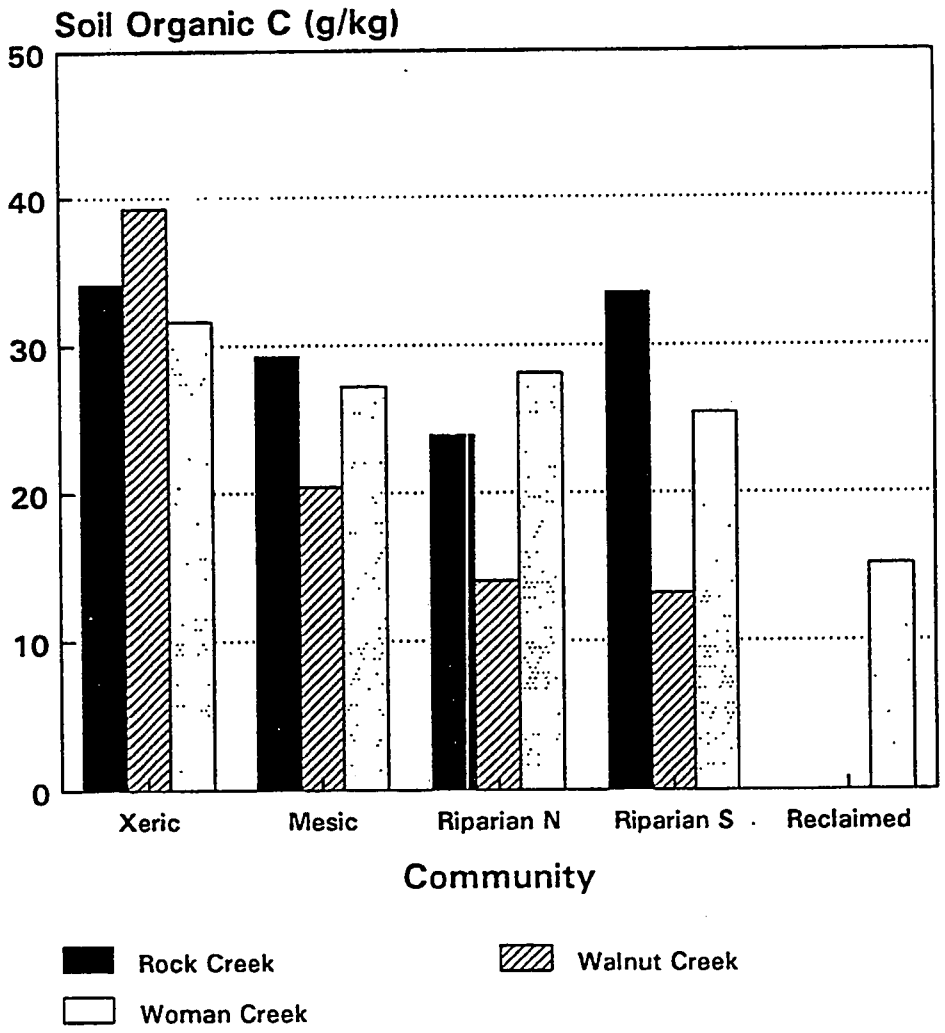


Figure A-2. Soil organic N concentrations.

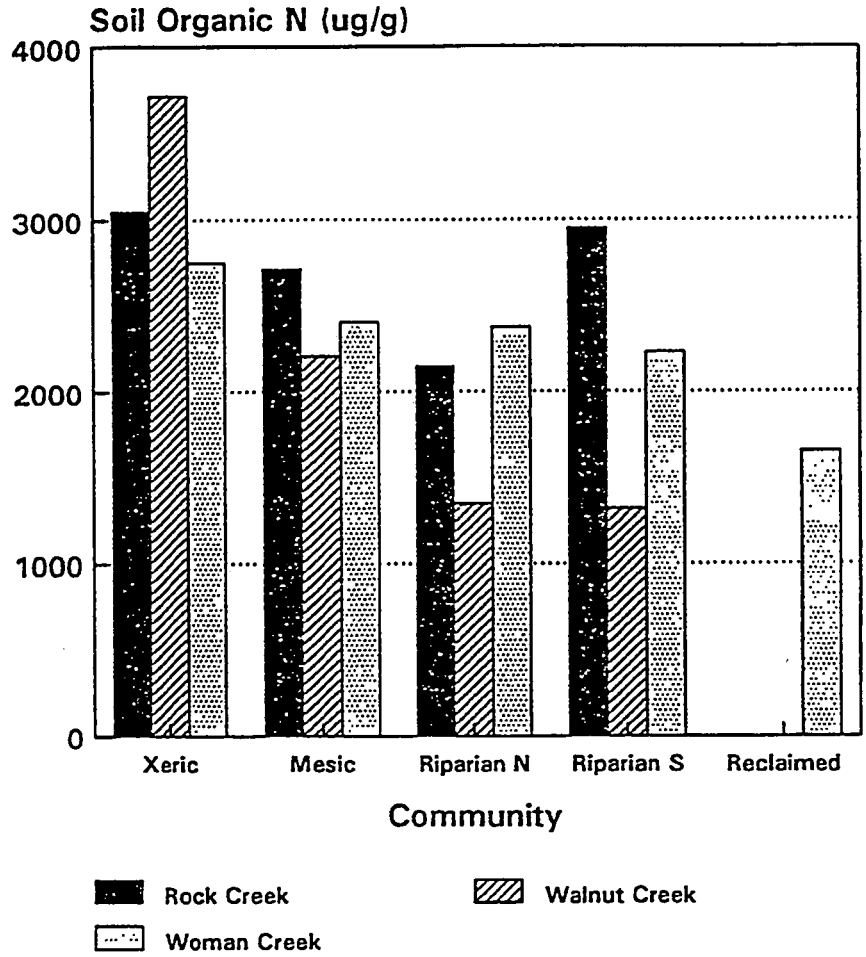


Figure A-3. Microbial biomass C concentrations.

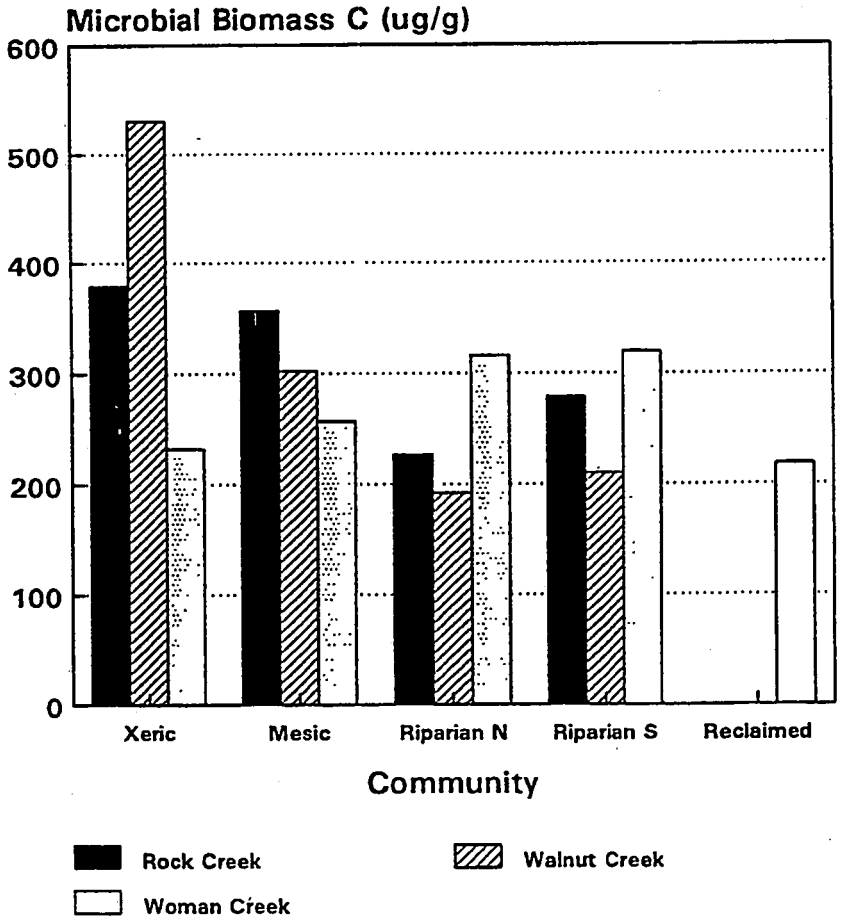


Figure A-4. Microbial Biomass N concentrations.

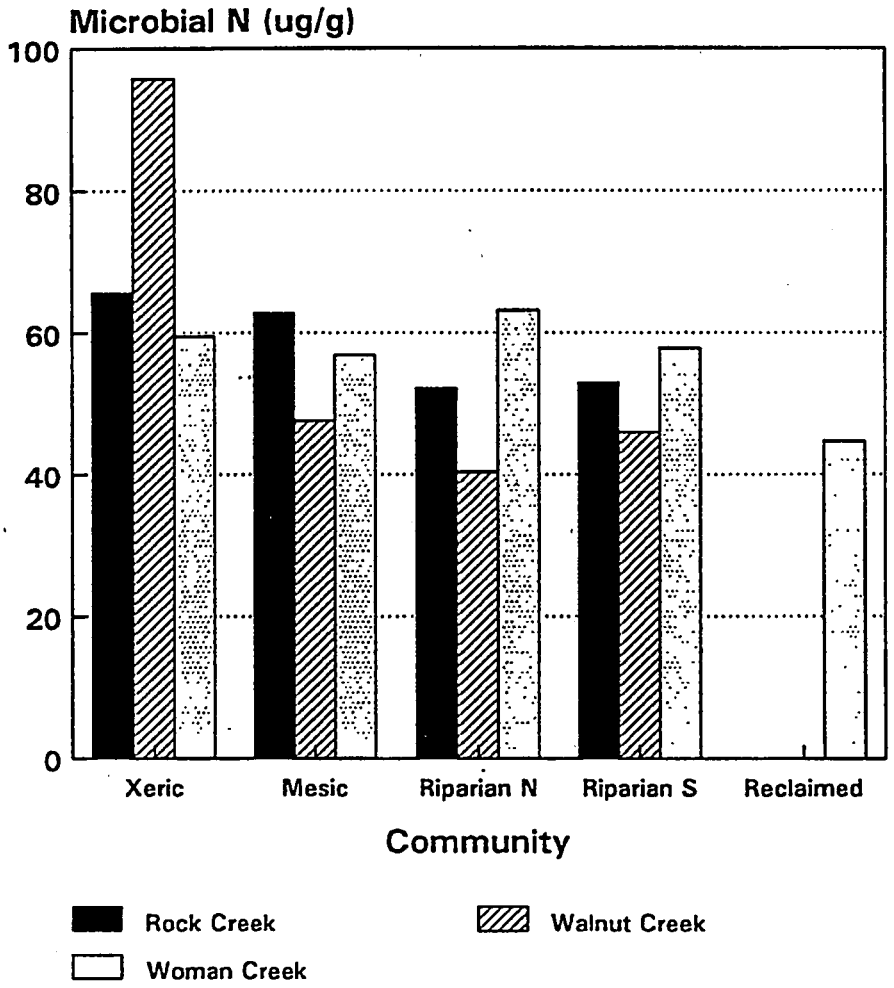


Figure A-5. Respirable C concentrations.

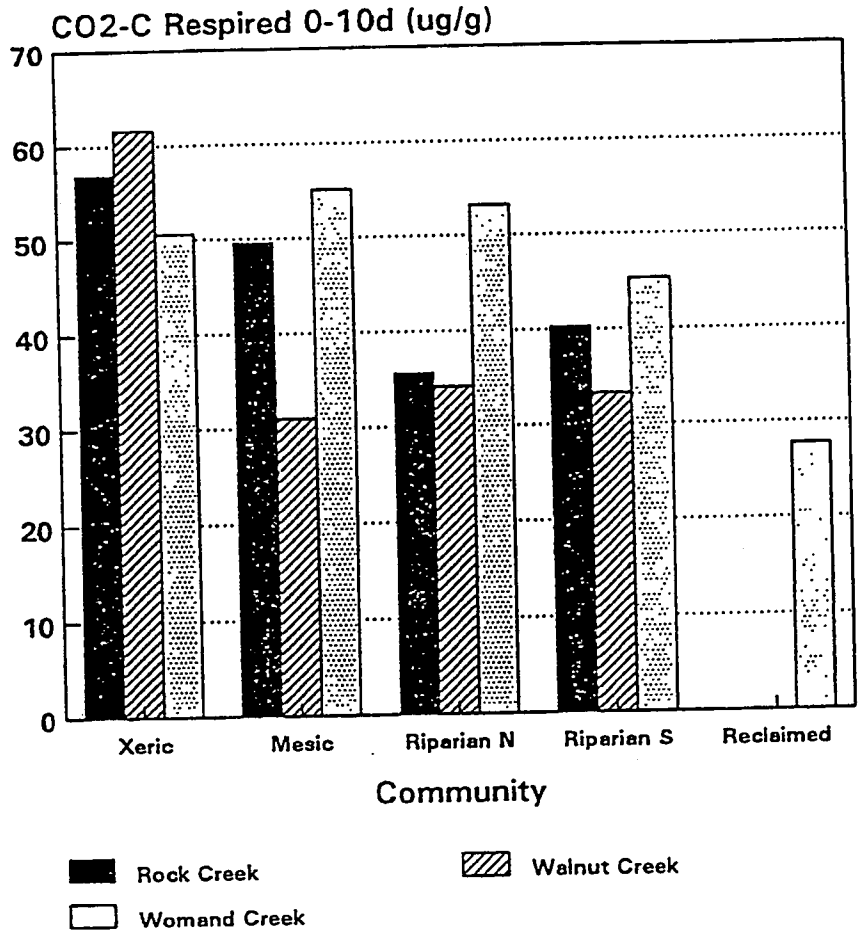


Figure A-6. Mineralizable N concentrations.

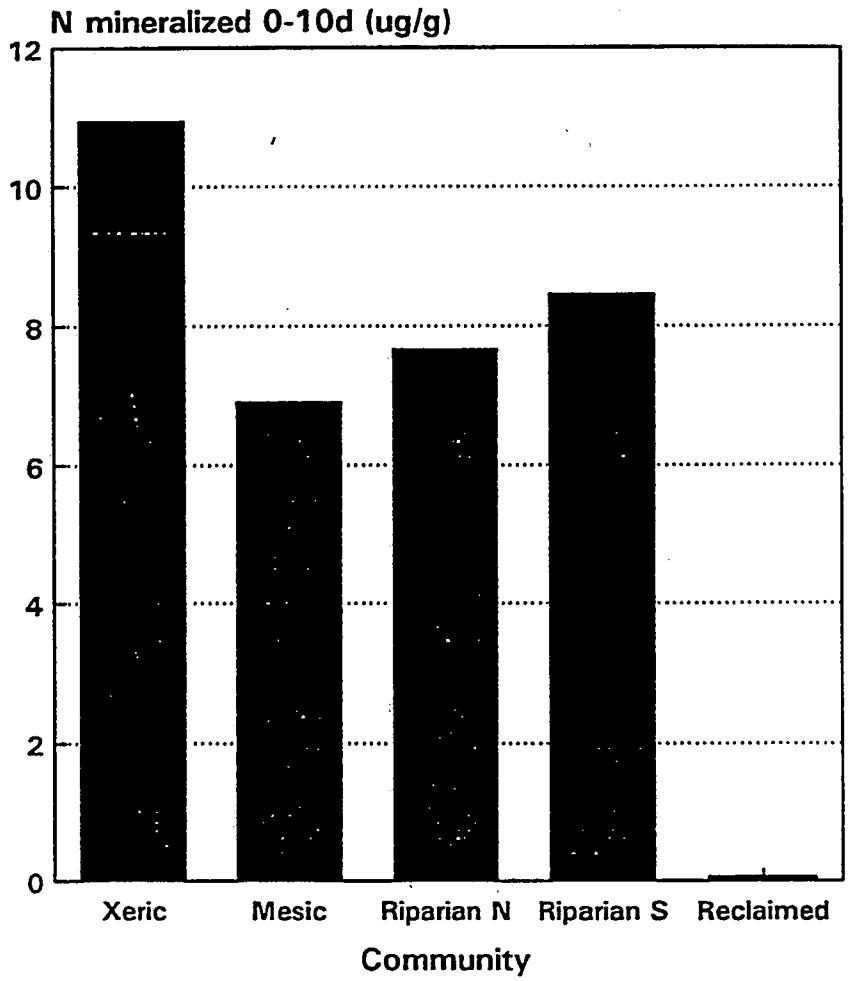


Figure A-7. Fine particulate organic C concentrations.

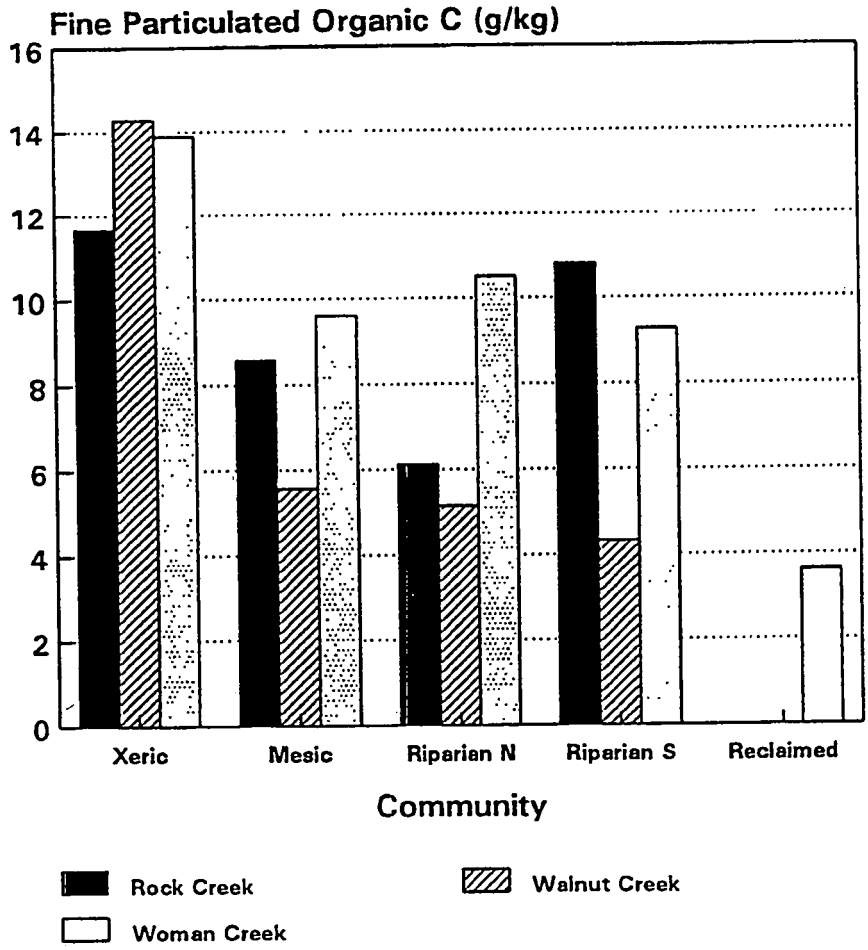


Figure A-8. Fine particulate organic N concentrations.

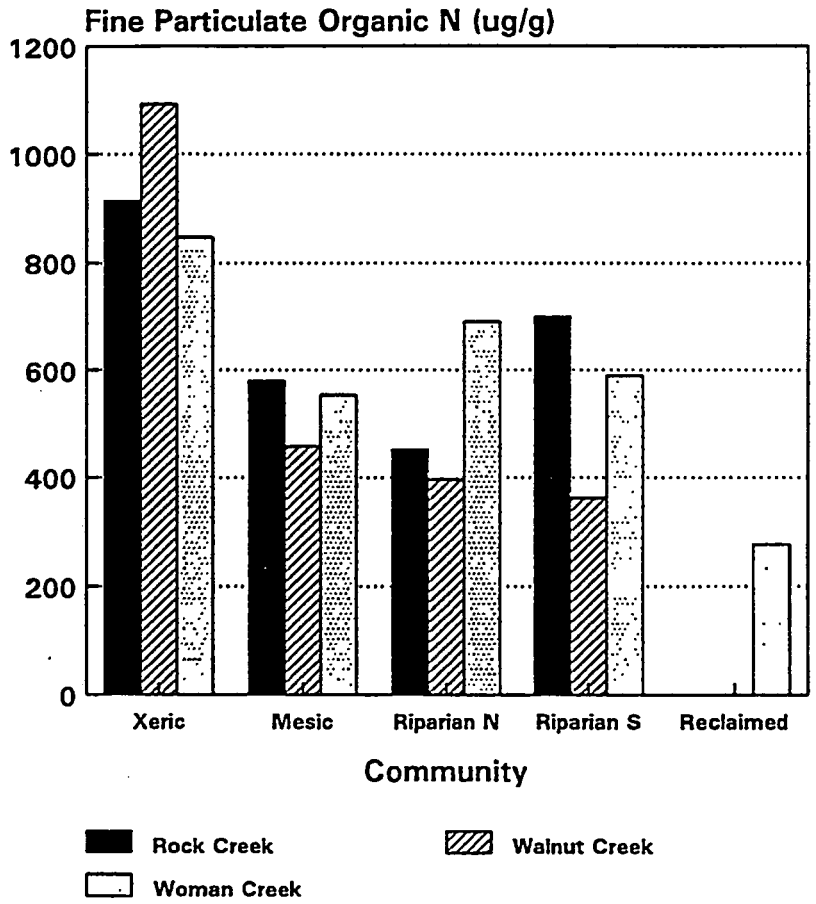
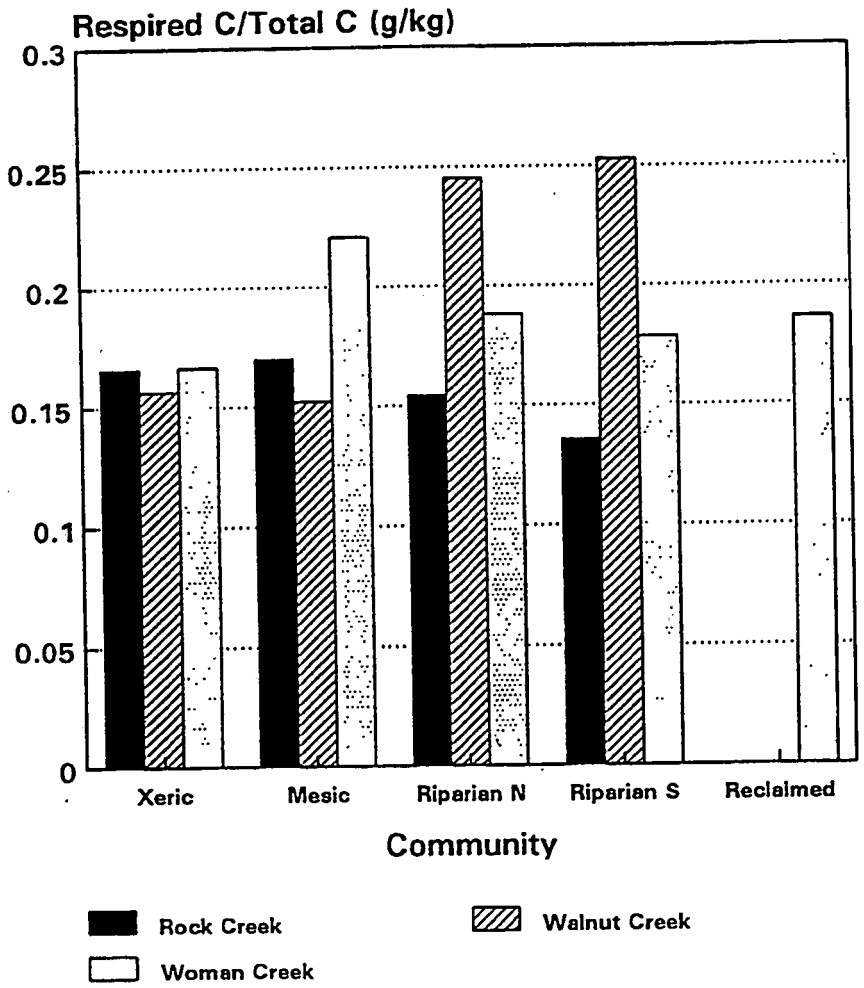


Figure A-9. Respirable C fractions.



F(6,62) = 3.06
Sig. of F = 0.01
HSD(13,60) = 0.11

Figure A-10. Microbial biomass C fractions.

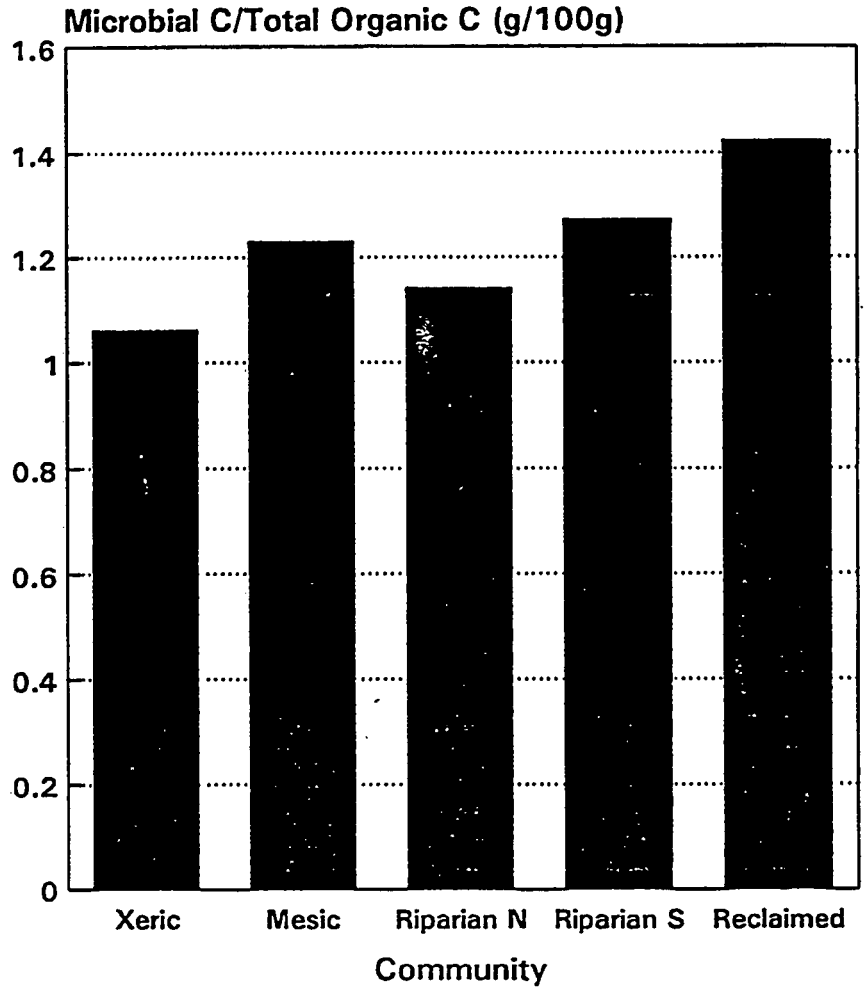


Figure A-11. Mineralizable N fractions.

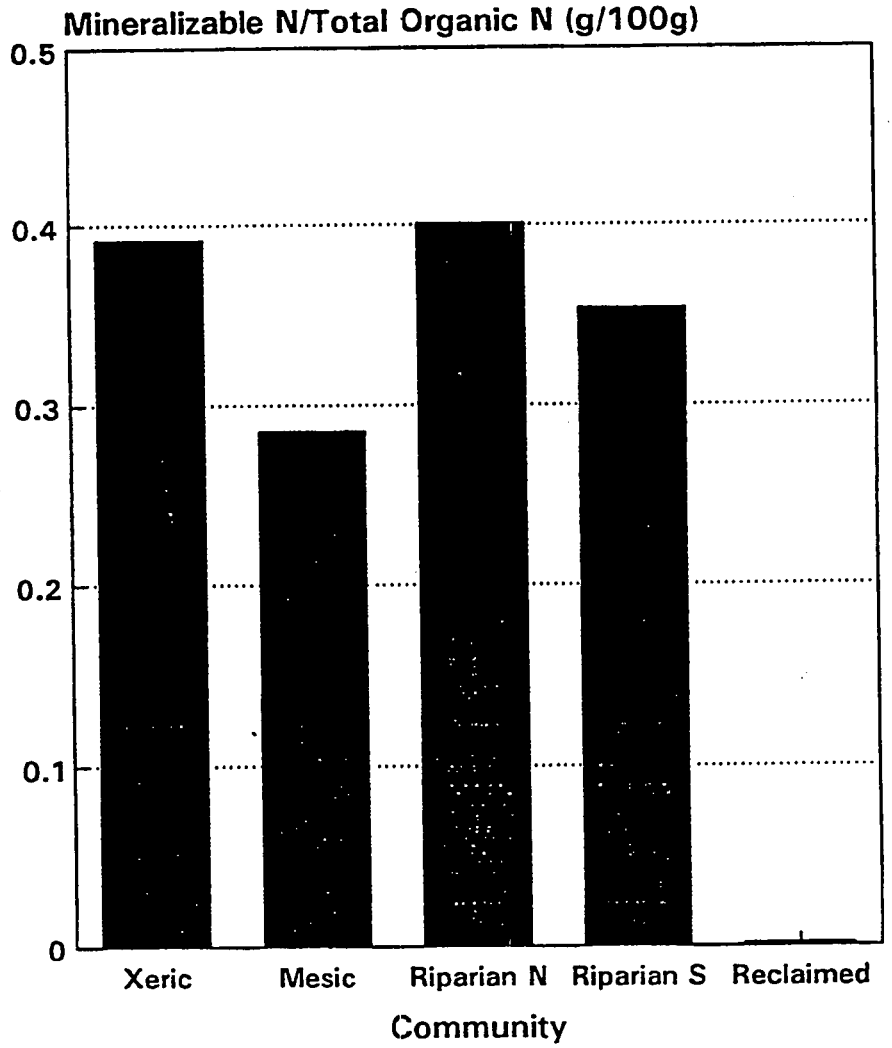


Figure 12. Fine particulate organic C fractions.

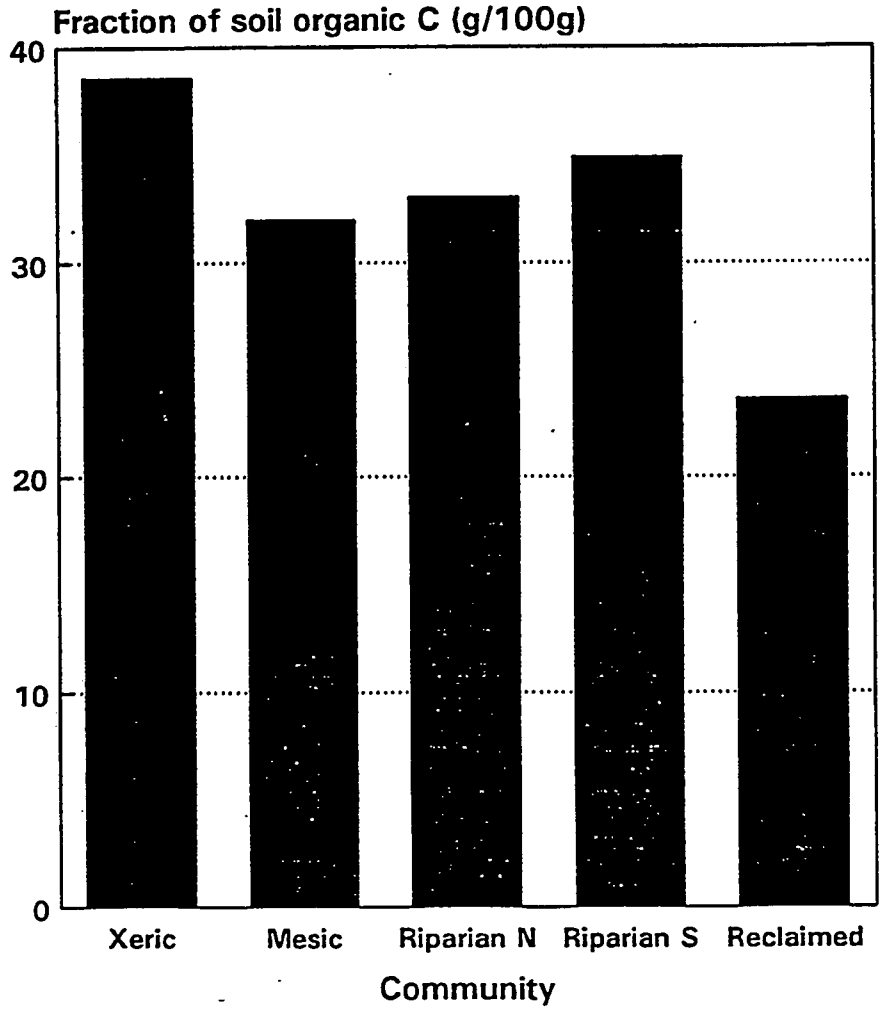


Figure A-13. Fine particulate organic N fractions.

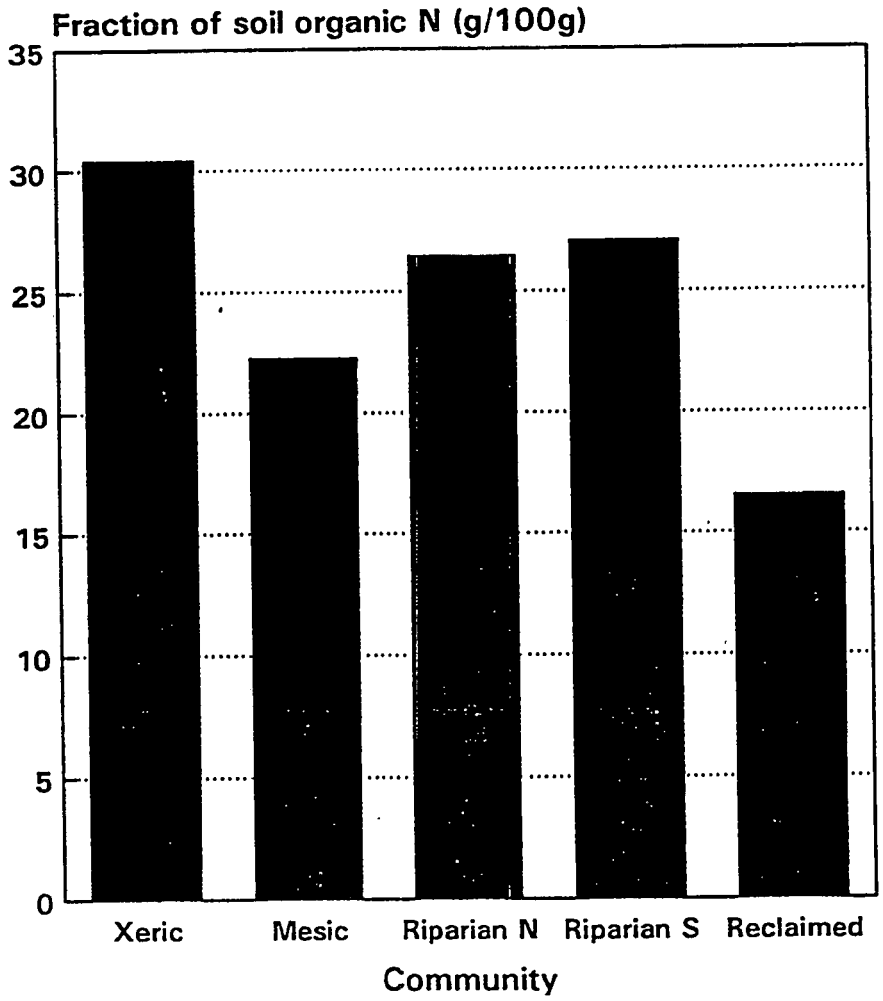


Table A-1 . Soil Texture of the surface 10 cm of Ecological Monitoring Program Sites by Community and Watershed.

			Sand	Silt	Clay	Texture
			g/g			
Community	Xeric					
Watershed		Rock	0.634	0.147	0.219	sandy clay loam
Watershed		Walnut	0.541	0.130	0.329	sandy clay loam
Watershed		Woman	0.668	0.117	0.215	sandy clay loam
	Average		0.615	0.131	0.254	sandy clay loam
Community	Mesic					
Watershed		Rock	0.339	0.234	0.427	clay
Watershed		Walnut	0.441	0.223	0.335	clay loam
Watershed		Woman	0.457	0.209	0.333	sandy clay loam
	Average		0.413	0.222	0.365	clay loam
Community	Riparian North					
Watershed		Rock	0.501	0.157	0.342	sandy clay
Watershed		Walnut	0.519	0.141	0.341	sandy clay loam
Watershed		Woman	0.412	0.180	0.408	clay
	Average		0.477	0.159	0.363	sandy clay
Community	Riparian South					
Watershed		Rock	0.470	0.183	0.347	sandy clay loam
Watershed		Walnut	0.512	0.145	0.343	sandy clay loam
Watershed		Woman	0.353	0.208	0.439	clay
	Average		0.445	0.179	0.376	clay loam
Community	Reclaimed					
Watershed		Woman	0.292	0.208	0.500	clay
	Average		0.292	0.208	0.500	clay
Average of all sites			0.448	0.180	0.372	clay loam

Table A-2. Analysis of Variance for Total Soil Organic Carbon by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	862295797.37	6	643715966.23	16.310	0.000
Community	2924654951.02	4	731163737.76	18.526	0.000
Watershed	783343705.633	2	391671852.82	9.924	0.000
2-way Interactions					
Community By Watershed	1160047826.37	6	193341304.39	4.899	0.000
Residual	2446993970.93	62	39467644.69		
Total	7469337594.67	74	100936994.52		

Table A-3. Analysis of Variance for Total Soil Organic Nitrogen by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	23257499.980	6	3876249.997	13.650	0.000
Community	18003952.319	4	4500988.080	15.850	0.000
Watershed	3240954.433	2	1620477.217	5.706	0.005
2-way Interaction					
Community By Watershed	9464545.967	6	1577424.328	5.555	0.000
Residual	17606468.400	62	283975.297		
Total	50328514.347	74	680115.059		

Table A-4. Analysis of Variance for Microbial Biomass Carbon by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	247967.647	6	41327.941	5.723	0.000
Community	191031.736	4	47757.934	6.614	0.000
Watershed	10643.033	2	5321.517	0.737	0.483
2-way Interaction Community By Watershed	308347.767	6	51391.294	7.117	0.000
Residual	447686.933	62	7220.757		
Total	1004002.347	74	13567.599		

Table A-5. Analysis of Variance for Microbial Biomass Nitrogen by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	7083.847	6	1180.641	6.165	0.000
Community	6624.393	4	1656.098	8.648	0.000
Watershed	40.300	2	20.150	0.105	0.900
2-way Interaction Community By Watershed	6002.767	6	1000.461	5.224	0.000
Residual	11873.333	62	191.505		
Total	24959.947	74	337.297		

Table A-6. Analysis of Variance for Respirable Carbon by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	763023.020	6	127170.503	10.181	0.000
Community	726665.971	4	181666.493	14.544	0.000
Watershed	121771.900	2	60885.950	4.874	0.011
2-way Interaction					
Community By Watershed	218025.700	6	36337.617	2.909	0.015
Residual	774448.800	62	12491.110		
Total	1755497.520	74	23722.939		

Table A-7. Analysis of Variance for Mineralizable Nitrogen by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	6228.048	6	1038.008	11.214	0.000
Community	5708.142	4	1427.035	15.416	0.000
Watershed	594.566	2	297.283	3.212	0.047
2-way Interaction					
Community By Watershed	596.994	6	99.499	1.075	0.387
Residual	5739.185	62	92.568		
Total	12564.227	74	169.787		

Table A-8. Analysis of Variance for Fine Particulate Organic Carbon by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	837050447.620	6	139508407.94	23.618	0.000
Community	792386317.069	4	198096579.27	33.536	0.000
Watershed	122247210.633	2	61123605.32	10.348	0.000
2-way Interaction Community By Watershed	137961392.567	6	22993565.43	3.893	0.002
Residual	366228843.600	62	5906916.83		
Total	1341240683.79	74	18124874.10		

Table A-9. Analysis of Variance for Fine Particulate Organic Nitrogen by Community and Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3642720.153	6	607120.026	30.778	0.000
Community	3314619.938	4	828654.985	42.009	0.000
Watershed	105136.633	2	52568.317	2.665	0.078
2-way Interaction Community By Watershed	636605.500	6	106100.917	5.379	0.000
Residual	1222995.733	62	19725.738		
Total	5502321.387	74	74355.694		

Table A-10. Analysis of Variance for the fraction of the total soil organic C found in microbial biomass: Microbial biomass percent by Community by Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	3.600	6	0.600	5.530	0.000
Community	1.787	4	0.447	4.118	0.005
Watershed	2.477	2	1.238	11.415	0.000
2-way Interaction					
Community By Watershed	1.037	6	0.173	1.593	0.164
Residual	6.726	62	0 .108		
Total	11.363	74	0.154		

Table A-11. Analysis of Variance for the fraction of the total soil organic N found in microbial biomass: Microbial biomass N percent by Community by Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	6.130	6	1.022	2.369	0.040
Community	2.672	4	0.668	1.550	0.199
Watershed	3.390	2	1.695	3.932	0.025
2-way Interaction					
Community By Watershed	3.535	6	0.589	1.366	0.242
Residual	26.733	62	0.431		
Total	36.397	74	0.492		

Table A-12. Analysis of Variance for the fraction of the total soil organic C in respirable C: Respirable C percent by Community by Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	0.031	6	0.005	1.973	0.083
Community	0.009	4	0.002	0.871	0.486
Watershed	0.022	2	0.011	4.148	0.020
2-way Interaction					
Community By Watershed	0.048	6	0.008	3.048	0.011
Residual	0.162	62	0.003		
Total	0.240	74	0.003		

Table A-13. Analysis of Variance for the fraction of the total soil organic N mineralized: Mineral N percent by Community by Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	4.011	6	0.669	11.466	0.000
Community	2.129	4	0.532	9.131	0.000
Watershed	2.362	2	1.181	20.258	0.000
2-way Interaction					
Community By Watershed	6.732	6	1.122	19.243	0.000
Residual	3.615	62	0.058		
Total	14.358	74	0.194		

Table A-14. Analysis of Variance for the fraction of the total soil organic C in fine particulate organic C percent fine particulate organic C by Community by Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	2578.498	6	429.750	5.411	0.000
Community	2541.707	4	635.427	8.001	0.000
Watershed	741.770	2	370.885	4.670	0.013
2-way Interaction Community By Watershed	407.623	6	67.93	0.855	0.533
Residual	4924.046	62	79.420		
Total	7910.167	74	106.894		

Table A-15. Analysis of Variance for the fraction of the total soil organic N in fine particulate organic N: percent fine particulate organic N by Community by Watershed.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	1808.435	6	301.406	9.275	0.000
Community	1607.309	4	401.827	12.366	0.000
Watershed	101.456	2	50.728	1.561	0.218
2-way Interaction Community By Watershed	141.255	6	23.542	0.724	0.631
Residual	2014.698	62	32.495		
Total	3964.387	74	53.573		

Table A-16. Analysis of Soil Properties

Nested Analysis of Variance, EcMP Soil Extractable Phosphorus

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	1142.2147	4	285.55367	3.75	0.0408
Sites within Community	760.22	10	76.022	1.29	0.2540
Residual	3522.032	60	58.700533		
Total	5424.4667	74			

Nested Analysis of Variance, EcMP Soil Exchangeable Potassium

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	2.2438987	4	0.5609747	7.02	0.0059
Sites within Community	0.799	10	0.0799	1.05	0.4136
Residual	4.56112	60	0.0760187		
Total	7.6040187	74			

Nested Analysis of Variance, EcMP Soil Exchangeable Calcium

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	270.27411	4	67.568529	1.24	0.3533
Sites within Community	543.12844	10	54.312844	8.55	0.0000
Residual	381.15432	60	6.352572		
Total	1194.5569	74			

Nested Analysis of Variance, EcMP Soil Exchangeable Magnesium

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	82.437805	4	20.609451	12.39	0.0007
Sites within Community	16.624933	10	1.662493	2.04	0.0440
Residual	48.79484	60	0.8132473		
Total	147.85758	74			

Nested Analysis of Variance, EcMP Soil Exchangeable Sulfate

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	143534.93	4	35883.733	3.41	0.0525
Sites within Community	105118.13	10	10511.813	0.79	0.6332
Residual	792833.6	60	13213.893		
Total	1041486.7	74			

Nested Analysis of Variance, EcMP Soil Exchangeable Sodium

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	1.141557	4	0.2853892	6.97	0.006
Sites within Community	0.4089912	10	0.0408991	1.49	0.1639
Residual	1.613155	59	0.0273416		
Total	3.1634662	73			

Nested Analysis of Variance, EcMP Soil Cation Exchange Capacity

Source	Sum of Squares	df	Mean Squares	F-Ratio	p - Value
Community	873.1245	4	218.28113	1.89	0.1887
Sites within Community	1154.6493	10	115.46493	5.32	0.0000
Residual	1300.356	60	21.6726		
Total	3328.1299	74			

All data from 0-10 cm depth and collected in 1993

Table A-17. Soil Properties for EcMP Community Types

Mesic Community

Soil Property	Count (n)	Average	Standard Deviation	Minimum	Maximum
Carbon Concentration	15	3.32867	0.732646	2.08	4.25
Nitrogen Concentration	15	0.282667	0.0601743	0.15	0.39
Phosphorus Concentration	15	11.5867	21.3512	7.2	25.4
Potassium Concentration	15	1.18267	0.409537	0.13	1.83
Calcium Concentration	15	11.27	2.99884	6.22	16.8
Magnesium Concentration	15	3.10533	0.895432	1.73	4.65
Sodium Concentration	15	0.202667	0.0830924	0.09	1.24
Sulfate Concentration	15	16.9333	3.45309	9	23
Cation Exchange Capacity	15	23.7333	6.91114	11.5	34.7

Reclaimed Community

Soil Property	Count (n)	Average	Standard Deviation	Minimum	Maximum
Carbon Concentration	15	2.12467	0.750703	1.51	4.45
Nitrogen Concentration	15	0.207333	0.0832781	0.13	0.44
Phosphorus Concentration	15	7.82	3.45171	5.8	10.9
Potassium Concentration	15	1.21867	0.107628	1.07	1.44
Calcium Concentration	15	15.9027	4.27479	9.84	21
Magnesium Concentration	15	4.53933	0.772283	3.25	5.99
Sodium Concentration	15	0.164667	0.00412667	0.09	0.32
Sulfate Concentration	15	20.9333	12.0799	5	44
Cation Exchange Capacity	15	30.2267	3.88412	22.2	34.9

Riparian North Community

Soil Property	Count (n)	Average	Standard Deviation	Minimum	Maximum
Carbon Concentration	15	2.81533	1.38559	1.27	5.36
Nitrogen Concentration	15	0.256667	0.122105	0.11	0.5
Phosphorus Concentration	15	19.4533	136.911	5.9	54.5
Potassium Concentration	15	0.824667	0.324761	0.44	1.46
Calcium Concentration	15	15.0967	2.70149	10.7	19.3
Magnesium Concentration	15	4.51333	1.54127	3.08	9.57
Sodium Concentration	15	0.408	0.0198457	0.15	0.58
Sulfate Concentration	15	149.667	241.448	15	937
Cation Exchange Capacity	15	25.52	7.25841	14	38.9

Riparian South Community

Soil Property	Count (n)	Average	Standard Deviation	Minimum	Maximum
Carbon Concentration	15	2.75133	1.41495	0.98	4.64
Nitrogen Concentration	15	0.264667	0.10412	0.12	0.43
Phosphorus Concentration	15	16.46	118.293	8.3	52.9
Potassium Concentration	15	0.842667	0.215422	0.41	1.17
Calcium Concentration	15	14.4753	2.33947	9.73	19.3
Magnesium Concentration	15	4.19267	0.88135	2.7	5.76
Sodium Concentration	15	0.400667	0.0385495	0.11	0.71
Sulfate Concentration	15	64.9333	46.0395	12	200
Cation Exchange Capacity	15	26.4133	6.79358	16.2	41.7

Xeric Community

Soil Property	Count (n)	Average	Standard Deviation	Minimum	Maximum
Carbon Concentration	15	5.134	1.14292	3.35	7.28
Nitrogen Concentration	15	0.410667	0.0704543	0.29	0.55
Phosphorus Concentration	15	12.9133	21.3512	7.6	25.2
Potassium Concentration	15	1.144	0.230211	0.87	1.72
Calcium Concentration	15	11.514	5.09126	7.9	21.5
Magnesium Concentration	15	1.802	0.272716	1.44	2.18
Sodium Concentration	14	0.110714	0.000145604	0.09	0.13
Sulfate Concentration	15	21.2	9.48081	9	35
Cation Exchange Capacity	15	19.78	3.67699	15.2	26.4

All data from 0-10 cm depth and collected in 1993

Table A-18. Summary Statistics for Rocky Flats Vegetation

Summary Statistics for Vegetation Aluminum at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	26.144	636.113	4.58	88.38	83.8	3554	376.15
Reclaimed Grassland	20	26.207	89.263	11.52	45.29	33.77	565	59.94
Xeric Mixed Grassland	7	3.64429	1.73983	1.85	5.46	3.61	1174	17.32

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Calcium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	882.903	1.06287E6	186.69	4024.33	3837.64	3554	12702.99
Reclaimed Grassland	20	461.482	16609.0	300.07	856.86	556.79	565	1055.55
Xeric Mixed Grassland	7	152.58	4535.57	73.88	275.79	201.91	1174	725.17

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Cadmium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.05	0.00502395	0.0	0.25	0.25	3554	0.77
Reclaimed Grassland	20	0.00	0.0	0.0	0.0	0.0	565	0.00
Xeric Mixed Grassland	7	0.01	0.0002	0.0	0.04	0.04	1174	0.05

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Cobalt at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.05	0.0063053	0	0.29	0.29	3554	0.72
Reclaimed Grassland	20	0	0	0	0	0	565	0.00
Xeric Mixed Grassland	7	0.01	0.0002	0	0.04	0.04	1174	0.05

Means are expressed as mg element / m^2

Table A-18 Cont'd. Summary Statistics for Rocky Flats Vegetation

Summary Statistics for Vegetation Chromium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.3145	0.104005	0.04	1.05	1.01	3554	4.52
Reclaimed Grassland	20	0.7325	0.0526934	0.42	1.14	0.72	565	1.68
Xeric Mixed Grassland	7	0.218571	0.0073476	0.08	0.3	0.22	1174	1.04

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Copper at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	1.1805	0.983016	0.15	3.17	3.02	3554	16.98
Reclaimed Grassland	20	0.1665	0.0034134	0.09	0.37	0.28	565	0.38
Xeric Mixed Grassland	7	0.12	0.0048	0.06	0.21	0.15	1174	0.57

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Iron at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	29.3705	974.505	5.83	134.67	128.84	3554	422.58
Reclaimed Grassland	20	19.5175	36.304	11.52	37.17	25.65	565	44.64
Xeric Mixed Grassland	7	4.10143	1.03655	2.93	5.46	2.53	1174	19.49

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Potassium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	1668.33	3662240	251.69	7706.16	7454.47	3554	24003.52
Reclaimed Grassland	20	951.484	73730.5	669.39	1641.73	972.34	565	2176.33
Xeric Mixed Grassland	7	300.763	13578	187.58	471.74	284.16	1174	1429.45

Means are expressed as mg element / m^2

Table A-18 Cont'd. Summary Statistics for Rocky Flats Vegetation

Summary Statistics for Vegetation Magnesium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	231.268	63827.6	45.92	984.68	938.76	3554	3327.43
Reclaimed Grassland	20	172.275	3946.66	102.14	379.46	277.32	565	394.05
Xeric Mixed Grassland	7	45.6557	984.479	18.76	105.24	86.48	1174	216.99

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Manganese at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	4.46	10.9903	0.75	11.99	11.24	3554	64.17
Reclaimed Grassland	20	11.4995	5.83666	7.54	16.58	9.04	565	26.30
Xeric Mixed Grassland	7	0.997143	0.201057	0.43	1.64	1.21	1174	4.74

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Molybdenum at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.0525	0.0066513	0	0.31	0.31	3554	0.76
Reclaimed Grassland	20	0.233	0.0100326	0.12	0.43	0.31	565	0.53
Xeric Mixed Grassland	7	0.01	0.0001667	0	0.03	0.03	1174	0.05

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Sodium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	9.8215	65.3394	2.41	35.53	33.12	3554	141.31
Reclaimed Grassland	20	6.193	11.7119	2.71	17.87	15.16	565	14.17
Xeric Mixed Grassland	7	1.78571	0.253929	1.07	2.54	1.47	1174	8.49

Means are expressed as mg element / m^2

Table A-18 Cont'd. Summary Statistics for Rocky Flats Vegetation

Summary Statistics for Vegetation Nickel at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.167	0.0102432	0.02	0.37	0.35	3554	2.40
Reclaimed Grassland	20	0.2425	0.0081566	0.11	0.4	0.29	565	0.55
Xeric Mixed Grassland	7	0.102857	0.0006905	0.06	0.13	0.07	1174	0.49

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Nitrogen at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	1.481	1.12213	0.45	4.25	3.8	3554	21308.26
Reclaimed Grassland	20	0.874	0.868057	0.36	4.54	4.18	565	1999.10
Xeric Mixed Grassland	7	0.302857	0.0028238	0.24	0.39	0.15	1174	1439.40

Means are expressed as g element / m^2

Summary Statistics for Vegetation Lead at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.069	0.0124516	0	0.39	0.39	3554	0.99
Reclaimed Grassland	20	0.0135	0.0017503	0	0.15	0.15	565	0.03
Xeric Mixed Grassland	7	0.0185714	0.0007476	0	0.07	0.07	1174	0.09

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Phosphorus at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	154.637	31358	32.54	770.62	738.08	3554	2224.88
Reclaimed Grassland	20	54.1835	184.107	32.62	86.91	54.29	565	123.93
Xeric Mixed Grassland	7	22.3143	32.8384	17.56	34.47	16.91	1174	106.05

Means are expressed as mg element / m^2

Table A-18 Cont'd. Summary Statistics for Rocky Flats Vegetation

Summary Statistics for Vegetation Sulfur at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	210.176	24981.4	70.76	642.18	571.42	3554	3023.96
Reclaimed Grassland	20	124.249	1949.56	76.61	269.3	192.69	565	284.20
Xeric Mixed Grassland	7	41.1757	380.027	25.7	79.83	54.13	1174	195.70

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Vanadium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	0.2455	0.0618155	0	1.03	1.03	3554	3.53
Reclaimed Grassland	20	0.0395	0.0008471	0	0.09	0.09	565	0.09
Xeric Mixed Grassland	7	0.0285714	0.0008476	0	0.07	0.07	1174	0.14

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Zinc at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	3.5285	6.15128	0.62	9.29	8.67	3554	50.77
Reclaimed Grassland	20	0.8535	0.0941818	0.34	1.64	1.3	565	1.95
Xeric Mixed Grassland	7	0.554286	0.0393619	0.29	0.83	0.54	1174	2.63

Means are expressed as mg element / m^2

Summary Statistics for Vegetation Carbon at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	20	65.0105	1837.53	20.19	185.38	165.19	3554	935355.09
Reclaimed Grassland	20	38.301	116.272	21.96	68.95	46.99	565	87606.06
Xeric Mixed Grassland	7	12.8614	4.57385	9.79	16.07	6.28	1174	61126.84

Means are expressed as g element / m^2

Table A-19. Summary Statistics for Rocky Flats Litter

Summary Statistics for Litter Aluminum at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	1431.53	5059150	59.51	9209.57	9150.06	3554	20596.50
Reclaimed Grassland	55	1861.38	15096800	217.86	24414.5	24196.7	565	4257.54
Xeric Mixed Grassland	35	888.86	666029	73.66	3346.1	3272.44	1174	4224.52

Means are expressed as mg element / m^2

Summary Statistics for Litter Calcium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	1948.91	5777650	71.3	8081.87	8010.57	3554	28040.44
Reclaimed Grassland	55	1222.47	1856730	337.69	7546.31	7208.62	565	2796.16
Xeric Mixed Grassland	35	1355.03	1686430	178.4	4431.32	4252.92	1174	6440.10

Means are expressed as mg element / m^2

Summary Statistics for Litter Cadmium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	0.446571	0.502917	0	2.83	2.83	3554	6.43
Reclaimed Grassland	55	0.200545	0.0903015	0	1.56	1.56	565	0.46
Xeric Mixed Grassland	35	0.206286	0.041677	0	0.86	0.86	1174	0.98

Means are expressed as mg element / m^2

Summary Statistics for Litter Cobalt at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	0.226857	0.297357	0	2.93	2.93	3554	3.26
Reclaimed Grassland	55	0.002	8.667E-05	0	0.06	0.06	565	0.00
Xeric Mixed Grassland	35	0.086	0.0119953	0	0.38	0.38	1174	0.41

Means are expressed as mg element / m^2

Table A-19 Cont'd. Summary Statistics for Rocky Flats Litter

Summary Statistics for Litter Nickel at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	1.12486	2.79473	0.05	6.58	6.53	3554	16.18
Reclaimed Grassland	55	1.614	6.39146	0	14.43	14.43	565	3.69
Xeric Mixed Grassland	35	1.22886	2.1468	0.07	6.91	6.84	1174	5.84

Means are expressed as mg element / m^2

Summary Statistics for Litter Nitrogen at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	3.542	19.6353	0.15	19.43	19.28	3554	50961.43
Reclaimed Grassland	55	1.71509	2.37588	0.44	7.75	7.31	565	3922.93
Xeric Mixed Grassland	35	2.93257	8.90718	0.32	11.88	11.56	1174	13937.73

Means are expressed as g element / m^2

Summary Statistics for Litter Lead at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	3.02857	21.0007	0.21	18.24	18.03	3554	43.57
Reclaimed Grassland	55	1.57727	4.47288	0	12.21	12.21	565	3.61
Xeric Mixed Grassland	35	3.30771	11.6536	0.27	13.57	13.3	1174	15.72

Means are expressed as mg element / m^2

Summary Statistics for Litter Phosphorus at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	284.255	158607	11.41	1635.17	1623.76	3554	4089.79
Reclaimed Grassland	55	160.881	20150.8	35.79	787.92	752.13	565	367.98
Xeric Mixed Grassland	35	198.769	44241.5	18.46	786.79	768.33	1174	944.70

Means are expressed as mg element / m^2

Table A-19 Cont'd. Summary Statistics for Rocky Flats Litter

Summary Statistics for Litter Sulfur at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	430.138	308089	18.54	2443.36	2424.82	3554	6188.72
Reclaimed Grassland	55	239.579	34652.2	60.35	826.11	765.76	565	547.99
Xeric Mixed Grassland	35	370.262	136728	40.29	1446.96	1406.67	1174	1759.76

Means are expressed as mg element / m^2

Summary Statistics for Litter Vanadium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	3.09571	25.7377	0.11	20.67	20.56	3554	44.54
Reclaimed Grassland	55	4.64564	79.643	0.13	53.27	53.14	565	10.63
Xeric Mixed Grassland	35	1.72229	2.59031	0.12	6.33	6.21	1174	8.19

Means are expressed as mg element / m^2

Summary Statistics for Litter Zinc at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	15.4934	365.797	1.13	65.78	64.65	3554	222.92
Reclaimed Grassland	55	9.19291	142.067	1.82	67.69	65.87	565	21.03
Xeric Mixed Grassland	35	9.66686	77.6139	1.11	36.17	35.06	1174	45.94

Means are expressed as mg element / m^2

Summary Statistics for Litter Carbon at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	160.421	37012.4	5.6	781.91	776.31	3554	2308097.91
Reclaimed Grassland	55	90.7382	4230.27	23.23	317.11	293.88	565	207545.92
Xeric Mixed Grassland	35	118.102	11223.5	14.94	362.66	347.72	1174	561307.62

Means are expressed as g element / m^2

Table A-19 Cont'd. Summary Statistics for Rocky Flats Litter

Summary Statistics for Litter Chromium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	1.43743	5.01505	0.08	9.21	9.13	3554	20.68
Reclaimed Grassland	55	2.55073	16.9498	0	24.41	24.41	565	5.83
Xeric Mixed Grassland	35	2.138	9.46179	0.08	14.3	14.22	1174	10.16

Means are expressed as mg element / m^2

Summary Statistics for Litter Copper at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	4.35857	23.4865	0.17	18.8	18.63	3554	62.71
Reclaimed Grassland	55	2.50491	8.95751	0.36	16.65	16.29	565	5.73
Xeric Mixed Grassland	35	2.95171	7.94448	0.26	12.66	12.4	1174	14.03

Means are expressed as mg element / m^2

Summary Statistics for Litter Iron at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	1220.43	4089020	51.72	8519.02	8467.3	3554	17559.25
Reclaimed Grassland	55	1608.19	5942480	152.5	13317	13164.5	565	3678.42
Xeric Mixed Grassland	35	710.867	436037	60.93	2622.62	2561.69	1174	3378.56

Means are expressed as mg element / m^2

Summary Statistics for Litter Potassium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	977.753	1976080	34.22	6202.36	6168.14	3554	14067.67
Reclaimed Grassland	55	657.953	505294	161.41	4217.06	4055.65	565	1504.94
Xeric Mixed Grassland	35	685.585	341355	63.79	1989.57	1925.78	1174	3258.40

Means are expressed as mg element / m^2

Table A-19 Cont'd. Summary Statistics for Rocky Flats Litter

Summary Statistics for Litter Magnesium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	431.723	338271	24.24	2067.45	2043.21	3554	6211.52
Reclaimed Grassland	55	404.189	342227	91.23	3551.21	3459.98	565	924.50
Xeric Mixed Grassland	35	260.144	52135.5	29.88	813.92	784.04	1174	1236.40

Means are expressed as mg element / m^2

Summary Statistics for Litter Manganese at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	35.1646	3384.2	1.56	219.78	218.22	3554	505.94
Reclaimed Grassland	55	42.9404	2732.61	7.85	288.54	280.69	565	98.22
Xeric Mixed Grassland	35	22.8289	358.861	2.55	76.87	74.32	1174	108.50

Means are expressed as mg element / m^2

Summary Statistics for Litter Molybdenum at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	0.0017143	0.0001029	0	0.06	0.06	3554	0.02
Reclaimed Grassland	55	0.0110909	0.0030469	0	0.38	0.38	565	0.03
Xeric Mixed Grassland	35	0	0	0	0	0	1174	0.00

Means are expressed as mg element / m^2

Summary Statistics for Litter Sodium at Rocky Flats

Vegetation Community Type	Number of samples (n)	Average	Variance	Minimum	Maximum	Range	Acres at RFETS	kg element in community type
Mesic Mixed Grassland	35	27.9186	1314.3	1.04	156	154.96	3554	401.69
Reclaimed Grassland	55	23.864	478.905	6.74	122.07	115.33	565	54.58
Xeric Mixed Grassland	35	20.9994	376.277	2.42	68.77	66.35	1174	99.80

Means are expressed as mg element / m^2

APPENDIX B) TERRESTRIAL VEGETATION

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BACKGROUND

The diversity of plant communities at the Rocky Flats Environmental Technology Site (Site) are a result of the ecotonal effect found along the Front Range of Colorado. The mixing of prairie and foothills species in the diverse habitats provided by the varied physical environment has resulted in a vegetational mosaic which is rapidly disappearing with human encroachment along the Front Range.

Plant distribution, composition, and abundance are influenced by many environmental factors. Local climate, topography, and geology, all part of the physical environment, control abiotic factors such as light, temperature, moisture, and nutrients, which directly affect plant growth. In addition, biotic factors such as competition, herbivory, availability of pollinators, and nitrogen fixation by bacteria, interact with the abiotic factors to create habitats. Plant survival in these habitats requires availability of natural resources necessary for them to grow and reproduce. The spatial and temporal variation of biotic and abiotic factors found at the Site allow for the diversity of the distinct plant communities found here. Additionally, the human impact at the Site involving physical disturbance and/or contamination of soils and groundwater interacts with the pre-existing biotic and abiotic factors to modify plant habitats in measurable ways.

Ecological monitoring of the abundance and distribution of plant species is important to the Environmental Restoration Mission at the Site for several reasons. Variation in plant species composition may indicate human disturbance at a given site. The composition, abundance, and dispersion of plant species at a site determine the quality of wildlife habitat at a site and strongly affect soil stabilization. Since vegetation ground cover is the primary factor in soil stabilization, effective establishment of vegetation may be the first concern in reclaiming a contaminated site. As primary producers, plants are the first link in terrestrial food chains. In addition to any direct effects on plant growth (e.g., phytotoxicity), metals or other contaminants present in the soil may accumulate in plant tissue and be transferred to herbivores and their predators. Finally, it provides a general description of the Site and serves as a model from which all other terrestrail sampling is derived.

The data collected in this Ecological Monitoring Program (EcMP) Study Module will be used to document patterns of association among plant species at the Site, which will contribute to the further definition of the distinct plant communities at the Site (identified in the Baseline Report, U.S. Department of Energy, 1992). Long-term data sets from this program will be used to quantify both spatial and temporal variation in these associations. By correlating variation in plant species distribution and abundance with physical factors at a given site, it may be possible to predict changes in plant communities with various types of anthropogenic disturbance. Thus, the findings of this study module could aid in the development and evaluation of reclamation procedures, as well as the future management of the Site.

OBJECTIVES

The objective of this study is to characterize and monitor changes in the composition, distribution, and production of plant species within the major plant communities located at the Site (Baseline Study(U.S. Department of Energy, 1992)). In addition, the information gathered can be used to assess qualitative and quantitative changes in the vegetation resulting from human activities and/or natural disturbances and processes occurring at the Site.

HYPOTHESES

A number of hypotheses, some of which are listed in the EcMP Program Plan, may be addressed by data collected by the Terrestrial Vegetation Module. The data were used to test hypotheses concerning the plant distribution, species richness, basal cover types, percent native species, and production of plant species by site and communities represented by the 12 EcMP study sites. They include:

1) H_O: Species richness does not vary among sites and communities at the Site.
   H_A: Species richness does vary among sites and communities at the Site.

2) H_O: Composition and relative importance of basal cover types do not vary among sites and communities at the Site.
   H_A: Composition and relative importance of basal cover types do vary among sites and communities at the Site.

3) H_O: Species composition by native species versus non-native species does not vary by site and community at the Site.
   H_A: Species composition by native species versus non-native species does vary by site and community at the Site.

4) H_O: Herbaceous plant production does not vary among the grassland sites communities at the Site.
   H_A: Herbaceous plant production does vary among the grassland sites communities at the Site.

5) H_O: Litter production does not vary among grassland sites and communities at the Site.
   H_A: Litter production does vary among grassland sites and communities at the Site.

METHODS

EcMP Terrestrial Study Sites

The EcMP Terrestrial Vegetation Module monitors 12 permanent study sites located in the buffer zone at the Site (Figure 1). The study sites are located in uncontaminated areas and represent three replicates of four community types. Included are nine grassland sites and three riparian sites. The grassland sites are divided into 3 community types, roughly following the hydrologic gradient zones (xeric=dry, mesic=moderate moisture, hydric=wet) defined in the Baseline Report (U. S. Department of Energy, 1992). Xeric grasslands are the driest of the communities and occur at the highest elevations on Site. Found on the hilltops in the buffer zone, the xeric community comprises approximately 18% (481 ha; 1,189 ac) of the Site. The mesic community has an intermediate moisture availability and is primarily found on hillsides at the Site. Comprising 77% of the land on Site, it represents the largest of the community types (2,038 ha; 5,033 ac). Two types of mesic communities (mesic mixed grassland and reclaimed grassland) were of interest here. Differences between the two communities are related to past management practices. The reclaimed community was previously farmed agricultural land, while the mesic community was grazed lands. Neither use has occurred on Site for the past 20 years. The riparian community represents the most hydric of the communities. It has the most available moisture and is found along the streams and at seeps which flow from the hillsides. The riparian community is the smallest of the communities sampled, representing only 5% (133 ha; 329 ac) of the Site.

Field Methods

The field sampling methodology used for the spring 1994 sampling session is described in the Ecological Monitoring Program - Program Management/Technical Performance Report - GHS-462-93 (Appendices 2 and 4, Ecological Monitoring Program,1993). The field sampling methodology used for the late summer sampling session is described in the Vegetation Sampling Standard Operating Procedure (SOP) (4-H64-ENV-ECOL.10, Revision 0). In addition, more specific, detailed field instructions (although following the SOP methods) were written for the belt transect, point-intercept transect, and production plot methods for use as field training manuals for the late summer sampling.

During the 1994 field season, data were collected during two sampling sessions. The first occurred in the spring, from May 3 through May 25. The second sampling session ran from August 8 through October 4. Five 50-m long permanent terrestrial vegetation transects, located at each of the twelve sites, were sampled. At the riparian sites, these transects were halved, with one half on each side of the stream channel. Three different sampling methods were employed during 1994. The spring sampling consisted of belt transect sampling at all 12 EcMP sites. For the late summer sampling, three different types of measurements were taken at the nine grassland study sites: belt transect, point-intercept transect, and production plot. Sampling at the three riparian sites during the late summer differed from the grasslands in that no production plot data were taken. A brief description of the sampling methods follows. For more details, refer to the Program Management/Technical Performance Report, Terrestrial Vegetation SOP, and field training manuals, mentioned above.

Belt Transect

Species richness was determined in a 2-m wide belt centered along each permanent 50-m transect. Every plant species observed within this 100 m^2 area was recorded and its phenological state noted, and the densities of woody and succulent species determined. Densities were determined for the grassland sites during the spring sampling only. Densities were determined at the riparian sites for both the spring and late summer sampling, since some adjustment of the actual transect lines had taken place after the spring sampling to make them follow the stream channel more closely. Density measurements will hereafter be done on an annual basis. A total of 60 belt transects, five at each site were sampled during both the spring and late summer sessions.

Point-intercept Transect

Transects at all 12 EcMP terrestrial sites were sampled by the point-intercept method during the late summer session. Basal and foliar cover were determined at 50-cm increments along each transect for a total of 100 "hits" per transect. A 2-m long rod with 0.25 inch diameter, was dropped along the right side of a tape measure stretched along the 50-m length of the transect. Two types of hits were observed: basal and foliar. Material at ground level was recorded for the basal hit. A basal hit could be vegetation (live plant), litter (fallen dead material), rock (greater than the diameter of the point-intercept rod), bare ground, or water in that order of importance. Importance was determined by a cover type's potential to protect the soil from erosion.

Three categories of foliar hits were defined by height and growth form. The topmost hit of each growth form was recorded. The growth forms measured were herbaceous, woody <2-m in height, and woody >2-m in height. A total of 60 point-intercept transects were sampled, five at each of the 12 sites.

Production Plot

Production plots were sampled only at the nine grassland EcMP sites during the late summer sampling. No production plot sampling was done at the three riparian sites. Five randomly located 0.25 m^{-2} quadrats were placed outside each belt transect for a total of five quadrats/transect, times five transect/site, times 12 sites = 225 quadrats.. The height of the three tallest graminoid individuals of each species was measured. Biomass was determined by clipping all herbaceous material within the quadrat. Clipped material was sorted into two biomass classes: current year dead (CYD) and current year live (CYL). Both CYL and CYD were sorted by species. Litter was also collected from the quadrats. Oven dry weights were determined for each sample collected and recorded on drying forms. Biomass results, given in grams/meter^2 (gm^{-2}), were calculated from the actual quadrat values.

Quality Assurance/Quality Control

Data were collected onsite by EcMP personnel. Nomenclature was standardized using the Flora of the Great Plains (Great Plains Flora Association, 1991) as the primary reference, and data were recorded on field sheets in the form of unique site, wildlife habitat, and species codes. If a plant species could not be identified with confidence in the field, plant species were recorded as unknowns on the field data sheets. Voucher specimens were made of unknown species and later identified by keying, making comparisons with known specimens in the reference collection or herbarium collection, or by trips to the University of Colorado Herbarium in Boulder. In some cases due to lack of key characteristics, specimens were only identified to the family or genus level. If a specimen could not even be identified to that level it was ignored. Taxa identified to the family or genus level were only included in calculations when there were no verified species from the same family or genus present at the site.

Prior to data entry, all unknown specimens were identified and corrections made to the field data sheets. Data entry and QA of database files were done by EcMP personnel. The QA process used for data entry was as follows:

-data entry,
-printout hardcopy of electronic file for proofreading,
-initial 100% proofreading of hardcopy,
-corrections made to the database from the corrected hardcopy proofreading pages,
-second hardcopy printout after corrections made to database,
-second proofreading consisting of checking corrections made to database,
-if errors still found another round of correcting and proofreading followed,
-if no errors were found then a spot check of two records from each page of the final proofreading printout were made.

Each stage of the QA process was documented by a signature on a Quality Assurance Form.

Data Analysis

Data analysis of the 1994 Terrestrial Vegetation data was conducted during the winter of 1994-1995 and consisted of the following reductions and analyses:

- Species Richness
  -Species lists by site and by community in tabular form
  -number of families, number of species, percent natives, number of annuals, number of biennials, number of perennials, growth form (forb, graminoid, cactus, shrub, vine, tree), type (dicot, monocot, pteridophyte), form (herbaceous, succulent, woody), by site, by community
  -Woody stem and cactus densities by site and by community

- Cover
  -Basal cover (vegetation, litter, rock, bare ground, water) summaries by site and by community
  -Foliar, shrub, and tree cover by site and by community
  -Basal cover dominant species by site and by community
  -Foliar, shrub, and tree cover dominant species by site and by community
  -Percent native basal and foliar cover by community

- Biomass
  -Current year production by site and community
  -Litter by site and community
  -Percent native biomass by site and community
  -Biomass dominant species by site

- Ordination and Classification
  -Community ordination and classification using the following statistical programs:
    -DECORANA - Detrended Correspondence Analysis and reciprocal averaging methods by overall species richness at EcMP sites and by transects (Hill, 1979a)
    -TWINSPAN - Two -way Indicator Species Analysis (Hill, 1979b)
    Both of these analyses are explained further in the results section.

One-way analysis of variance (ANOVA), using a Tukey means separation, was performed on cover and biomass data to determine if differences between sites and differences between communities were significant at the α=.05 level. Variances were checked and a Cochran's C test run to determine if the variances were equal. In addition, residuals were plotted against predicted values to make sure they were evenly distributed. Site and community were considered separately as the factors. Analyses were performed using the statistical program Statgraphics, on an IBM compatible computer. Correlation analysis was also performed using Statgraphics between current year production and litter biomass amounts to see how they were related to each other.

In addition, the Current Approved Species List (CASCL) list, the official flora list for the Site, was also analyzed. Determinations were made for number of families, number of genera, number of species, percent native, number of annuals, number of biennials, number of perennials, numbers for growth form and life form categories, number of endemics, and number of species of special concern. A list of plant species found in 1994 and not previously recorded for the Site was also generated.

DATABASE STATUS

Data from the 1994 sampling sessions were originally recorded on field data sheets by hand in black ink. After the identification of unknown plant specimens were made, the data from the field data sheets were entered into one of three types of terrestrial vegetation database files. The files were for belt transect, point-intercept transect, and production plot data and were generated separately for spring and fall sampling. The process of data entry and QA was done as mentioned previously in the Quality Assurance/Quality Control section. Four electronic database files were made from the 1994 field season terrestrial vegetation sampling. They are:

Belt941.dbf - 2788 records - spring 1994 belt transect data,
Belt942.dbf - 3660 records - fall 1994 belt transect data,
PIT942.dbf - 990 records - fall 1994 point intercept data, and
Quad942.dbf - 1832 records - fall 1994 production plot data.

STATUS OF THE SITE HERBARIUM

The Site herbarium is currently incomplete. During 1994, an inventory of the specimens found in the herbarium revealed that the only mounted specimens in the collection were those which were given to the Site by the University of Colorado after an initial botanical inventory in 1974. Since that time collections which have been made of the Site flora have not been labelled, mounted, or placed in the collection. Attempts have been made to identify and locate necessary information needed for labels for numerous plant specimens found in newspapers in the herbarium cabinet. However, progress is slow and many specimens are not of high enough quality to make herbarium mounts. The result is that there are no voucher specimens for many of the species on the CASCL which lists all the currently accepted species for the Site. This represents a problem, since the accepted standard botanical practice is to create a species list based on collected specimens, which documents the occurrence of a species at a site. This is the scientifically accepted method because it allows for independent verification of the species on the plant list, should there ever be concern whether a given species actually occurs at a site or if a misidentification was made. At present, this independent verification is not possible.

In order to remedy the situation the following steps have been taken. In 1994, a database was set up for the herbarium collection and all the current herbarium specimens were entered into it. A list of the specimens contained in the database was printed out and compared to the CASCL list. Then a collection list of those species which need a specimen for documentation was made. During the 1995 field season, collections will be made of those species needed to complete the collection in order to bring the collection up to date. These will then be labelled, mounted, and filed in the herbarium collection. This will greatly enhance and facilitate vegetation work at the Site.

SITE DESCRIPTION

Community types were named and defined using terminology from the Baseline Report (U. S. Department of Energy, 1992). The three xeric grassland sites (TR01, TR06, and TR12) are all located on relatively flat ridgetops (Figure 1). TR01 is located in the Rock Creek watershed in the northwestern corner of the Site. This area is relatively undisturbed although a gravel mining operation exists to the west of this site and the site may be destroyed by mining activities in the near future. TR06 is located on the eastern portion of the Site just north of the East Access Road on the edge of the montane-plains ecotone in which the Site lies. Its vegetation differs from the other two xeric sites. TR12 is located in the southwestern portion of the Site on a terrace. It is also undisturbed, but gravel mining is planned for the area. All three of the xeric sites are located in the land area acquired in 1974 and were grazed until that time.

The mesic grassland sites (TR02, TR04, and TR11) are all located on gently sloping southeast facing slopes. Slope angles range from 6-16°. TR02 lies in the Rock Creek watershed east of TR01. TR06 lies in the Walnut Creek watershed and TR11 lies in the southern portion of the Buffer Zone in the Smart Ditch drainage of the Woman Creek Watershed. These sites also lie within the land area acquired in 1974.

The reclaimed grassland sites (TR07, TR08, and TR09) are all located in the southeastern portion of the Site which was farmed prior to 1974. It has since been reseeded. The topography is rather flat with gentle slopes of 7-8°.

The riparian sites are TR03, TR05, and TR10. TR03 is located in the Rock Creek drainage, which has remained relatively undisturbed by Site activities. One TR03 transect, transect 5, is located within the boundaries of the 1952 acquisition and has not been grazed in over 40 years. The other four transects are located in the area acquired in 1972. TR05 is located in Walnut Creek downstream from the industrial area. Portions of this site have been riprapped with boulders of

sandstone and basalt. All of the TR05 transects are located in the land area acquired in 1974. Water entering the Walnut Creek channel is controlled by plant personnel. TR10 is located in the southern side of the Site in the Smart Ditch drainage, which is a natural drainage with controlled flow from Rocky Flats Lake. Two of the TR10 transects, transects 1 and 2 , are located within the boundaries of the 1952 Site land acquisition. All riparian sites slope gently at 2-3°; one transect at TR03 lies on a steeper slope with an angle of 19°.

All EcMP site corners and transects have been located using a Global Positioning System (GPS) and mapped. Slope angle and aspect were recorded at each end of each of the Terrestrial Vegetation transects. All site location information has been entered into the database and may be used to determine height above water, horizontal distance to water, and distance to human activity. This information may correlate with community composition.

RESULTS

This section summarizes the belt transect, point-intercept, and production plot data. Ordination and classification results are also presented. In addition, a list of plant species collected for the first time on Site is presented. Summaries are presented by the use of tables and figures primarily, with the text highlighting some of the important facts. The interpretation, discussion, and comparison of the results with other studies may be found in the discussion.

NOTE: For the analyses which are presented, the following "rules" were applited. Taxa identified only to the family or genus level were only included in the calculations which follow when there were no verified species from the same family or genus present at the same site or community. When determining the percent of native species at a site or community, since no genera or families have a species status, they were left out of the determinations altogether. When counting the number of annuals, biennials, and perennials, plants identified to genus were included in the counts only if the species known to occur here could be placed in one category or another. In cases where a species could be an annual, biennial, perennial, or a combination of these, (as listed in plant manuals), the following rules were applied. A biennial was counted as biennial when it was considered to be only a biennial. Plants were counted annuals only when considered an annual or annual/biennial. Plants were counted perennial whenever they were considered to be perennials, even though they may occur as annuals or biennials also. As used in the results and discussion which follow, totals for sites are based upon a mean from data from five transects (n=5). If a mean is given for the community total, it is based on the means for the three sites that represent that community (i.e. TR01, TR06, and TR12 = the xeric community). In other cases, however, the community value is based on a combination all three sites for the given community to determine the total value for the variable being considered for that community (i.e., total species richness for the xeric community = 133 as compared to the xeric mean species richness = 89). If a mean value is given in the text, it will be designated as a mean value. If no such designation is given, it is a combined value.

Species Richness

Flora

During the 1994 field season, 21 plant species previously unknown from the Site were collected, identified, verified at the University of Colorado Herbarium in Boulder, and assigned unique species codes. These new species include those collected both inside and outside the Ecological Monitoring Program permanent transects. They are:

Draba reptans (Lam.) Fern.	DRRE1
Microsteris gracilis (Hook.) Greene	MIGR1

Euphorbia spathulata Lam.	EUSP1
Erysimum repandum L.	ERRE1
Hybanthus verticillatus (Ort.)Baill.	HYVE1
Asperugo procumbens L.	ASPR1
Senecio tridenticulatus Rydb.	SETR1
Senecio fendleri Gray	SEFE1
Astragalus parryi Gray	ASPA1
Potentilla pensylvanica L.	POPE1
Solidago rigida L.	SORI1
Picradeniopsis oppositifolia (Nutt.)Rydb.	PIOP1
Triodanis sp. Raf.	TRI2
Agrostis scabra Willd.	AGSC1
Parietaria pensylvanica Muhl. ex Willd.	PAPE1
Aster fendleri A. Gray	ASFE1
Triticum aestivum L.	TRAE1
Aster hesperius A. Gray	ASHE1
Asclepias stenophylla Gray	ASST1
X *Agrohordeum macounii* (Vasey) Lepage	AGMA1
Agropyron spicatum(Pursh) Schrib. and Sm.	AGSP1

The new species were added to the CASCL, bringing the total to 512 species for the Site. A summary table of the Site flora is found in Table B-1. Endemic species were determined by reference to Weber and Wittman (1992). Species of concern were determined using an unpublished list from the Colorado Natural Heritage Program (1994). During the 1995 field season herbarium quality specimens of these new species will be collected if one has not already been collected. (Often the identifications from 1994 were made using lesser quality specimens. Properly collected specimens will be labelled and mounted and placed in the Site herbarium.) The specimen of *Triodanis* was only identifiable to genus, since it lacked the key characteristics necessary for species determination.

EcMP Sites And Communities

A total of 271 species of vascular plants representing 51 families and 73 genera were documented from the EcMP terrestrial vegetation permanent transect sites during the 1994 field season (Table B-2). Native species represented 81% of the total flora. Thirty-nine species were annuals, three species were biennials, and 228 species were perennials. Of the 271 species, 199 were dicots, 68 monocots, and four were pteridophytes. Classified by life form, 251 species were herbaceous, 15 were woody, and five were succulent. Classified by growth form, the flora included 190 forbs, 61 graminoids, nine shrubs, five trees, five cacti, and one vine. These data were obtained by combining the species lists from belt transects (100 m^2/belt x 5 belts/site x 12 sites = 6000 m^2 sampled) and production plot samples (0.25 m^2 quadrats x 5 quadrats/belt x 5 belts/site x 9 grassland sites = 56.25 m^2). The total number of species found at the EcMP sites comprises approximately 52% of the total flora for the Site. Presently the total Site flora has 512 species, as listed on the CASCL.

None of the species documented at the EcMP sites were listed as threatened or endangered, however, one species (*Carex oreocharis* Holm.) was present at TR02 and was listed as a species of concern by the Colorado Natural Heritage Program (Colorado Natural Heritage Program, 1994). It was listed with a global ranking of G3 which means it is considered rare to uncommon. The state listing was an S? which means it is believed to be rare, but it is awaiting formal rarity ranking.

Summaries of species richness data are reported for the EcMP study areas by both site and by community in Table B-2 and Figures B-1 and B-2. The highest species richness occurred at the

riparian sites and communities (based on site means and combined site values, respectively), followed by the mesic, xeric, and reclaimed sites and communities. The difference in mean species richness was only one species between the mesic and riparian community (103 and 104 species, respectively). However, at the community level, the combined total differences between the mesic and riparian communities were greater - 143 and 163 respectively. Species richness at the xeric sites and communities fell between that for the mesic and reclaimed sites, with a mean of 89 and a total of 133 species, respectively.

Woody Stem And Cactus Densities

Stem densities were determined for woody stems and cacti from the belt transects (Table B-3 and Figure B-3). The greatest density of cacti was found at the xeric community which had a mean density of 0.65 cacti m^{-2}. The highest site density was at TR12 which had 0.95 cacti m^{-2}. The lowest cactus density was found at the reclaimed communities with a density of 0.01 cacti m^{-2}. Only the riparian community had a woody density of any sizable amount (6.42 stem m^{-2}). Of the riparian sites, TR10 had the highest woody stem density with 9.13 stems m^{-2}.

Species Composition

Although 271 species of vascular plants were documented at the EcMP study sites, the species found in the various communities differed considerably. The range of tolerance of different plant species varies considerably in response to factors such as soil moisture, light, temperature, slope, aspect, wind, competition, and herbivory. As Table B-2 shows, certain species are common across different habitats while others are restricted to the specific habitat requirements found only at certain sites. The arrangement of sites in the table is from xeric to mesic to hydric (riparian). The reclaimed sites fit the mesic category, but have been isolated in the table due to their great difference in species richness.

Three species were found to occur at all 12 EcMP study sites - *Tragopogon dubius*, *Poa pratensis*, and *Bromus japonicus*. All three species (one forb and two graminoids, respectively) are non-native, adventive species. Three other forbs, *Aster ericoides*, *Camelina microcarpa*, and *Alyssum minus*, were found at every site except one. Of these three, only *Aster ericoides*, a composite, is native. The other two are non-native, adventive mustards.

The riparian community with the highest species richness also had the greatest number of species (88) restricted to that community. The xeric and mesic communities each had 22 species restricted to them and the reclaimed community had only six species restricted to it. The species restricted to each community type are listed in Table B-4.

The species composition of a site or community may also be examined in terms of the growth form (forb, graminoid, cactus, shrub, vine, or tree), percent native species, life form (annual, biennial, or perennial or herbaceous, succulent, or woody), and type (dicot, monocot, or pteridophyte). Summaries of the 1994 EcMP terrestrial site species compositions by these categories are found in Table B-5 and Figures B-4, B-5, B-6, B-7, and B-8. Summaries by community are found in Table B-5 and Figures B-9, B-10, B-11, and B-12. Community summaries were determined by combining the three site floras for that community - not based on the mean values for the sites making up the community.

Forbs and graminoids made up the largest portion of the flora at the Site in all communities and at all sites (Figures B-6 and B-11). The number of graminoid species averaged about 21 at the xeric and mesic sites with two to five additional species found at the riparian sites (Figure B-6). The reclaimed sites were rather depauparate in terms of number of graminoid species (five to eight species). Forb numbers were relatively consistent at the xeric sites (62-66) and mesic sites (70-79), but varied most at the riparian sites, ranging from 48-80 (Fgiure B-6). Shrub and tree species

were most abundant at the riparian sites and community (Fgiure B-6). The greatest percentage of native species were found in the xeric community. In general, the percent native species decreased by community type in the order xeric, mesic, riparian, reclaimed Figure B-9). However, on a site basis, two of the mesic sites (TR02 and TR11) had a greater percentage of native species than TR06 (a xeric site, Figure B-4). Perennial species far outnumbered annual species present at the sites and at the communities (Figures B-5 and B-10, respectively). The highest numbers of annual species were found at the mesic sites and community. The dicot versus monocot figures (Figures B-7 and B-12) showed a strong similarity to the forb versus graminoid figures (Figures B-6 and B-11) at the site and community levels, in that forbs and dicots outnumbered graminoids and monocots by factors greater than two or three to one.

Cover

Basal cover is a measure of the amount of vegetation cover at the ground's surface. This measure is important, because vegetation acts to protect the soil from wind and water erosion. Basal cover point-intercept sampling records the cover at the soil's surface as either vegetation, litter, rock, bare ground, or water. The results of the point-intercept sampling for basal cover are presented by site and by community in Tables B-6 and B-7 and Figures B-13 and B-14. A one-way ANOVA (factor=site or community, Tukey means separation procedure) was done for the basal cover classes vegetation, litter, rock, and bare ground at both the site and community levels. Water was not analyzed since it only occurred at the riparian community. Results exhibited in Figures B-13 and B-14, showed that significant differences existed between sites and between communities for each cover class. The missing letters in Figure B-13 for litter and rock at TR05 are due to the fact that the variances for each of these cover classes at TR05 were much larger than those of the other sites (Table B-6). The ANOVA was run without the data for TR05 for these two cover classes.

At the community level, the highest vegetation basal cover was found in the mesic community (mean=29%, Table B-7). This difference was found to be significant (α=0.05 level), compared to the reclaimed community (11.2%), but not to the riparian or xeric communities (Figure B-14). The reclaimed community had the lowest amount of vegetation cover (11.2%) and the greatest amount of litter cover (70.4%, Table B-7). This only differed significantly (α=0.05 level) from the mesic community (55.3%), but not significantly from the xeric or riparian communities (Figure B-14). The lowest amount of litter cover was found in the mesic community. Rock cover was highest in the mesic and xeric communities (14% and 13.9% respectively, Table B-7). These two communities differed significantly (α=0.05 level) from the riparian community which had the lowest mean rock cover (5.2%, Figure B-14). The reclaimed community was intermediate in terms of rock cover. The highest amount of bare ground cover occurred in the reclaimed community (5.1%, Table B-7) and was significantly higher than any other community (α=0.05 level, Figure B-14). The lowest amount of bare ground cover occurred in the riparian community (1.3%).

Between sites, TR04, a mesic community site, had the highest amount of vegetation basal cover (40%, Table B-6) and it was significantly different (α=0.05 level) from seven of the other sites studied (Figure B-13). TR04 did not differ significantly from any of the other mesic sites, however. It was significantly different from all of the reclaimed sites. TR08 (a reclaimed community site), had the lowest amount of vegetation cover (6.8%, Table B-6). Significant differences (α=0.05 level) were found for litter cover between TR04 and four other sites (Figure B-13). TR04 had the lowest amount of litter cover (51%) and TR03, a riparian community site, had the highest amount at 74% (Table B-6). Significant differences (α=0.05 level) were also found for rock cover between sites. Rock cover at TR01, a xeric community site, and TR02, a mesic community site, was found to be significantly higher than four other sites (Figure B-13). Although rock cover was greatest at TR05, a riparian community site, it was not included in the ANOVA because the variances were extremely large compared to the other sites (Table B-6). Of those sites analyzed by ANOVA, TR01, had the

highest amount of rock cover (21.6%) while TR06, a xeric community site, had the lowest amount (3.4%, Table B-6). Bare ground cover was highest at TR08, a reclaimed community site (Table B-6) and was found to differ significantly (α=0.05 level) from 10 other sites (Figure B-13). The only site it did not differ significantly from was TR07, another reclaimed community site. Water cover was only found at the riparian community type (Table B-6) and was not analyzed statistically.

Foliar, shrub, and tree cover are measures of the amount of vegetation cover above the ground's surface (the canopy as projected vertically to the ground). The amount of cover present is important as it affects the amount of light reaching the ground surface, the temperature of the ground surface, the amount of moisture reaching the ground in a precipitation event, the rate of moisture loss from the surface, and the wind speed at ground surface. The results of the sampling for foliar, shrub, and tree cover are summarized by site and by community in Tables B-6 and B-7. The foliar cover in the three grassland communities was highest in the mesic community (91.3%) followed by the xeric community (87%) and reclaimed community (80.2%, Table B-7). A one-way ANOVA (factor=site or community , Tukey means separation procedure) was done for foliar cover at both the site and community levels. Results from the ANOVA on foliar cover by site and by community revealed variances at the riparian sites, TR03, TR05, and TR10, to be extremely high compared to the non-riparian sites (Tables B-6 and B-7) and model assumptions were violated. Therefore the results were not used.

The only community with any significant vertical stratification was the riparian community. It had the lowest amount of foliar cover of grasses and forbs (66.5%), but the highest amounts of both shrub and tree cover (39.8% and 18.6% respectively, Table B-7). Although the xeric and mesic communities did have a shrub layer, the shrubs were sparsely distributed, and the amount of cover provided by this layer was less than 2% in each community (Table B-7). A check of the variances for the shrubs present at both the xeric and mesic sites and communities revealed that their variances were not close to that of the riparian community (Tables B-6 and B-7) and so they were not included in the ANOVA. Therefore, shrub and tree cover were tested for significance only for the riparian sites. The results showed that between the three riparian sites, both shrub and tree cover were highly non-significant. The ANOVA for the shrub cover had an F-ratio of 0.210 with a significance level of 0.8132 and the ANOVA for the tree cover had an F-ratio of 0.439 with a significance level of 0.6545.

Species richness (combined) from the point-intercept sampling data alone (basal and foliar cover) increased from the reclaimed to xeric to mesic and then to the riparian communities (Table B-8). This paralleled the findings of the combined belt transect and point-intercept species richness data, in which species richness increased in the same community order (Table B-5). The highest percentage of native species, in terms of species richness from cover data, was found in the xeric communities, followed by mesic, riparian, and reclaimed communities in that order. However, the percentages of native versus non-native species comprising the basal and foliar cover varied considerably between the different communities (Table B-8). In the xeric community, native species made up over 80% of both relative native basal and foliar cover. This declined to just over 50% for the riparian and mesic communities. In the reclaimed community, native species made up only 2% of the total relative basal and foliar cover.

The dominant species by community (means) based on basal and foliar cover are shown in Table B-9. Dominant species by site (means) for basal cover are shown in Table B-10 and for foliar cover in Table B-11. In the xeric community, *Stipa comata* was the dominant species for both basal and foliar cover. However, differences were found to exist between the three sites which have been designated as the xeric community. Although *Stipa comata* was dominant at TR06 and TR12, it was not even in the top five at TR01. TR01 was dominated by *Andropogon scoparius*. At the xeric sites, TR06 had the highest non-native cover, based on the top five cover species, in terms of both basal and foliar cover. The mesic community, was dominated largely by *Bromus japonicus*

- a non-native annual grass, however *Andropogon smithii* and *Bouteloua gracilis*, both natives, were common in terms of basal and foliar cover. The reclaimed sites were completely dominated by *Bromus inermis* and *Agropyron intermedium* - both non-native, planted species. In the riparian community, foliar cover was dominated by *Juncus balticus*. However, non-native species such as *Poa pratensis*, *Poa compressa*, and *Cirsium arvense* also comprised a large part of both the basal and foliar cover. Dominant species for shrub and tree cover are only presented for the riparian sites since significant stratification was found only at these sites. *Salix exigua* was the dominant shrub at TR05, while at TR10 it shared its dominance with *Amorpha fruticosa*. At TR03, *Amorpha fruticosa* is the dominant. Tree cover at the riparian sites was dominated by *Populus deltoides* at TR03 and TR10, while at TR05, *Salix exigua*, (> 2m tall) comprised more of the cover than *Populus deltoides*. (Shrubs were considered woody species < 2m tall; trees were considered woody species > 2m tall).

Biomass

Biomass is a measure of the amount of above ground vegetation produced during a given growing season. The vegetation is clipped at ground level at the time of maximum growth (usually late summer for grasslands), then sorted by species for current year live and current year dead, dried, and weighed. The resulting weights in grams per square meter provide a means of comparing the production from one site or community to that of another. The results from the nine EcMP grassland sites are found in Table B-6 and Figure B-15. Biomass comparisons by community are presented in Table B-7 and Figure B-16. No biomass data were gathered from the riparian sites

Of the three grassland communities studied, the reclaimed community had the highest amount of current year production (145.8 gm^{-2}, Table B-7). The lowest amount of current year production was found in the mesic community (120.1 gm^{-2}Table B-7). A one-way ANOVA (factor=community, Tukey means separation procedure) showed a significant difference (α=0.1 level) in current year production between the reclaimed and mesic communities (Figure B-16). The xeric community had the highest amount of litter (262.9 gm^{-2}) and the mesic communities had the least (225 gm^{-2}). No significant differences (α=0.1 level) were found for litter between communities. No production plot data was gathered at the riparian community type. For this analysis the five quadrat values for each transect were averaged for each transect. Then the analysis was done with an n=15 (fifteen transects per community).

Significant differences (α=0.05 level) were shown to exist between sites for both current year production and litter using a one-way ANOVA (factor=site, Tukey means separation procedure, Figure B-15). This analysis was done after averaging five quadrat values for each transect. Then the analysis was done with an n=5 (five transects per site). TR09 (a reclaimed site) had the highest site current year production value (177.71 gm^{-2}, Table B-6). TR09 differed significantly (α=0.05 level) for current year production from five other sites (Figure B-15). Within the reclaimed community, TR09 (178 gm^{-2}) differed significantly from TR08 (120 gm^{-2}, Figure B-15). In the xeric community, TR01 (102 gm^{-2}) had significantly lower current year production than TR06 (157 gm^{-2}, Figure B-15). No significant differences for current year production occurred between the mesic community sites (Figure B-15).

Significant differences (α=0.05 level) were also found for litter biomass between sites (Figure B-15). The site with the highest litter biomass was TR06 (342.8 gm^{-2}), while TR04 had the least (148.5 gm^{-2}, Table B-6). No significant differences for litter biomass were found between any of the reclaimed sites (Figure B-15), however significant differences were found between sites in the xeric community and in the mesic community. In the xeric community, TR01 (179 gm^{-2}) differed significantly from TR06 (342.8 gm^{-2}). In the mesic community, TR04 (148.5 gm^{-2}) differed significantly from TR11 (319.4 gm^{-2}, Figure B-16). A correlation analysis calculated from the 225

quadrats of 1994 production plot data revealed that current year production and litter amounts had a correlation coeffiecient of R^2=0.3387 ($p<0.000$).

The biomass amounts produced by native versus non-native species by site and by community varied considerably (Table B-12, Figures B-17 and B-18). The xeric community had the highest amount of biomass produced by native species (71%). This compared to 63% and 0.22% at the mesic and reclaimed communities respectively. Within the xeric community, native species biomass accounted for 91% and 87% at TR01 and TR12, respectively. But at TR06, native species biomass accounted for only 46% of the total. This was largely due to high biomass amounts of non-native species, *Linaria dalmatica*, *Poa compressa*, *Alyssum minus*, and *Sisymbrium altissimum*, found at TR06 (Table B-13). In the mesic community, native species biomass accounted for 74% and 66% at TR02 and TR11, respectively, while they made up only 48% at TR04. *Bromus japonicus* found at TR04 accounted for a high percentage of the non-native species biomass found there (Table B-13). Native species biomass accounted for less than 1% at each of the reclaimed sites. This was due mostly to the large amounts of non-native *Agropyron intermedium* and *Bromus inermis*, which have been planted at these sites (Table B-14).

Multivariate Analysis

Ordination

Ordination is a method commonly used by community ecologists to organize plant community data based on species presence/absence exclusively. It does not take into account other environmental data, but instead leaves environmental interpretation to the expertise of the scientists involved and often requires supplemental studies to relate the ordination axes to their appropriate environmental parameters. The result of an ordination analysis are an arrangement of species and/or samples in two-dimensional space such that closely related groups of species or samples are clustered together and those not closely related are further apart. The first step in the ordination produces a graphical representation of the species or samples. The second step is the interpretion of the graphical representation in terms of environmental factors, to explain the patterns that have been revealed (Gauch, 1982).

One of the goals of ordination analysis is the production of a grouping of related samples (transects or species in this study) based on the type of data used (in this case species presence/absence data). The results commonly display a continuum between transects (or species) which is representative of the relationships between the transects (or species) in their environmental setting. A continuum is displayed along each axis, with each axis representing a unique environmental parameter. The x-y plot of transect (or species) points in two-dimensional space, clusters the transects (or species) which are closely related, based on the two unknown environmental factors represented by the x- and y-axes. With the availability of this information for reference site transects, it is possible to incorporate information from remediation sites (transect data based on species presence/absence taken prior to, during, and after remediation activities) to determine where the remediation site transects fit in relation to the reference transects from the different plant communities at the Site. If, for example, a remediation site was sampled prior to disturbance and found to belong to the mesic community, it would be possible to sample the site every year (or every x years) during or subsequent to the disturbance, ordinate the data with the reference site transect information, and see how much the natural community has been altered. Transect data taken after remediation has begun can be analyzed to see how the remediation and revegetation efforts are progressing. It will yield information on the current status of the remediation work and also serve as an indicator of how long it will take to return the site to a state similar to its pre-disturbance state. It may also produce significant information as to what steps may be needed to speed up the remediation/revegetation process. The end goal of the reclamation/remediation project would be to have the remediation site transects grouped closely with the reference mesic community transects. Such a grouping would indicate that the remediation site had been returned

to its natural community type or state. Additionally, it should be possible to relate soil, ecosystem function, and other ecological information from the reference transects to the remediation transects (without actually sampling the remediation sites for these factors) based on the transect (or species) groupings in the ordination. For example, if a series of remediation transects cluster with the reference mesic community transects, it can be assumed that the environmental factors of that particular ordination analysis at both sites are similar. If a series of remediation transects from a site which was once determined to be a mesic community do not cluster with the reference mesic community transects, it is evident that remediation processes have not yet achieved their goal of returning the site to its pre-disturbance state. This type of information will then be available to assist those making management decisions concerning remediation seed mixes, fertilizers, and other factors relating to the revegetation of the area.

The Cornell Ecology Program DECORANA (Hill, 1979a) was used to analyze the Site plant species presence/absence data. 1994 species richness data from the belt transects and the production plots were combined into one data set to provide overall species richness for each transect. The data matrix consisted of an alphabetized list of all species (271 total) present in one or more belt transects or in one or more production plot quadrat. Taxa identified only to genus or family were not generally included in this analysis. The one exception was the *Triodanus* sp., which was included because it was the only representative of this genus found during the study and, consequently, represented an additional species, even if it was not identifiable to species at the time of sampling. The second "axis" of this matrix corresponded to 60 transects, recorded in the following order, TR01 T1, TR01 T2, TR01 T3, TR01 T4, TR01 T5, TR02 T1, ... , TR11 T5, TR12 T1, TR12 T2, TR12 T3, TR12 T4, and TR12 T5. This file was then run through the Cornell Ecology Program, COMPOSE (Mohler, 1987), to produce a data matrix with a format acceptable to DECORANA. The COMPOSE-created matrix was then run through the two ordination options provided by DECORANA, 1) the Detrended Correspondence Analysis (DCA) option and 2) the reciprocal averaging analysis (RAA) option. The DCA and the RAA each produced two ordinations of the data, one by species and the other by transect (samples). The RAA has two weaknesses when compared to the DCA. First, the scaling of the axes in RAA does not have any clear meaning and often is different for different parts of the axis. This commonly results in contraction of the ends of the axis, which gives the impression that the points at the ends are closer together than they actually are or would be if they were spread out along an axis scaled with uniformly sized units. The second major weakness of the RAA is that the second axis (and often subsequent axes) may be strongly related to the first axis. This results in the production of a graph whose points form a characteristic "horseshoe" or arch shape. The DCA is designed to overcome both of these problems. First, the axis ends are not contracted, producing a graph which better shows the true relationship and separation of the points with respect to one another. Second, the DCA avoids the arch effect by ensuring that there is no correlation between the first and higher axes (Hill, 1979a).

Graphs of the DCA and RAA results by transect (sample) and by species were plotted for three different axis combinations in Figures B-19 through B-30. Only the axes which showed the greatest clustering of transects as relating to the four community types were plotted. For the ordinations done by transect, the actual transect numbers for the points on the figures can be determined from the axis coordinates found in Tables B-14 and B-15 for the respective type of ordinations. Lines were drawn around the clusters of points which represent different community types. For the figures of the DCA and RAA results by species, the species code for each point may be determined from the axis coordinates found in Tables B-16 and B-17. The scientific name for each species code may be determined by looking at Table B-2. For both the DCA and RAA figures by transect and by species, only figures for axis one plotted against axes two, three, and four are presented, because they showed the greatest amount of clustering of points (Figures B-19 through B-30). The higher axes (two, three, and four) plotted against one another did not show much clustering or separation of the transects, but had most of the transects lumped together as a large mass (not shown), making it difficult to interpret the differences displayed.

Ordinations done by both DCA and RAA techniques revealed very similar patterns for both the ordinations by transect (sample) and ordinations by species (Tables B-14 through B-17, Figures B-19 through B-30). DCA and RAA ordinations by transect grouped the transects from each given community - xeric, mesic, riparian, and reclaimed - together with the other transects from that community (Figures B-19 through B-24). The contraction of the axis ends was more apparent in the RAA results (Figures B-22 through B-24) where the transect points at the ends of the axes tended to group closer together than those of the DCA (Figures B-19 through B-21). The DCA results show the transects at the ends of the axes to be more spread out and in fact show some differences in grouping among transects within communities. The riparian community tended to have the greatest amount of spread among the transects and occurred on the far right in the figures (Figures B-19 through B-21). The xeric and mesic transects grouped together fairly close and in some cases were almost intermixed near their common border. The reclaimed transects fell out in between these two broad groups. The DCA and RAA results by species showed some grouping of certain species, but the grouping was not as distinct as that found in the ordinations by transect, possibly due to the larger number of species as compared to the number of transects (Figures B-25 through B-30). In general, two groups of species can be recognized. There are, however, a number of species which fall out in between these two groups. The DCA results (Figures B-25 through B-27) show more distinct groupings than do the RAA results (Figures B-28 through B-30). The RAA results show the contraction of points at the axis ends much more than the DCA results. However, some generalizations and discussion of these results can be made. Interpretation of these results are discussed in the ordination subsection of the discussion section.

Classification

Classification is another tool used by community ecologists to see patterns in vegetation. It involves assigning different entities or samples (in this case transects) to different classes or groups (Gauch, 1982). Three different purposes for classification are given by Gauch (1982). First, it allows the researcher to summarize large, complex sets of data. Second, it helps in the interpretation of environmental factors influencing community variation. Third, it helps refine understanding and models of community structure. All three of these purposes influenced the decision to use this type of analysis on the terrestrial vegetation data collected at the Site. Like ordination, classification is a useful tool for remediation monitoring and can be utilized in much the same manner as ordination for this purpose. In fact, classification techniques are often used in conjunction with ordination techniques to see the patterns in vegetation from the different perspectives each technique offers.

The classification analysis used on the 1994 EcMP terrestrial vegetation data was The Cornell Ecology Program, TWINSPAN (Hill, 1979b). TWINSPAN is a hierarchical classification analysis which groups transects together and arranges them into a hierarchy that shows relationships between the transects (Hill, 1979b; Gauch, 1982). It is also a polythetic divisive classification technique which uses information on all the species in the data set, rather than just one species as monothetic divisive classification analyses do. The basic principle involved is that the analysis begins with all transect species presence/absence data in a single large set. It then begins to divide the transects into a hierarchy of smaller and smaller groups until each group contains just one transect or a predetermined number of transects (Gauch, 1982). The TWINSPAN program first constructs a classification of the transects and then using this classification prepares a classification of the species based on their ecological preferences (Hill, 1979b). The end result is an ordered two-way table which shows the relationships between the trasnsects and between species. The hierarchical relationships between transects are often displayed as a dendrogram to show the relationships more clearly.

Species presence/absence data were arranged in the same manner as previously described for ordination techniques. This matrix was then run through The Cornell Ecology Program, COMPOSE (Mohler, 1987) to prepare the format in a form acceptable to the TWINSPAN program. The results for the TWINSPAN classification by transect are shown in Figures B-31A and B-31B. Figure B-31A

is a dendrogram which shows how the transects were broken into smaller and smaller groups by the TWINSPAN program. Figure B-31B is a legend that lists what transects were grouped together for each of the divisions.

Division 1 (B and C in Figure B-31A) split the grassland sites (TR01, TR02, TR04, TR06, TR07, TR08, TR09, TR11, and TR12) from the riparian sites (TR03, TR05, and TR10). AGST1 and JUBA1 (see Table B-2 for scientific names), each with occurrence in 14 of the 15 riparian transects, and CANE1 and MEAR1, each with occurrence in 12 of the 15 riparian transects) were identified as indicator species for the riparian sites.

Division 2 (D and E in Figure B-31A) split the reclaimed grassland sites (TR07, TR08, and TR09) from the mesic and xeric grassland sites (TR01, TR02, TR04, TR06, TR11, and TR12). BOGR1 served as the indicator species for the mesic and xeric grassland sites and occurred in 30 of the 30 mesic and xeric transects. BOGR1 did not occur at all in the reclaimed grassland transects.

Division 3 (F and G in Figure B-31A) split the riparian sites into two groups, TR05 and [TR03 and TR10]. This division was based on the indicator species, GABO1's, occurrence in all 10 of the TR03 and TR10 transects but its absence from all TR05 transects.

Division 4 (H and I in Figure B-31A) divided the reclaimed grassland sites into two groups, [TR07 and TR08] and TR09. The indicator species was GUSA1, which occurred in all 10 transects at TR07 and TR08 and in none of the 5 transects from TR09.

Division 5 (J and K in Figure B-31A) divided the xeric and mesic grassland sites such that the 3 mesic sites (TR02, TR04, and TR11) and one xeric site (TR06) formed one group and the two xeric sites (TR01 and TR12) formed the second group. The basis for this division was the presence of the indicator species, ARFE2, in the 10 transects at TR01 and TR12 and its absence from the transects at TR02, TR04, TR06, and TR11.

Within the group, TR02, TR04, TR06, and TR11, division 10 (P and Q in Figure B-31A) produced the two subgroups [TR02 T2, T4, T5; TR04 T1, T2, T3, T4, T5; and TR11 T2, T4] and [TR02 T1, T3; TR06 T1, T2, T3, T4, T5; and TR11 T1, T3, T5]. This division was based on the three indicator species, DAPU1, LEMO1, and LEMO2, which occurred in 10, 9, and 8 of the transects in the second subgroup, respectively. If two or three of these indicator species were present at a transect, that transect was placed in subgroup two. If only one or no indicator species was present in a transect, that transect was placed in subgroup one.

The final divisions produced groups (N,O,R,S,T,U,V, and). Each contained between four and six transects which are listed in the legend (Figure B-31B) by their respective division letters.

DISCUSSION

The four communities (xeric grassland, mesic grassland, reclaimed grassland, and riparian community complex) chosen for study by EcMP personnel at the Site generally follow the hydrologic gradient from dry to mesic to wet as indicated in the Baseline Report (U.S. Department of Energy,1992). The following discussion will look at each of the communities individually based on the 1994 data collected from each of the three sites which make up those communities. Comparison to other studies from the literature will be made where possible, to put the Site vegetation into the larger regional context. Suggestions for the use and application of these data for decision-making are made where pertinent.

Xeric Grassland Community

The xeric grassland community (xeric community) on the Site represents approximately 18% of the land area of the Site (U.S. Department of Energy, 1992) and is the driest of the communities. The species found in this community must be able to withstand the harshest conditions on the Site. Located on the tops of mesas and on ridgetops, the xeric grasslands are subject to desiccating winds, high solar radiation, and generally dry conditions. The three xeric sites studied are TR01, TR06, and TR12. TR01 and TR12 are in the western portion of the Site with TR01 in the northwest corner and TR12 in the southwest corner. TR06 is near the eastern boundary of the Site and is approximately centered in the north to south direction. All three sites are found on mesa tops and all are underlain by Rocky Flats Alluvium. Each of these sites was grazed until the early 1970s' when the land was purchased by DOE and became part of the buffer zone. These sites have been free from grazing and have had little disturbance of any other type for the past 20 years.

The xeric plant community has the lowest species richness of the three natural communities (the reclaimed community was not considered natural since it was previously agricultural land and is composed mainly of planted species) studied, with a mean species richness of 89 species and a combined richness of 133 (Table B-2). Although the xeric community has the lowest species richness, it also has the highest percentage of native species (84%) (Table B-5). A total of 22 species are restricted to the xeric community (Table B-4). Cactus density is highest in the xeric community with a mean density of 0.65 cacti m^{-2} (Table B-3). Basal and foliar vegetation cover averages 19.3% and 87% respectively (Table B-7). Current year biomass production and litter production averages 128.6 gm^{-2} and 262.9 gm^{-2} respectively at the xeric community (Table B-7). The xeric community produces the highest amount of current year biomass by native species (71%, Table B-12) of all the communities sampled.

Some interesting differences are apparent between the three xeric sites representing the xeric community. The dominant species found at each of the sites, based on relative basal cover, are of primary interest (Table B-10). TR01 is dominated by *Andropogon scoparius*, however, *Andropogon gerardii*, *Carex heliophila*, and *Muhlenbergia montana* also have large cover values for this site. TR06 and TR12 are both dominated by *Stipa comata*. However, TR12 seems to be intermediate between TR01 and TR06 in that it also includes a relatively large cover of *Andropogon gerardii*, *Andropogon scoparius*, and *Carex heliophila*. TR06 has only very small amounts of *Andropogon gerardii* and *Andropogon scoparius*, totaling about 1% of the relative basal cover (not shown in table), but instead has large amounts of *Bouteloua gracilis*, *Poa pratensis*, and *Poa compressa*.

The cover data show that there are no sinificant differences (α=0.05 level) for bare ground or litter cover (Figure B-13) between the xeric sites. However, the amount of rock cover between TR01 and TR06 and between TR06 and TR12 was significantly different (α=0.05 level)(Figure B-13). The rock cover at TR01 (21.6%) was over six times that found at TR06 (3.4%)(Table B-6). One possible explanation for this might be that because TR06 is much further east than TR01 and TR12 (both of which had higher rock cover than TR06), the Rocky Flats Alluvium which underlies all three sites thins out to the east. It may also indicate that differences in the soils may be a factor in the different types of vegetation found at these two sites.

Biomass data from the xeric sites also reveals interesting differences. TR01 produced the least biomass (102.5 gm^{-2}), with TR12 intermediate (125.6 gm^{-2}), and TR06 having the greatest biomass (157.7 gm^{-2}, Table B-6). Statistically significant differences were found for current year biomass and litter production between sites TR01 and TR06 at the α=0.05 level (Figure B-15). Although the percentage of native species making up the species richness at each of the three xeric sites is very similar, ranging from 80-84% (Table B-5), the total biomass produced by native species at each site varies considerably (Table B-12 and Figure B-17). TR01 and TR12 are similar in total native

biomass produced, at 91% and 87% respectively. However, at TR06, only 46% of the total biomass is produced by native species. Four of the top five biomass producers at TR06, *Linaria dalmatica*, *Poa compressa*, *Alyssum minus*, and *Sisymbrium altissimum*, are all non-natives (Table B-13). This indicates that some type of disturbance has probably occurred at TR06 at some time in the past and has allowed the invasion of non-native species at the site. These species also probably account for the significant difference in current year biomass production between these two sites, especially since two of the top five biomass producers, *Linaria dalmatica* and *Sisymbrium altissimum*, are both large plants which add considerably to the biomass values of an individual quadrat. The density of cactus is also much lower and the density of woody stems much higher at TR06 than at either TR01 or TR12 (Table B-4). The dominant woody species at TR06 is *Yucca glauca* (no data shown).

Previous vegetation studies in Colorado have suggested that available soil moisture is the predominant factor in permiting the development and maintaining the tallgrass prairie remnants in the Front Range area (Livingston, 1952; Branson et al., 1965; Hanson and Dahl, 1956). Livingston (1952) suggests that "neither precipitation, temperature, nor evaporation appears to be the causal factor influencing or limiting the presence of these communities." He found that soil moisture was available at the tallgrass sites on dates sampling took place, but was unavailable at mixed prairie communities at the same time. The decrease in relative basal cover percentages and current year biomass amounts of *Andropogon gerardii* and *Andropogon scoparius*, both tallgrass prairie remnants, from TR01 to TR12 to TR06, would seem to indicate that available soil moisture levels decrease along similar lines at these sites. The fact that *Yucca glauca* is only found at TR06 (Table B-2) and typically only grows in, "well drained soils that have little or no subsurface water,"(Webber, 1953) would also support this idea. *Sorghastrum nutans* and *Sporobolis heterolepis*, both true prairie relicts (Livingston, 1952), only occur at TR01 and TR12. This also supports the idea that differences in the species composition at each of the three xeric sites may in part be explained by soil moisture differences between the sites.

The differences in species composition, cover, and biomass, at the three xeric sites would tend to indicate that at least two different plant associations are present at these sites. TR01, with the high amounts of *Andropogon scoparius* and associated species such as *Andropogon gerardii*, *Carex heliophila*, *Muhlenbergia montana*, *Aster porteri*, *Eriogonum alatum*, and *Arenaria fendleri*, fits the xeric tall grassland plant association given by Bunin (1985) for the xeric tall grasslands found on Boulder County Open Space just to the north of the Site. No description is given by Bunin however, for a *Stipa comata* plant association such as is found at TR06. However, TR06 does seem to match the description given by Hanson (1955) for the *Stipa comata-Bouteloua gracilis-Bouteloua curtipendula* association of the Colorado Front Range. In addition, he mentions that it is closely related to the *Andropogon scoparius* association found in this region. This would seem to describe the situation here at the Site quite well. The fact that TR12 seems to be the intermediate between TR01 and TR06 would support the idea of the close relationship between the two associations.

Clark et al. (1980) describes the vegetation of the buffer zone and surrounding private lands, as of 1974. Based on the descriptions given for the areas where the three xeric sites are located, it appears that some changes have taken place in the vegetation over the past 20 years. Although differences in methodology were used, some generalizations can be made. At TR01, the vegetation 20 years ago was described as over-grazed pasture, dominated by *Hypericum perforatum-Paronychia jamesii* and *Heterotheca (Chrysopsis) villosa-Buchloe dactyloides* associations. The area of TR06 was described as a dry, *Heterotheca (Chrysopsis) villosa-Buchloe dactyloides* pasture. In the TR12 area, the vegetation was listed as a dry, *Stipa comata-Koeleria macrantha (pyrimidata)* prairie, and described as representing the mapping unit which most closely represented the former native prairie. This information provides an interesting historical context and indicates that TR01 and TR06 were more similar to each other at that point in time than to TR12, possibly due to heavy grazing which occurred previous to and during the 1974 study, and which

stopped after DOE purchased the property in 1974-1975. What is interesting is that with the loss of grazing pressure and 20 years of time, TR01 and TR06 have become so different. A number of questions can be raised concerning this. Were the grazing pressures so different at the different sites (TR01 and TR06) and/or did some other type of disturbance occur which would account for the high cover and production values of non-native species at TR06? Perhaps the moisture differences previously mentioned could partly explain the differences now seen in the vegetation at these sites. The topography of the sites is very similar, but TR06 sits over 100 feet lower in elevation. All three sites are underlain by Rocky Flats Alluvium. Perhaps there are differences in subsurface moisture movement between the sites. Maybe higher precipitation is received on the western edge of the Site due to a closer proximity to the mountain front than is received on the eastern edge. But, if moisture differences were present at the sites in the past, wouldn't there have been different plant communities then also? Perhaps differences in soils or soil compaction can help explain the differences? Further study is needed to determine the reasons for this documented change in vegetation over the last 20 years.

Information concerning differences in vegetation in relation to environmental and/or physical conditions, has importance for decision-making concerning reclamation seed choices for revegetation of the xeric community areas on the Site. Broad generalizations concerning the xeric community as a whole may need further refinement for reclamation work in specific xeric areas on Site. Other environmental or physical factors may need to be considered. Further study is recommended concerning the soils and soil moisture availability in relation to plant communities or associations in the xeric areas on Site.

Direct comparisons of the vegetation on the Site to other studies found in the literature are not easily made due to differences in methodology, substrate type, precipitation events, topography, and other factors which influence final values. However, some generalizations may be made. Branson et al. (1965) studied plant communities in relation to soil conditions on Rocky Flats alluvium and shale derived soils just south of the Site. The species composition given for the stony soil on top of the Rocky Flats Alluvium (*Andropogon gerardii*, *Andropogon scoparius*, *Bouteloua gracilis*, and *Muhlenbergia montana*, leading cover and biomass producers) and shale derived soil (*Agropyron smithii*, *Buchloe dactyloides*, and *Bromus japonicus*, leading cover and biomass producers) vegetation are similar to the xeric grassland and mesic grassland communities respectively, found at the Site. Dry weights of 111 gm^{-2} and 155 gm^{-2} are given for the stony soil and shale derived soil vegetation, respectively. The xeric community on Site produced a higher mean current year biomass of 128.6 gm^{-2} and the mesic community a lower value of 120.1 gm^{-2} (Table B-7). Interpretation is difficult however, since Branson et al. (1965) mentioned that the fall, winter, and spring preceding sampling was especially wet. For the 1994 Site data, the fall, winter, and spring, precipitation data are not much different than normal (Balint, 1995). However, May, June, July, and September precipitation amounts were far below normal. When higher amounts of moisture are available, biomass values for vegetation on both types of soils would be higher and, when lower moisture is available, biomass values would be lower for both soil types. That the 1994 biomass amounts at the xeric community were higher than those given by Branson et. al.(1965) is interesting, because, due to the lack of summer moisture in 1994, most of the late season grasses did not put up very many flowering stalks which would have increased the biomass values. Under these same conditions, it seems to make more sense that the biomass in the mesic community on Site in 1994 would be lower than that found by Branson et. al. (1965) on the similar shale derived soil, since more summer moisture was available then. Perhaps other as yet undetermined factors (topography, solar radiation, slope angle) differ between the sites which account for these differences.

Moir (1969) found that biomass production values for *Andropogon gerardii-Poa pratensis* and *Stipa comata-Bouteloua gracilis* associations near Boulder were much higher than that of similar communities located elsewhere in Colorado. The biomass values of TR01 and TR12, 102.5 gm^{-2} and 125.6 gm^{-2}, respectively (Table B-6)(most similar to the *Andropogon gerardii-Poa pratensis*

association), are only approximately one-third of the 340 gm^{-2} Moir found. But TR01 and TR12 have very little *Poa pratensis*. At TR06, where *Stipa comata* and *Bouteloua gracilis* are dominant species (Table B-13), a biomass of 157.7 gm^{-2} was found, which is far less than the 257 gm^{-2} Moir found. Moir attributes the high biomass values he found to high precipitation from April to July. This is in stark contrast to the below normal precipitation received at the Site from May to July in 1994 (Balint, 1995). A more normal precipitation average over the summer at the Site would probably increase the biomass production found at the xeric sites considerably.

A comparison of biomass amounts for current year production and litter from the Site with other prairie areas (in midwestern and western North America) studied as part of the International Biome Program (IBP)(Coupland, 1979), shows the Site values to be closest to those found on the Pawnee National Grassland in northeastern Colorado. Current year production and litter biomass amounts from ungrazed grassland sites on the Pawnee were 135 gm^{-2} and 251 gm^{-2} respectively. Current year production values for the different communities on Site in 1994 range from 120 to 145 gm^{-2} and litter amounts from 225 to 262 gm^{-2} (Table B-7). Most of the other prairies studied by the IBP had much higher current year production and litter amounts, with the exception of some desert grassland and shrub steppe prairies. This would indicate that overall the biomass amounts produced at the Site tend to be fairly low in comparison with other prairies across the country, but in relation to the Pawnee, the closest of the IBP areas studied, the Site is very similar. Low precipitation and moisture availability are probably the biggest reason for the low biomass amounts.

A valuable and important aspect of the xeric community at the Site is represented by the presence of relict portions of tallgrass prairie. Found primarily along the western edge of the Site, where both TR01 and TR12 are located, tallgrass prairie species such as *Andropogon scoparius*, *Andropogon gerardii*, *Sorghastrum nutans*, and *Sporobolis heterolepis*, represent Pleistocene relict populations (Livingston, 1952) of the tallgrass prairie which remain confined to the moist, cobbly soils found in a narrow band paralleling the Front Range. The uniqueness of this habitat in Colorado, much of which has been lost due to increasing pressure from human development, has been recognized by the Colorado Natural Heritage Program (Kettler et al., 1994) and the assignment of G2/S2, rankings for the tallgrass prairies in the Rocky Flats area. This ranking indicates that, because of rarity and/or other factors, the habitat is facing potential extinction throughout its range. In addition, *Stipa comata* communities, part of the Great Plains mixed grass prairies, have also been ranked G2/S2, and representatives of this community also occur on the Site (TR06 being one location). The xeric community in general at the Site contains sizable portions of tallgrass prairie relicts and mixed grass prairie and as such should be disturbed as little as possible to preserve this habitat and its associated species for future generations to enjoy.

Mesic Grassland Community

The mesic grassland community (mesic community) is the most extensive of all community types present at the Site and covers approximately 54% of the total land area at the Site (U. S. Department of Energy, 1992). It represents the moderate hydrologic gradient zone between the dry (xeric community) and the wet (riparian communities) zones found at the Site. The higher soil moisture available to plants found in the mesic community (as compared to the xeric community) is due to a number of environmental factors. Slope, aspect, protection from desiccating winds, greater snow accumulation, subirrigation by seeps, and general soil characteristics, all are factors providing a higher soil moisture availability to the vegetation found there. The mesic community is found on moist hillsides on the Site (U. S. Department of Energy, 1992). The three EcMP mesic sites are located across the Site in three different watersheds, each on generally south facing slopes. TR02 is located in the Rock Creek watershed, TR04 is in the Walnut Creek watershed, and TR11 is in the Smart Ditch drainage of Woman Creek.

The mesic community has a higher species richness than does the xeric community. The three EcMP sites in the mesic community have a mean species richness of 103 species with a combined

species richness of 143 species (Table B-2). Native species comprise 81% of the species found in the mesic community, which is only 3% less than the xeric community (Table B-5). *Bromus japonicus*, an annual, non-native grass, is the dominant species (based on basal and foliar cover measurements) in the mesic community (Table B-9). No significant differences (α=0.05 level) were found for vegetation, litter, or bare ground cover between these three sites. Rock cover was the only cover class with any significant differences and these were between TR02 and TR04 (Figure B-13). The highest number of annual species are found in the mesic community (Table B-5). The mesic community has approximately half the cactus density (0.32 cacti m^{-2}) and approximately eight times the woody plant density (0.83 stem m^{-2}) of the xeric community (Table B-3). Twenty-two species occur only in the mesic community (Table B-4). Basal and foliar vegetation cover is higher in the mesic community at 29% and 91%, respectively, than at any of the other communities (Table B-7), while current year biomass and litter amounts (120.12 and 225 gm^{-2}, respectively) are lower than any other community (Table B-7). No significant differences (α=0.05 level) were found for current year production between the mesic sites, however, litter amounts were significantly different between TR02 and TR04 (207.1 gm^{-2} and 148.5 gm^{-2}, respectively). Native species produce only 63% of the current year biomass in the mesic community (Table B-12).

The differences between the three EcMP mesic sites are generally less distinct than those distinguishing the three xeric sites. *Bromus japonicus*, *Agropyron smithii*, and *Bouteloua gracilis* are the dominant species at the mesic sites, based on relative basal cover, although their order of importance varies between the sites (Table B-10 and B-11). TR04 differs from the other two mesic sites in that it has an abundance of *Bromus japonicus*, an annual, non-native species. TR04 has twice the *Bromus japonicus* basal cover that TR11 has and five times the *Bromus japonicus* basal cover found at TR02 (Table B-10). At TR04, *Bromus japonicus* is also the leading current year biomass producer with over twice the production of that species at TR11 and three times that found at TR02 (Table B-13). Native species current year biomass production comprises only 48% of the total current year biomass at TR04 (Table B-12), the lowest native production of the mesic sites. The high annual production from annuals such as *Bromus japonicus, Bromus tectorum*, and *Alyssum minus,* is not an uncommon problem on western rangelands. The competitive influences of these annuals are well known and in many areas these species are dominants in the community, often displacing the native species (Haferkamp et al., 1994; Monsen, 1994; Rosentreter, 1994). Areas converted to annuals often have lower species richness and diversity, resulting in lost genetic and structural diversity, ecosystem instability, a low-quality watershed with increased susceptibility to soil erosion, and an increased potential for more frequent wildfires (Rosentreter, 1994).

Currently the mesic community is the grassland community on Site which is most affected by the presence of exotic annuals. The potential for increased frequency of wildfires created by the high cover and biomass values for the annual species in the mesic community is of concern, because it would result in the loss of ground cover, exposing the soil to erosion processes. Wind erosion is considered a major mechanism of potential plutonium movement in contaminated soils (Little et al., 1980) on Site. With loss of ground cover, wind driven plutonium movement could become a distinct possibility in contaminated areas. Control of these species and the management of the vegetation to aid its return to a more natural, native, perennial, mesic mixed grassland would help reduce this as a potential problem. It would also prevent the spread of these exotics to other parts of the Site.

Although the mesic community does have a problem with "weeds," the community is essentially an *Agropyron smithii-Bouteloua gracilis* association, in various states of quality on the Site. It seems to match the description given for the mid-height grassland, *Agropyron smithii-Bouteloua gracilis* association, given by Bunin (1985) as occurring on Boulder Open Space lands. It also matches to some extent, the *Bromus tectorum-Agropyron smithii-Bouteloua gracilis* association of Hanson and Dahl (1956) which they studied between Boulder and Big Thompson Canyon. The major difference would be that on Site the *Bromus tectorum* has been replaced by *Bromus japonicus*.

The Colorado Natural Heritage Program says this shortgrass/mixedgrass prairie association is believed to be fairly common, but is highly impacted throughout much of its range (Kettler, 1994). As a result, it ranks this association as G5/S4 , indicating that globally it is very common and in the state it is common, although restricted to certain areas, and at present not susceptible to any immediate threats. Through proper management, the mesic community on Site could probably be returned to a higher quality shortgrass/mixedgrass prairie.

Reclaimed Grassland Community

The reclaimed grassland community (reclaimed community) at the Site represents approximately 9% of the total area at the Site (U.S. Department of Energy, 1992). It is an area previously used as agricultural land that was planted with seed mixtures of one to several species over 20 years ago. The three reclaimed sites, TR07, TR08, and TR09, are located on gentle east, southeast facing slopes in the southeastern corner of the Site. The pre-agricultural vegetation is thought to have been mesic mixed grassland (U.S. Department of Energy, 1992). No farming has taken place on the land in the past 20 years.

The fact that the reclaimed community represents an artificial community is apparent from the data from the three EcMP reclaimed sites. The reclaimed community has the lowest mean number of species (37) and combined number of species (61) of all the grassland communities at the Site (Table B-5). Only 62% of the species present are native species (Table B-5 and Figure B-9). The reclaimed community is dominated by two of the non-native, seeded species, *Bromus inermis* and *Agropyron intermedium* , which were planted as ground cover approximately 20 years ago. The two dominant species mentioned above account for 80-100% of the basal cover (Table B-10) and over 95% of the current year biomass (Table B-13) at the reclaimed sites. Basal vegetation cover is the lowest of all communities (11.2%, Table B-7). The reclaimed community has the highest current year biomass production of all the communities at 147.8 gm^{-2} (Table B-7).

TR09 differs considerably from TR07 and TR08 in that it shows the least amount of successional progression back toward the native, mesic mixed prairie. It has the lowest species richness and lowest percent of native species (Table B-5), the highest basal cover (Table B-6), and highest current year production for biomass (Table B-6) of all the reclaimed sites. The current year biomass production for 1994 was significantly higher at TR09 than at TR08 (α=0.05 level), which may suggest that some factor differed between these sites during 1994, allowing for better growing conditions at TR09. No significant differences were found for vegetation, litter, or rock cover between the three sites (Figure B-13). However, bare ground cover was significantly higher at TR08 than at TR09 (Figure B-13). Further study is needed to investigate why TR09 is different from TR07 and TR08 in terms of its successional stage since, all three sites were reseeded at the same time 20 years ago.

The impact of these two non-native planted species totally dominating the sites after approximately 20 years demonstrates the competitive edge these two species have over the native vegetation. The successional progression back to the native mixedgrass prairie, which was present prior to agricultural use (U. S. Department of Energy, 1992) is going to take a very long time. Wilson (1989) found that alien (non-native) species introduced for revegetation purposes actually suppressed revegetation by native prairie species. He found that, "naturally regenerating native vegetation was as efficient as any commercial mixture at producing plant biomass, and was most efficient at covering bare ground where it was not faced with competition from introduced species." This is of special concern at the Site because these sites were revegetated with the seed mixture to provide ground cover to prevent potential erosion, especially wind erosion. As previously mentioned, wind erosion is of special concern at the Site since it is considered the major mechanism of plutonium transport for plutonium in contaminated soils (Little et al., 1980). Although no contamination has been noted in these soils, erosion is still an important concern.

At the reclaimed community, total basal cover is only approximately one-third (11.2%) of that found in the mesic community (29%, Table B-6). This difference between the mesic and reclaimed communities (Figure B-14) for total basal vegetation cover was found to be significantly different (α=0.05 level). At the site level, a significant difference (α=0.05 level) was also found between TR04 (mesic site) and two of the reclaimed sites, TR07 and TR08 (Table B-6 and Figure B-14). The reclaimed community also differs significantly (α=0.05 level) from the mesic community in that it has less litter cover and more bare ground cover (Figure B-14). The percentage of bare ground at the reclaimed community is three times higher than that of the mesic community (1.7% and 5.1% respectively, Table B-7). A factor explaining some of the lower vegetation cover at the reclamimed community may be that *Bromus inermis* and *Agropyson intermedium* are rhizomatous graminoids. Because of this individual plants tend to grow father apart from one another than many of the other graminoids and forbs found in the mesic community. Because these two species dominate the reclaimed community and few other species provide any cover, there is more bare ground present. This implies that, if the reclaimed sites were converted to the original native mixed prairie, there would be more ground cover, less bare ground, and higher species richness than there is presently at the reclaimed sites.

This raises an important concern with regard to reclamation at the Site, suggesting that revegetation with a diversity of native species is preferable to using non-native species for providing ground cover to prevent soil erosion. The lack of species richness in the reclaimed community as compared to the other communities puts the reclaimed community at a serious disadvantage from an ecological standpoint. The di-culture formed by the two dominant species, *Bromus inermis* and *Agropyron intermedium* , means the vegetation there does not form a very stable community. If disease, drought, or some other condition, proved detrimental to the survival of either of these two species, the land would be essentially denuded and left barren. A higher species richness and cover and biomass spread out over more species tends to lessen the impact of the loss of one or two species to disease or some other cause. This means the community is much more stable and resistant to collapse should some unforeseen event occur. Attempts could be made to convert this community back to a more native, mesic mixed grassland by seeding with native species. Until then however, the community can be used to evaluate successional trends.

Riparian Community

The riparian community represents approximately 5% of the total area at the Site (U. S. Department of Energy, 1992). Although it is the smallest of the communities monitored by EcMP, it is one of the most important in terms of the plants present and the habitat it provides for the wildlife at the Site. The three EcMP Sites are located in three different watersheds which flow generally west to east across the Site. TR03 is located along Rock Creek, TR05 along Walnut Creek, and TR10 along the Smart Ditch drainage in Woman Creek.

The riparian community has the highest species richness of all the communities monitored by EcMP on Site. The three EcMP sites have a mean species richness of 104 species and a combined richness of 163 species (Table B-5). Only 74% of the species found in the riparian community are native species. This is the lowest percentage of native species of all the natural communities monitored (Table B-5). (The reclaimed community is the lowest of all communities monitored.) The data show that although there is an increase in the number of species along the hydrologic gradient from dry to wet, there is an accompanying decrease in the percentage of native species in the natural communities at the Site (Figures B-1, B-2, B-4, B-9). One possible explanation for this is that more disturbance has taken place in the riparian areas on Site allowing for the invasion and establishment of non-native species. It may also be that the riparian is more susceptible to disturbance, which would create openings for non-native species. For example, TR05 has the lowest number of species and lowest percentage of native species of the three riparian sites monitored (Table B-5) and it is the only riparian site of the three monitored which has had any significant disturbance to the stream channel (i.e. riprap placed along the channel, stream

water level controlled by upstream pond discharges). Another possible explanation is related to past livestock usage. Cattle may have preferred the shaded riparian areas during the hot summer months and/or the more lush vegetation which occurred in the riparian areas, so higher grazing and trampling took place in the riparian areas, causing greater disturbance which allowed the invasion of non-native species. One other possible explanation is that due to the dry, harsh conditions present in the xeric community, fewer non-native species have been able to invade and establish themselves, whereas in the more protected hydric areas, non-natives have been more successful.

Of the communities monitored, the riparian community has the greatest vegetational stratification and highest number of woody species present (Table B-5). Vertical stratification includes herbaceous, shrub, and tree layers. The basal vegetation cover mean is 19.2% at the riparian community (Table B-7), with woody plant stem densities averaging 6.42 stems m^{-2} (Table B-3). Foliar cover (another measure of the herbaceous layer) averages 66.5%, the lowest foliar cover of all the communities (Table B-7). The shrub cover (woody plants < 2m tall) averages 39.8% and tree cover (woody plants > 2m tall) averages 18.6% (Table B-7). The herbaceous layer in the riparian community is dominated by *Juncus balticus*, based on basal and foliar cover (Table B-9), however some differences exist between sites (Table B-10). At TR10, the herbaceous layer is dominated by two non-native grasses, *Poa pratensis* and *Poa compressa* (basal cover). The shrub layer is dominated by *Salix exigua* and then *Amorpha fruticosa* at TR05 and TR10, although TR05 has a high percentage of *Populus deltoides* saplings. At TR05, *Salix exigua* provides nearly three times as much cover as *Amorpha fruticosa*, whereas at TR10 the cover of each is almost equal. At TR03, *Amorpha fruticosa* provides twice as much cover as *Salix exigua*. The higher cover of *Amorpha fruticosa* than *Salix exigua* at TR03 may indicate that the water table is somewhat lower there than at TR05 and TR10, where *Salix* is more prevalent, since the *Amorpha* tends to occur in dryer locations (U. S. Department of Energy, 1992). Some of these differences could however also be due the subjective locations of the transects. The dominant tree at all three sites is *Populus deltoides*, although at TR05 some very tall *Salix exigua* (>2m tall) actually have a higher "tree" cover than the *Populus*.

The *Populus deltoides-Salix amygdaloides/S. exigua* (Plains cottonwood riparian woodland) and *Amorpha fruticosa* shrublands which both occur in the riparian community on the Site are plant communities of concern as determined by the Colorado Natural Heritage Program (Kettler, 1994). The former has been given a ranking of G2/G3, S2/S3, indicating that the community is very rare to rare at both the global and state levels. Although the report states that the Rock Creek community has been impacted, it is believed to be restorable. The *Amorpha* shrubland community is ranked as GU, SU, indicating that its overall status is not well known. Throughout most of their ranges both of these communities are thought to be highly impacted. Through proper management, these increasingly rare communities can be preserved and maintained as high quality examples of these community types, which were previously more common along the Front Range.

1993-1994 Comparisons

Species richness differed considerably at the monitored sites and communities between 1993 and 1994. In 1993, 198 species in 43 families were recorded from the EcMP terrestrial vegetation sites (Ecological Monitoring Program, 1994). In 1994, 271 species in 51 families were found at the same sites. Most of this difference was due to the late sampling times for the 1993 field season. Since the first sampling in 1993 took place in late July, most of the early spring ephemeral species which were found in the early sampling of 1994 were not observed. It is recommended that sampling be conducted at the same time of the year, each year, so that equal comparisons may be made.

A comparison of the current year production and litter biomass values from 1993 and 1994 by community and EcMP terrestrial site are found in Table B-18. Current year production biomass

values from the two years show the amounts produced to be nearly the same for the sites and communities (Figure B-32). Significant differences (α=0.1 level) were shown to exist for current year production amounts from the two different years only at the reclaimed community. No significant differences (α=0.1 level) in current year production were found between the two years in the xeric or mesic grassland communities. An examination of the current year production amounts by site for the two different years reveals the only significant difference (α=0.05 level) occurred at TR09 (a reclaimed site, Figure B-33). This one site probably accounts for the significant difference found at the community level for the reclaimed community as well. The factors that make TR09 different from the other reclaimed sites is not known at this time, since as previously mentioned it also has the lowest species richness, lowest percentage of native species, and the highest amount of basal cover of all the reclaimed sites. In general, however, values for these two years suggest that current year production at these sites does not vary much. It would be interesting to see how over a number of years current year production would correlate with precipitation. Similar comparison of litter data by community for the two years (Figure B-34) revealed however, that significant differences were found at the xeric and reclaimed communities for 1993 and 1994. The best explanation for these differences is the fact that different personnel conducted field work for the studies during the two field seasons and the quality of litter removal varied between years. During the second year litter was meticulously removed from the quadrats to obtain accurate results. Litter amounts between years by site were found to be significantly different (α=0.05 level) for only three sites (Figure B-35). Two of these sites were xeric sites, TR06 and TR12, and one was a mesic site, TR11. Whether or not these differences were real or not is questionable for the same reasons given above. Data collected in 1995 by the same personnel who did the 1994 sampling should show if the differences noted in litter at both the community and site levels were attributable to different personnel doing the sampling or were in fact real.

Multivariate Analysis

Ordination

Ordination results by both the DCA and RAA techniques by species and by transect (both based on species presence/absence data) reveal some interesting patterns about the sites, transects, and species. Ordinations by transect (Figures B-19 through B-24) seem to confirm the distinctiveness of the four communities - xeric, mesic, riparian, and reclaimed - studied by the EcMP. The figures show certain transects tend to group together into discrete clumps, indicating that based on this analysis using species presence/absence data, the vegetation studied on Site is composed of discrete units and is not a continuum. The results, however, also show that variation exists within the communities. This is discussed below. Both DCA and RAA techniques show the transects of the different communities (circled on the Figures B-19 through B-24) to be grouped together, with the xeric community found on the far left and the riparian community on the far right. The different axes (one through four) plotted on the different figures can represent environmental variables, community variables, or both. For both analyses, axis one plotted against axes two, three, and four, all show the same general community pattern. The xeric or driest community is on the left and the riparian or wettest community is on the far right. This seems to indicate that axis one may be the hydrologic gradient. This same pattern is shown in the DCA and RAA by species results (Figures B-25 through B-30). The species found on the left side of the figures are largely xeric species such as *Koleria pyrimidata*, *Townsendia hookeri*, and *Oxytropis lamberti*, while those on the right side of the figures are hydric species such as *Carex nebraskensis*, *Equisetum lavigatum*, and *Salix exigua*. What axes two, three, and four might represent however, will require further study of environmental and community data to determine this more precisely. Some clues however, can be found in examining some the grouping of particular transects within the larger community groups. In a number of cases, the specific grouping of certain transects reveals some of the variation found within the different communities. Many of these differences have been noted previously (see discussion sections by community types) for the different sites which make up communities, based on species richness, cover, and biomass data.

In the six figures (Figures B-19 through B-24) showing the DCA and RAA by transect results, the transects from three sites seem to have patterns that repeat for a number of the axes combinations. The TR06 (a xeric site) transects in all six figures separate out as a distinct cluster within the xeric community. Associated with this is the fact that in five out of six instances, it is the site most closely positioned to the mesic community transects. It was previously mentioned that species richness, cover, and biomass data, had indicated that TR06 was different from TR01 and TR12 (both xeric sites). The ordination plots tends to support that idea. TR06 has been placed closer to the mesic community sites by the ordination because of the large number of species typical of the mesic community occurring in it (Table B-2). TR06 has a larger number of weedy species and non-natives than do the TR01 and TR12 (the other two xeric sites) and these species are more common in the mesic community. In the reclaimed community, the ordinations separate out the TR09transectsfrom the other two reclaimed sites in all three of the DCA figures (Figures B-19 through B-21). This corroborates previously mentioned observations that TR09 has the lowest species richness, lowest percent of native species, highest basal cover, and the highest current year production biomass of all three reclaimed sites. In figure B-20, which plotted axis one with axis three, both TR06 and TR09 are grouped towards the top of the figures, quite separated from the other sites in their respective communities. Because this is the only one of the six figures shown in which both TR06 and TR09 responded in the same manner, it may indicate that the same variable (axis three) is affecting both of these sites in a similar fashion. Further examination of environmental and/or community variables needs to be undertaken to see if such a variable exists for both of these sites that might explain this pattern.

In the riparian community, TR05 is grouped by itself in three out of the six figures (Figures B-19, B-22, and B-24). Two of the cases are found with the results of DCA and RAA when axis one was plotted with axis 2. It also occurred when axis one was plotted with axis four for the RAA results. TR05's difference may be attributed to the fact that it is the only one of the three monitored riparian sites which has had much disturbance. The stream channel at TR05 has been considerably modified with riprap and waterflow is controlled from upstream water impoundments. It also had the lowest species richness and the lowest percentage of native species of all the riparian sites. Other variables should be examined to see if they could explain the separation of TR05 from the other riparian sites as well. Another point to keep in mind when interpreting these ordinations is that the tighter grouping of xeric, mesic, and riparian transects in the RAA figures (Figures B-22 and B-24) may be largely due to the way in which the RAA scales the axes and tends to contract projected points near the ends of the axes. The DCA ordinations (in which the axis ends are not contracted)by transect (Figures B-19 through B-21) suggest that the transects in the riparian community are less closely related to each other (based on the environmental/ community gradients represented by axes two, three, and four) than those in the other three communities since these transects are spread further apart along the x- and y- axes.. This suggests that the environmental or community factors represented by these axes may be more variable or have a greater effect in the riparian community than in the other communities. Further inquiry is needed to determine if this is the case.

An examination of DCA and RAA ordinations by species (Figures B-25 through B-30, Tables B-16 and B-17) reveal some similar trends. Due to lack of space on the figures only a few characteristic species have been listed for the general groups that were formed. (Speccodes for individual points may be determined by going to the appropriate table (Table B-16 or B-17) and finding the coordinates for the point. Then, the speccode information can be translated into a scientific name by going to Table B-2). All of the figures ordinate the more xeric species on the left side of axis one and the more hydric species on the right side. Therefore axis one is probably related to a hydrologic gradient which is similar to what was found for the ordinations by transects. The greater separation of points in the DCA ordination than in the RAA ordination is probably due to the characteristic RAA contraction of points at the axis ends. The DCA ordination reveals three or four general groups of species, depending on the axes plotted (Figures B-25 through B-27). The four groups found in Figures B-25 and B-27 are a xeric species group, mesic/reclaimed species group,

and two distinct riparian species groups. Axes two and four when plotted with axis one (Figures B-25 and B-27) showed the greatest separation of two riparian species groups. However, why this separation is present is unknown because no readily apparent differences seem to exist between the species which make up each group. Further examination of other environmental and/or community variables is needed to determine what variable(s) axes two and four represent. The RAA ordination by species (Figures B-28 through B-30) shows the species primarily spread out along axis one with only two general groups formed but many species in between. Only Figure B-30, which has axis one plotted against axis four, exhibits any spread of the riparian species group. What variable axis four might represent at this time is unknown.

One of the purposes of the ordination work, in addition to those mentioned earlier, is to elucidate different patterns in the vegetation monitored at the Site. It provides an additional tool to bring into focus things that may otherwise not be seen or overlooked. Once the patterns are found then the question of "Why?" may be asked. Consequently, ordinations commonly serve as a catalyst for further study which will provide a better understanding of the role of different variables in the ecosystem.

Classification

The results of the TWINSPAN classification (Figures B-31A and B-31B) on the EcMP transects placed the transects into groups similar to those as determined by the DECORANA and reciprocal averaging ordination techniques (all three methods based on species presence/absence data). Two points of major interest were noted. First, the TWINSPAN classification separates the four major community types - xeric, mesic, riparian, and reclaimed. This agrees with the ordination analyses. Secondly, within community types, TWINSPAN generally placed the transects into the same groups that the ordination analyses showed. TR09 (a reclaimed site) is different from TR07 and TR08 (also reclaimed sites). TR05 (a riparian site) is different from TR03 and TR10 (also riparian sites). However, within the xeric and mesic communities the TWINSPAN results reveal more detail concerning the clustering of site TR06 (a xeric site). In the ordination results, TR06 was often more closely associated with the mesic community than the xeric community. In the TWINSPAN classification, TR06 is grouped completely with the mesic community and is closely associated with particular transects at TR02 and TR11 (mesic sites). One possible explanation for this is that TR06 differs from the other xeric sites because of a high percentage of non-native species. Since the mesic community, in general, also has a higher percentage of non-native species than the xeric community, the specific transects at TR02 and TR11, with which all of the TR06 transects are most closely associated may also have a high percentage of the same species present. The locations of the specific TR02 and TR11 transects could also be a factor. Their locations on the hillsides or soil conditions may be similar to that found at TR06. These factors need to be examined further. However, this suggests that perhaps TR06 should be considered a mesic site, rather than a xeric site.

Finally, because the TWINSPAN results agree with the ordination results so well, all three of these analyses should prove useful for future ecological work here at the Site. Future applications could include ordination and classification of soil, invertebrate, aquatic, bird, and other environmental data. One of the things that both the classification and ordination results (in addition to the other data presented) point out, is that there are real differences between what are currently considered different communities - xeric, mesic, riparian, and reclaimed. However, within these communities and in some cases across community boundaries, considerable variation exists. This will always be the case since at every level (community, site, transect, or quadrat) change is always taking place, whether from natural or human causes. These types of ecological studies and the patterns they yield will provide a better understanding of the ecosystems here at the Site and provide important information for better managing and restoring the environment in places where is has been or will be disturbed.

CONCLUSIONS

The terrestrial vegetation at the Site differs considerably between the sites and communities studied by the EcMP. Species richness was found to differ between communities and increased along the hydrologic gradient from xeric to mesic to riparian. The reclaimed community had the lowest species richness of all the communities. The percent of native species present at different communities was found to decrease along the hydrologic gradient from xeric to mesic to riparian. The reclaimed community had the lowest percent of native species of all the communities. The percent of native species present at different sites was found to differ between sites, but the difference did not directly follow along community differences. Significant differences (α=0.5 level) were found for basal cover classes (vegetation, litter, rock, and bare ground) between sites and between communities for each of the classes. Water was not analyzed since it only occurred at the riparian community. Herbaceous biomass production was found to be significantly different (α=0.1 level) between the mesic and reclaimed communities. Significant differences (α=0.05 level) were also found for herbaceous biomass production between many of the sites. Litter production was not found to be statistically significant (α=0.1 level) between communities, but was significant (α=0.05 level) between a number of the sites.

RECOMMENDATIONS

The following recommendations are made:

1) Revegetation and remediation activities at the Site should be done using only native perennial species of plants. Species such as *Bromus inermis* or *Agropyron intermedium*, while readily available and generally quick to establish, in the long run are less suitable and provide lower quality revegetation than the native species of plants that were present before remediation was needed. The non-native species mentioned above provide less basal cover (soil holding capability) than the native species, thus increasing erosion potential. In addition, they tend to dominate the plant community and do not allow the native vegetation to reestablish.
2) The xeric community (found primarily on the flat hilltops, pediment, and ridgetops) should be disturbed as little as possible. The relict tallgrass prairie plant communities are threatened here in Colorado and the Site contains one of the remaining areas where this type can be found.
3) Driving off roads in the buffer zone should be minimized at all costs. Once the vegetation has been damaged or destroyed, the environmental and economic costs of revegetation generally outweigh any inconvenience caused by walking.
4) Prior to disturbance of areas in the buffer zone, preliminary belt transect and point-intercept transect sampling should be done to get species richness and cover data. With this information it will be possible using the ordination and classification analyses to determine where the remediation site fits in with regard to reference vegetation areas at the Site. This will provide important information concerning revegetation seed mixes and other factors which could prove important in ensuring a successful remediation effort. Post-remediation transect sampling should also be done to document the success of the revegetation effort.

FUTURE STUDY SUGGESTIONS

The differences which have been shown to exist between the sites and communities studied at the Site are due to the diversity of abiotic and biotic factors which exist at the Site. Variation shown in species richness, vegetation cover, and biomass at the different grassland sites tends to suggest that a mosaic of plant associations from the tallgrass, mixed grass, short grass prairies, along with some species from the mountains and adventive or introduced species are present at the Site. In

addition, the riparian community along with a number of other communities which are not monitored by the EcMP contribute to the high diversity of plant communities present. Each of these associations is restricted to given localities at the Site based on the habitat requirements of each. The vegetation at the Site needs to be classified and ordinated to prepare an up dated vegetation map based on plant associations for the entire Site. Further analysis of the Site flora should be done using phytogeographic information and similarity indices to determine how the Site flora fits in with the regional flora. Future study should also focus on some of the communities not presently monitored. These would include the wetlands (marshes, seeps, etc.), tall upland shrub, short upland shrub, and Ponderosa pine woodlands. Although some information on soils and other biotic and abiotic factors are available for the different EcMP terrestrial sites, further study is warranted to see how these factors are correlated to and potentially influence and affect the distribution of plant species and communities on the site.

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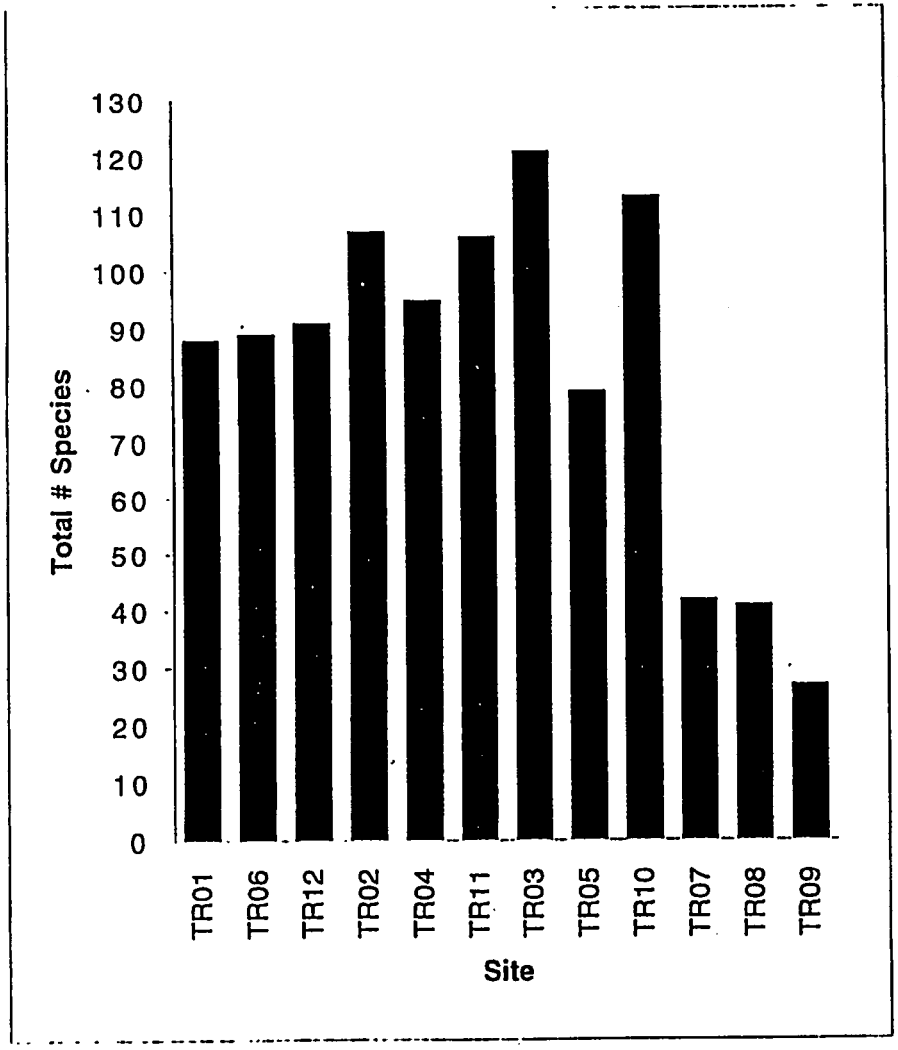


Figure B-1. 1994 Species Richness by EcMP Site.

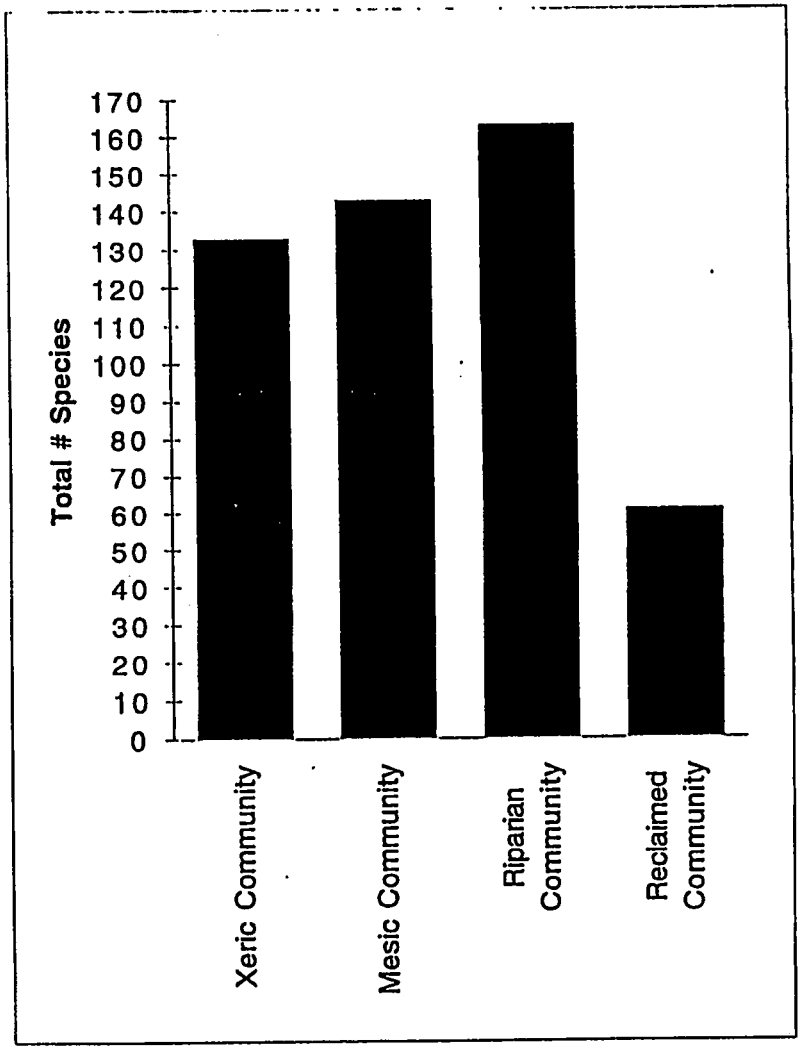


Figure B-2. 1994 Species Richness by Community.

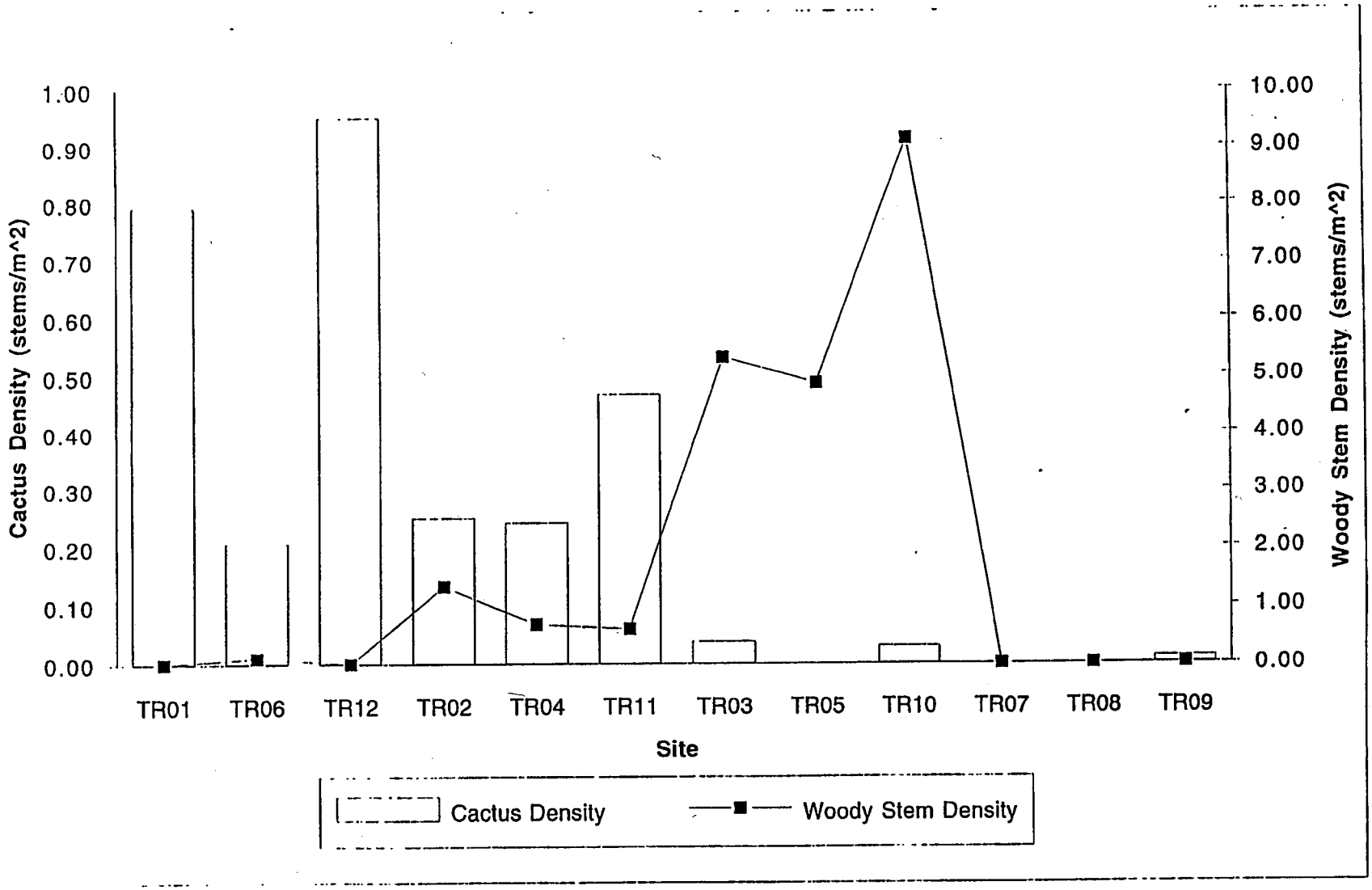


Figure B-3. 1994 Woody Stem and Cactus Density Mean Values by EcMP Site.

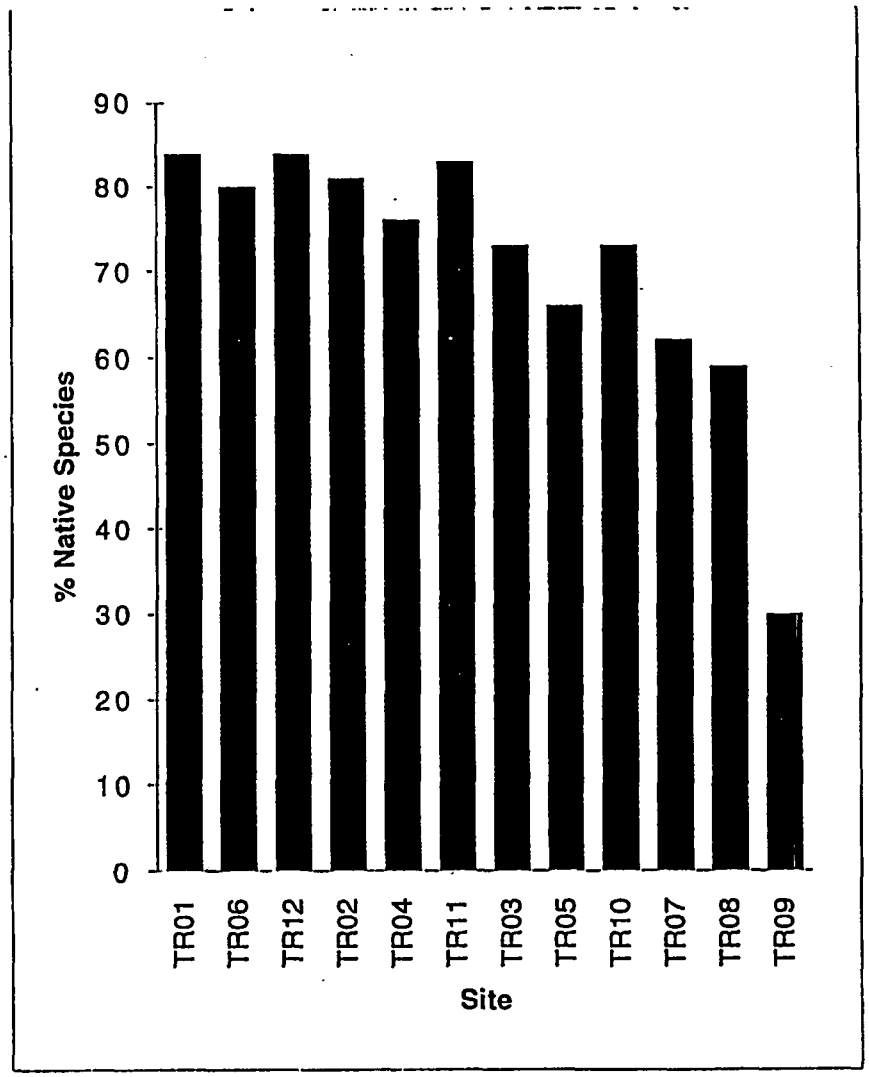


Figure B-4. 1994 % Native Species by EcMP Site.

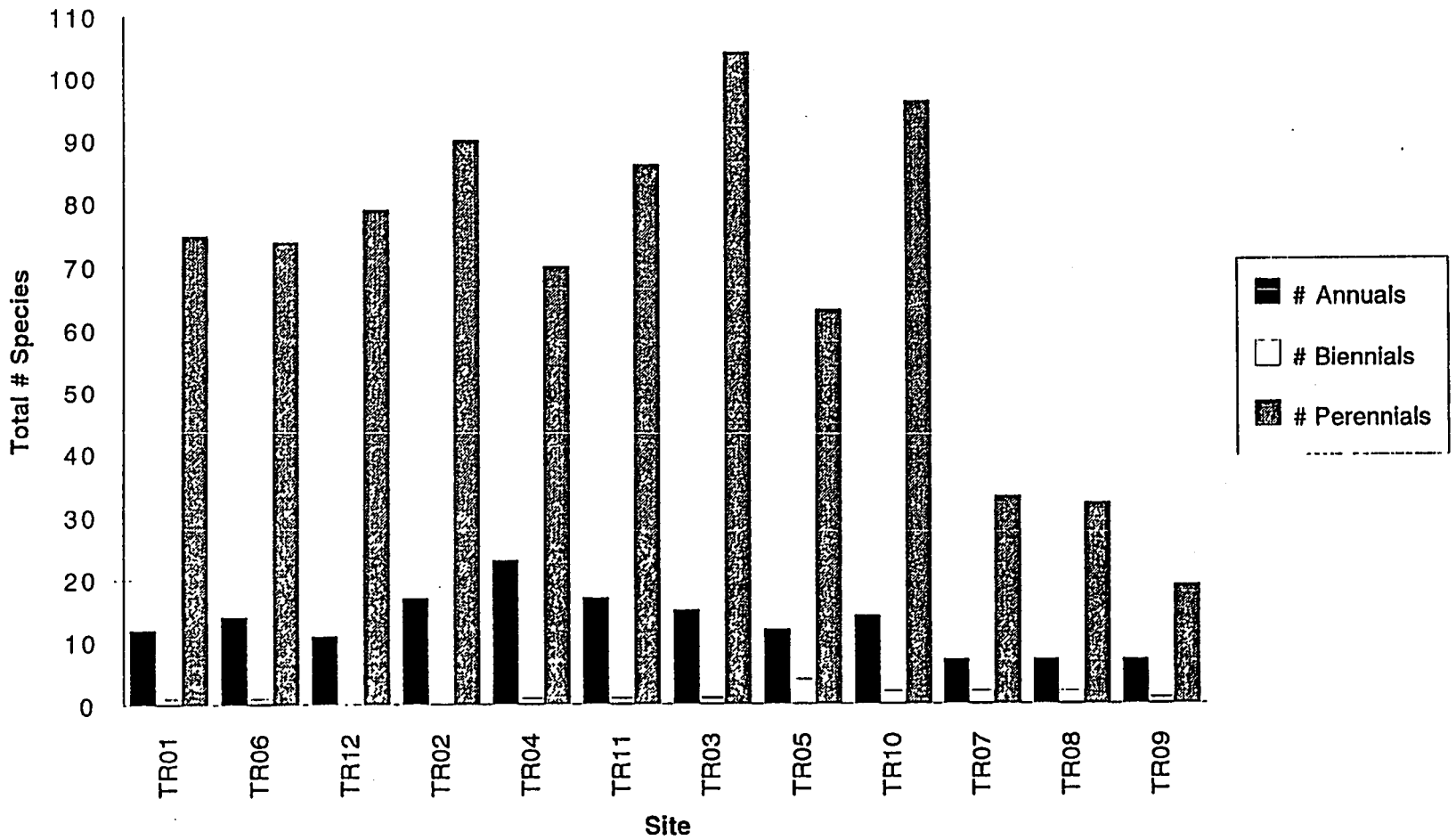


Figure B-5. 1994 Annual, Biennial, & Perennial Life Forms by EcMP Site.

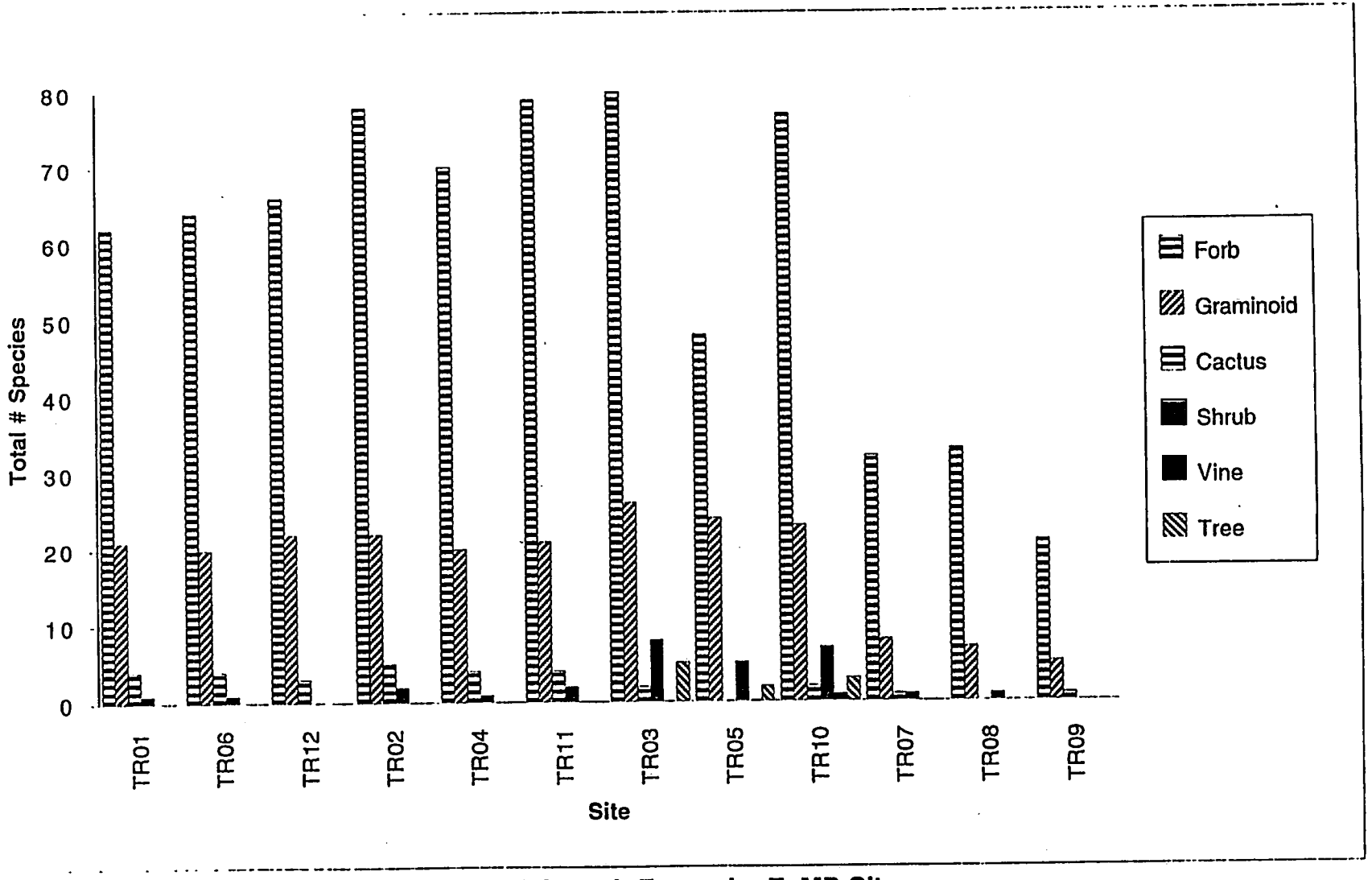


Figure B-6. 1994 Growth Forms by EcMP Site.

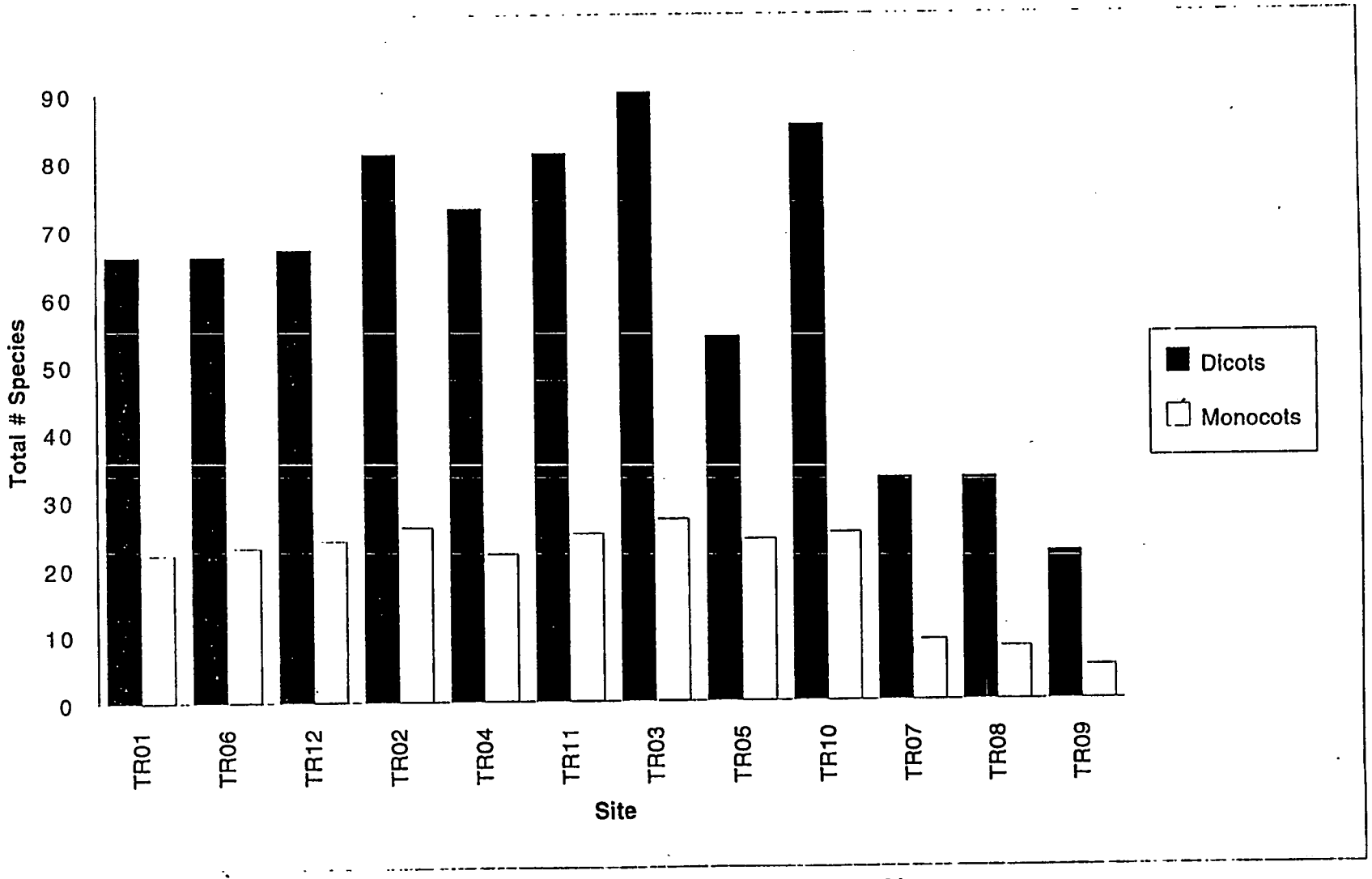


Figure B-7. 1994 Dicots/Monocots by EcMP Site.

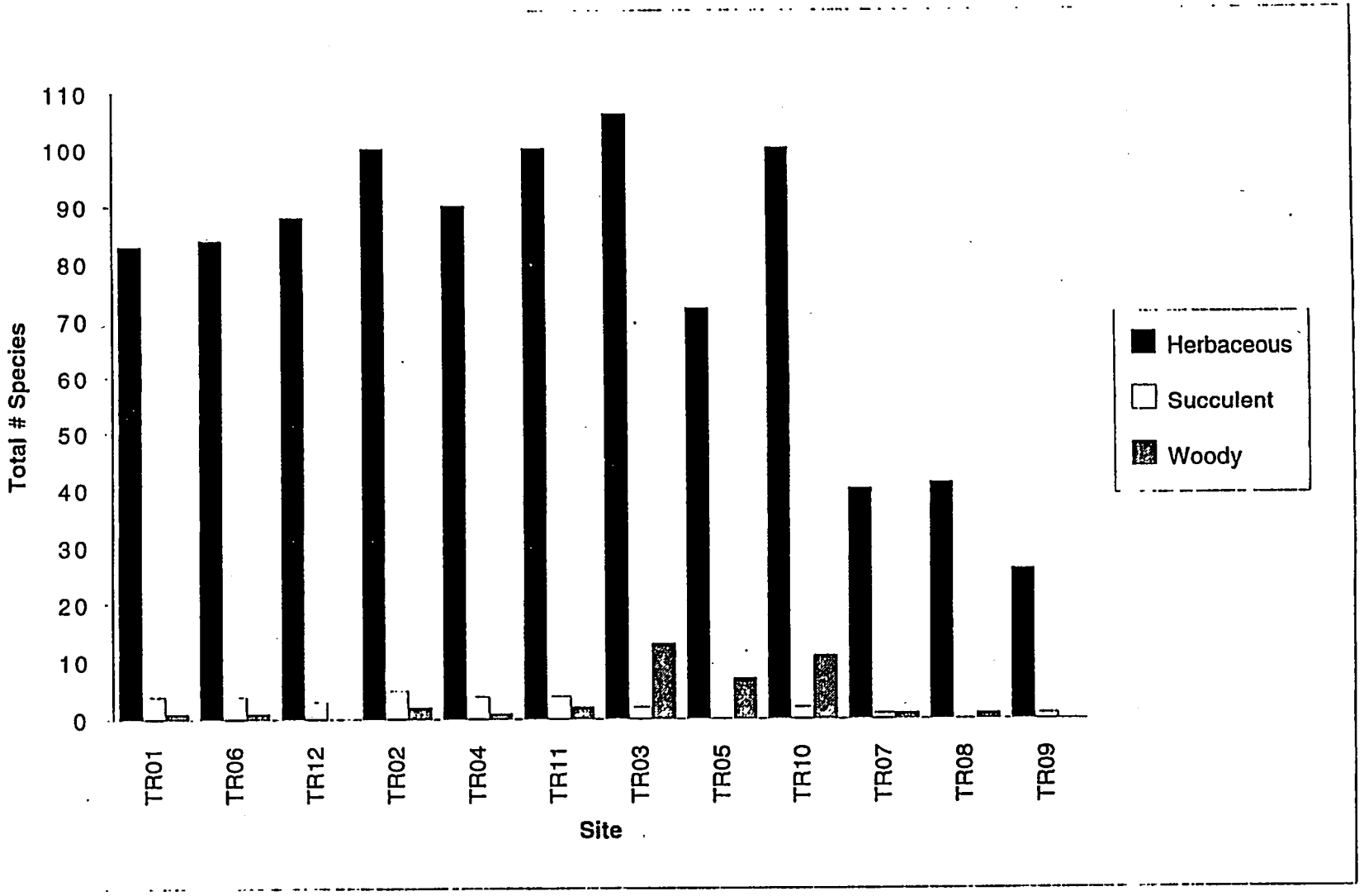


Figure B-8. 1994 Life Forms by EcMP Site.

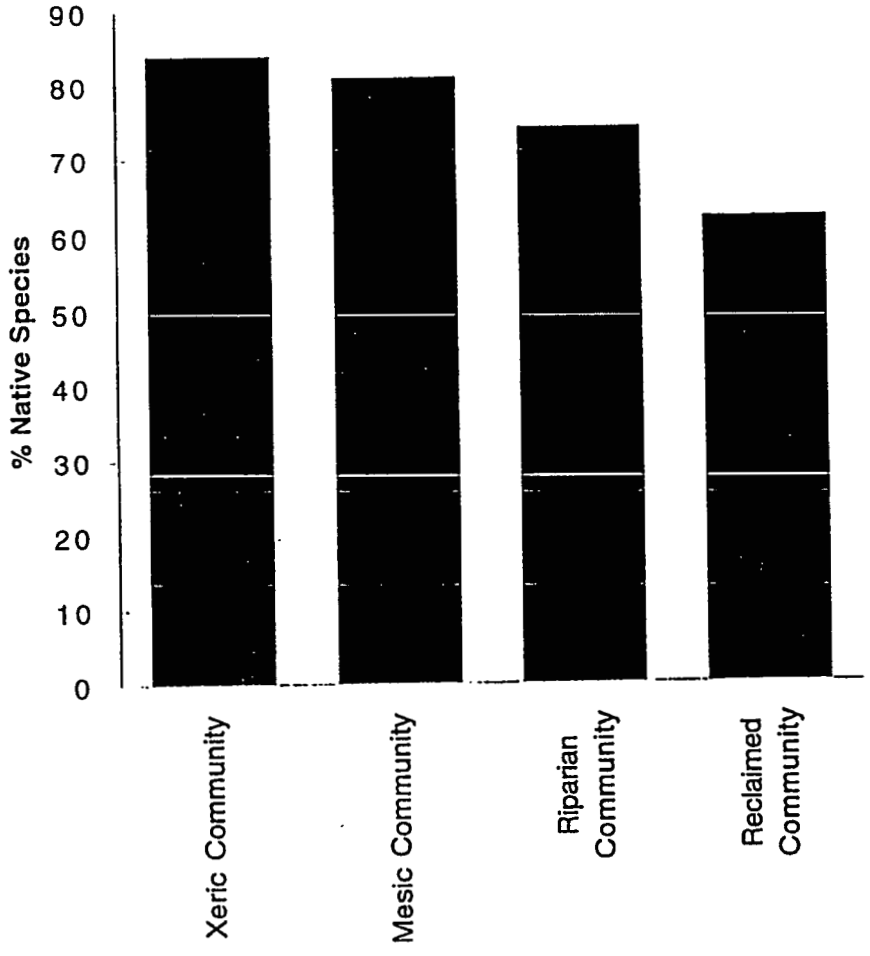


Figure B-9. 1994 % Native Species by Community.

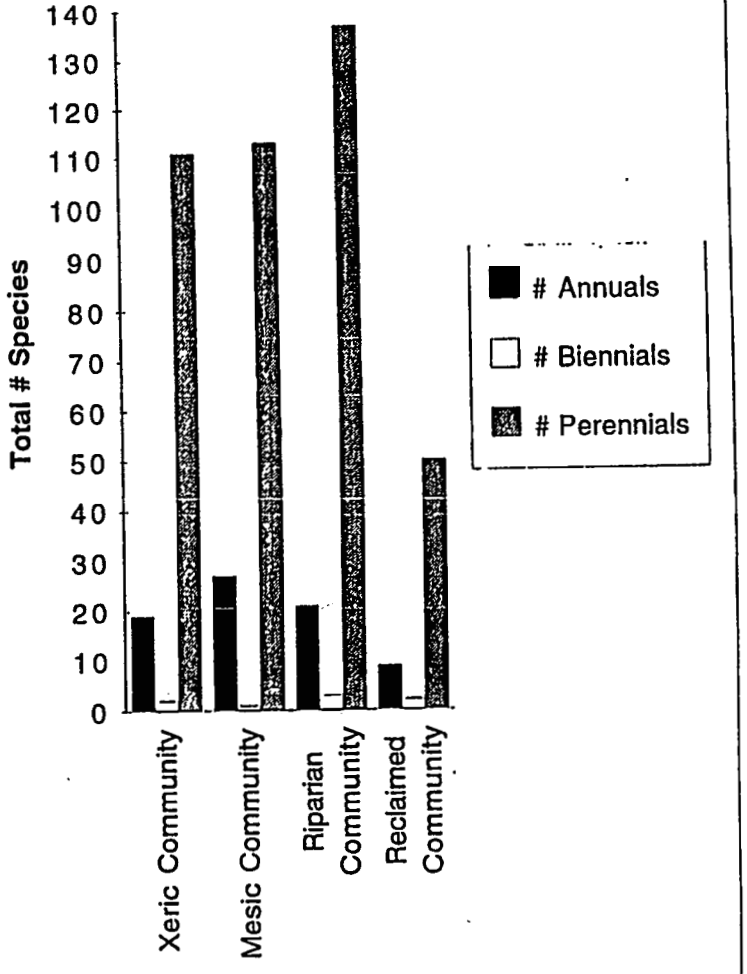


Figure B-10. 1994 Life Forms by Community.

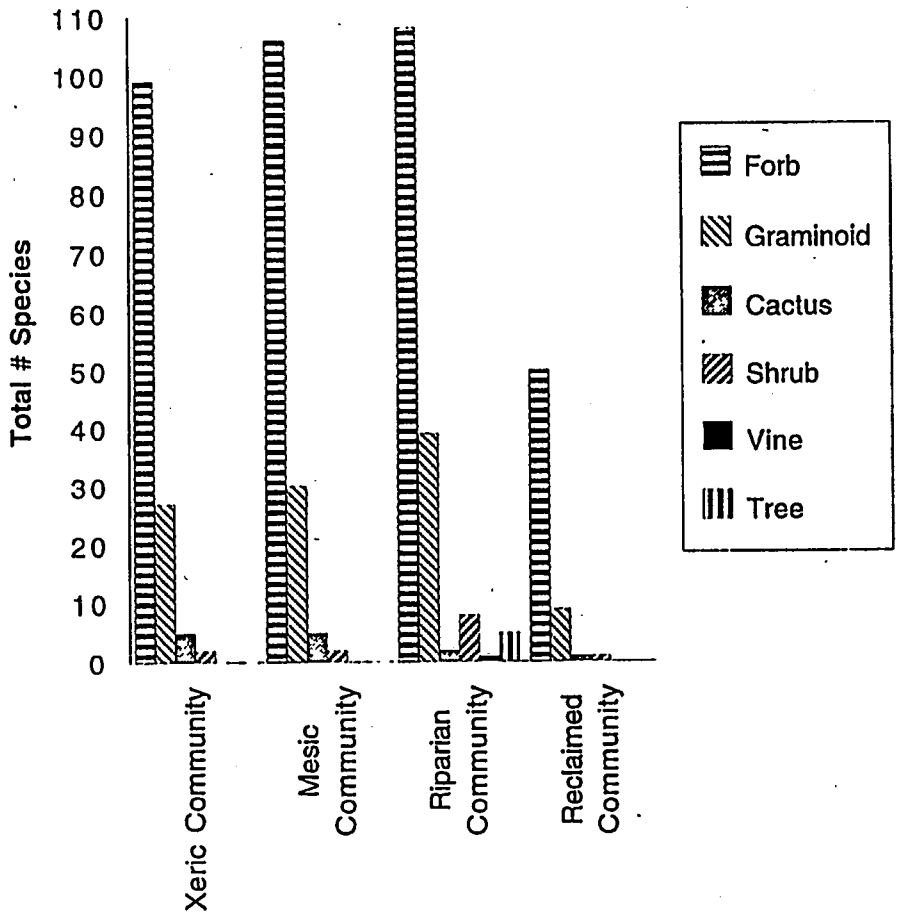


Figure B-11. 1994 Growth Forms by Community.

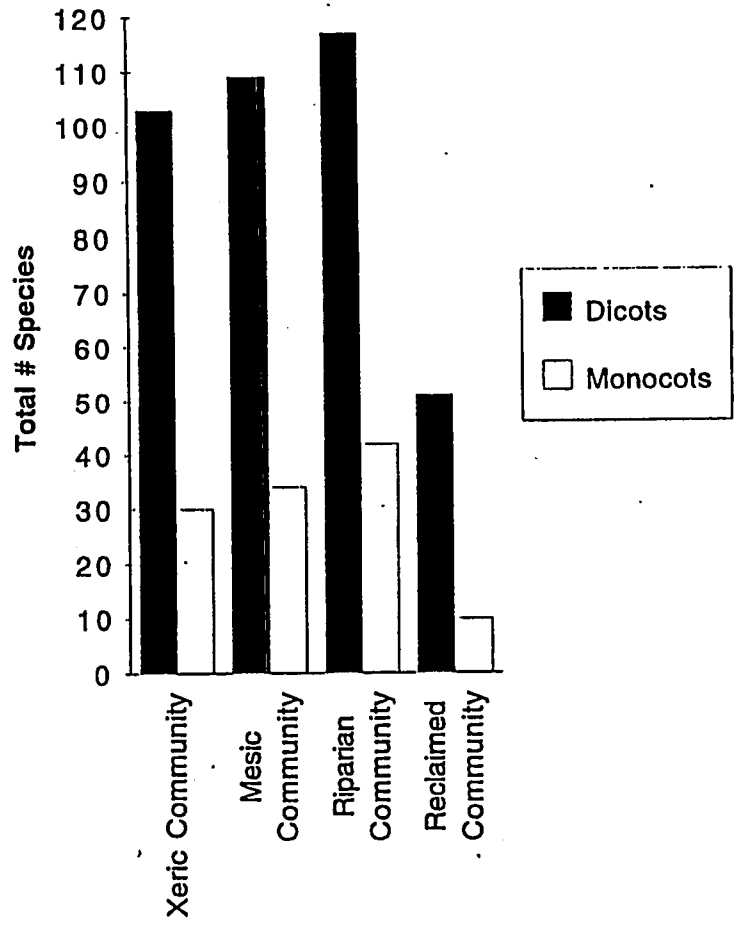
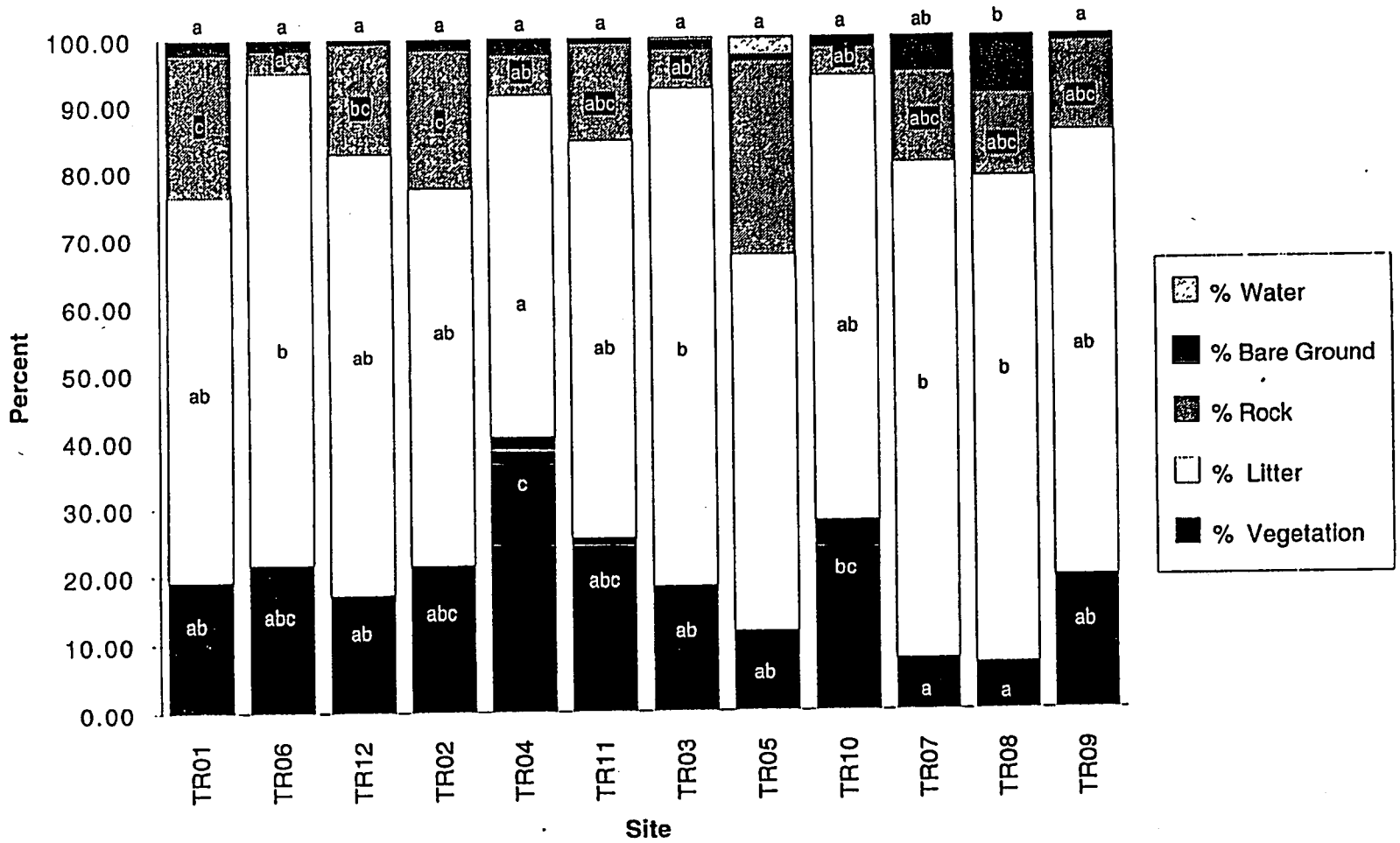


Figure B-12. 1994 Dicot/Monocots by Community.

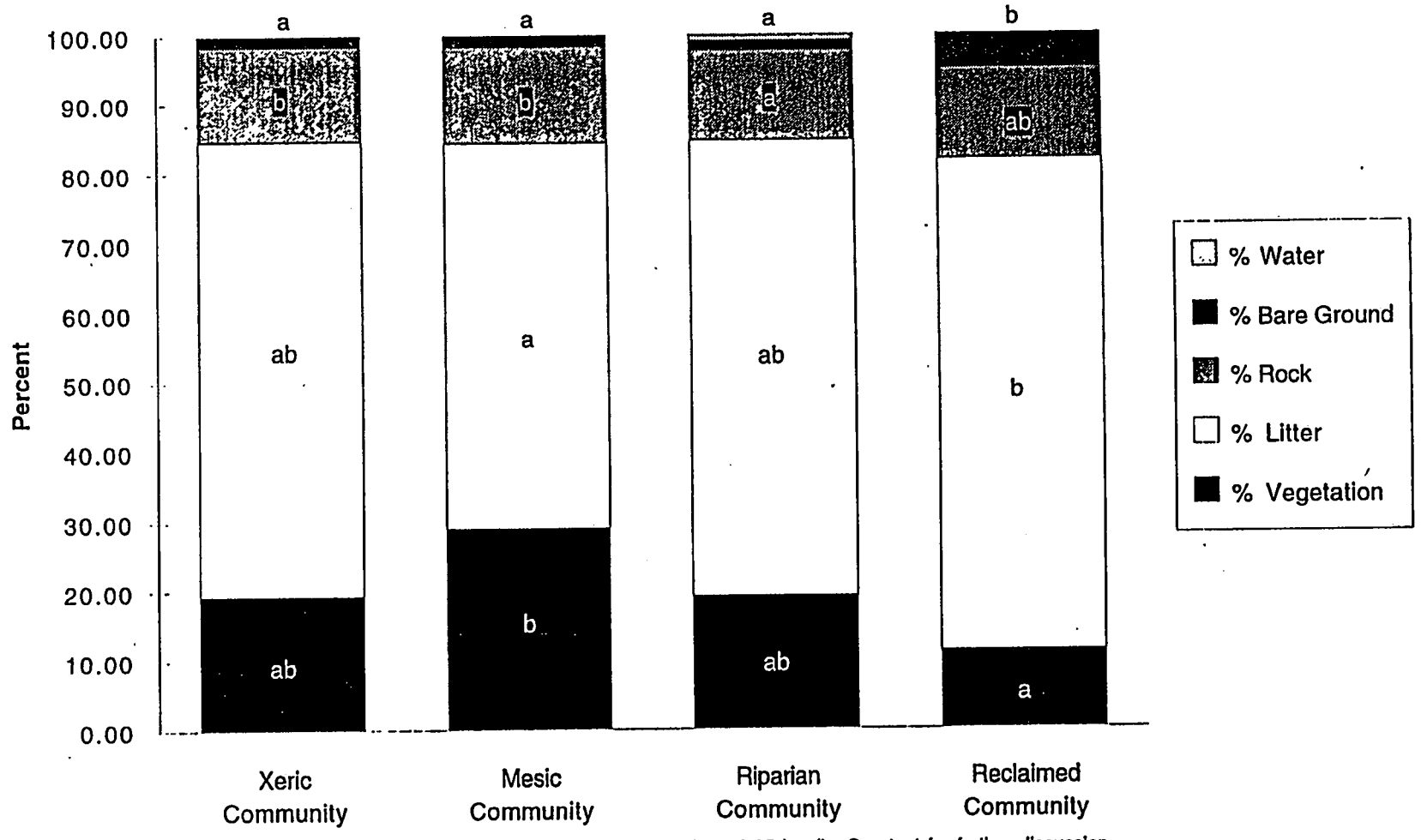
Letters on top of bars refer to Bare Ground cover class. No analysis was done for the Water cover class.



For each cover class, one or more common letters indicate no significant difference at the α =0.05 level. See text for further discussion.

Figure B-13. 1994 Basal Cover Percentages by EcMP Site.

Letters on the top of the bars are for the Bare Ground cover class. No analysis was done on the Water cover class.



For each cover class, one or more common letters indicate no significant difference (α =0.05 level). See text for further discussion.

Figure B-14. 1994 Basal Cover Percentages by Community.

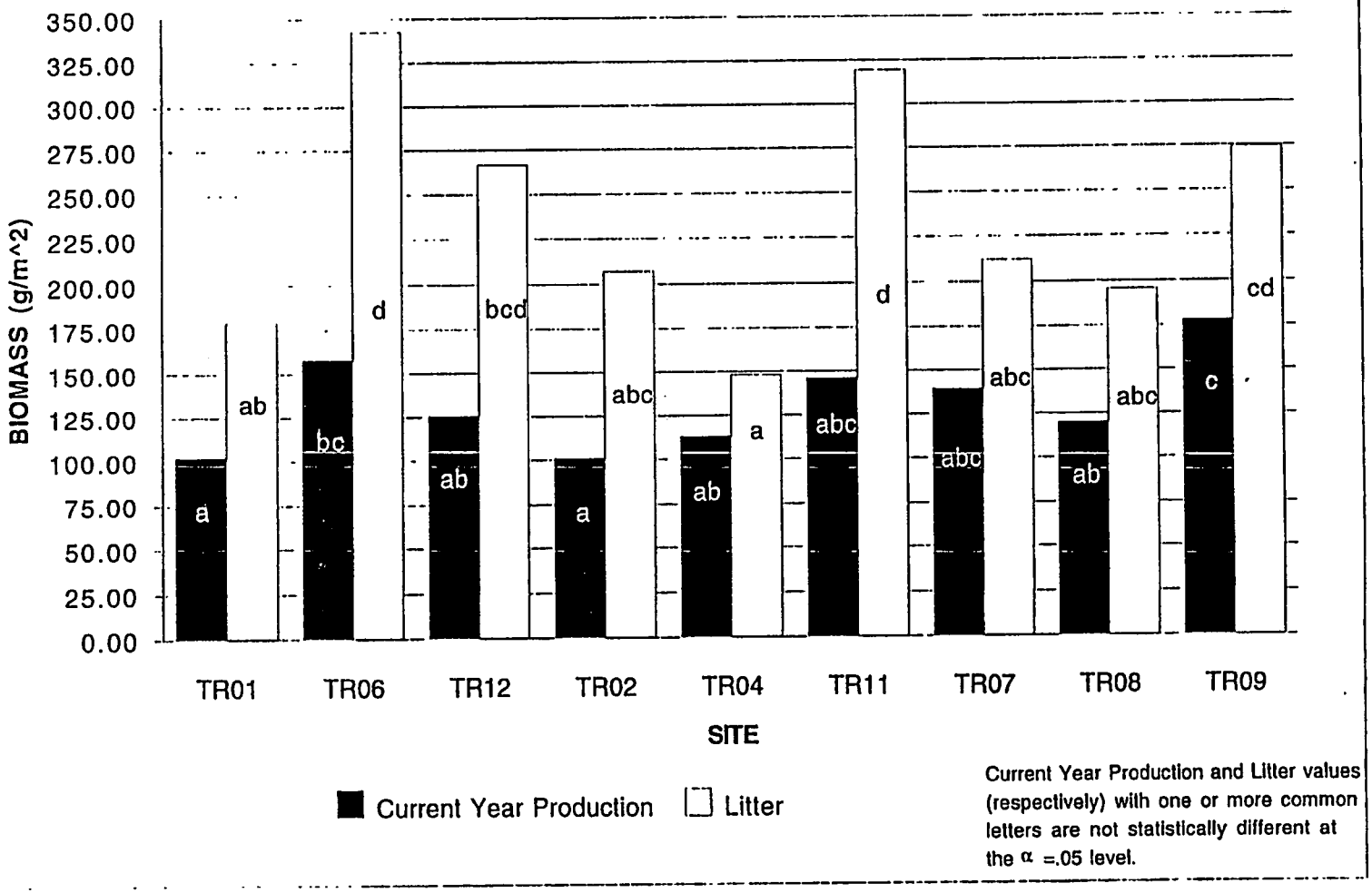
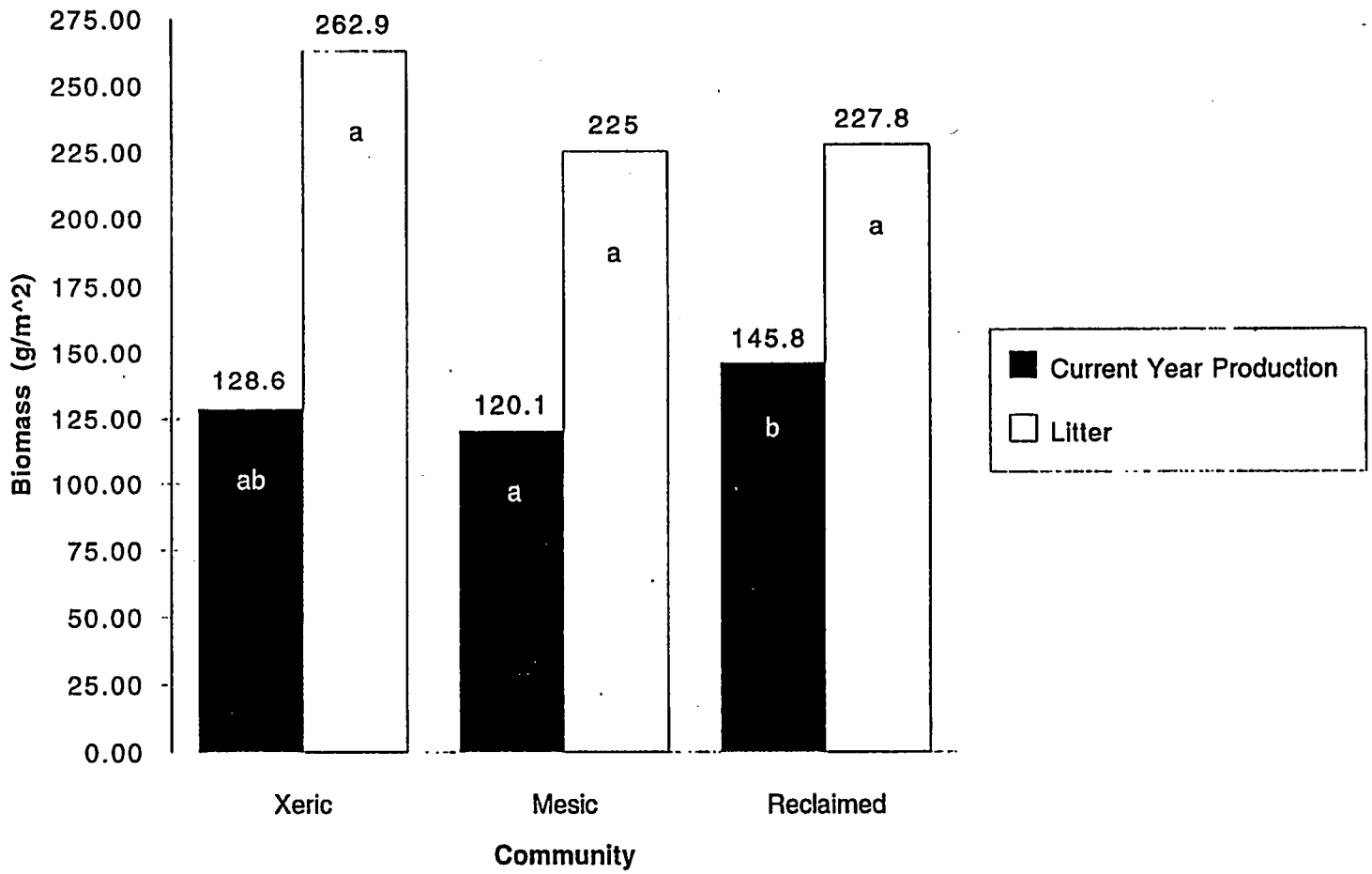


Figure B-15. 1994 Biomass Amounts from EcMP Sites.



Bars having values with one or more common letters are not statistically different at the α =0.1 level for each biomass type.

Figure B-16. 1994 Biomass Amounts by Community.

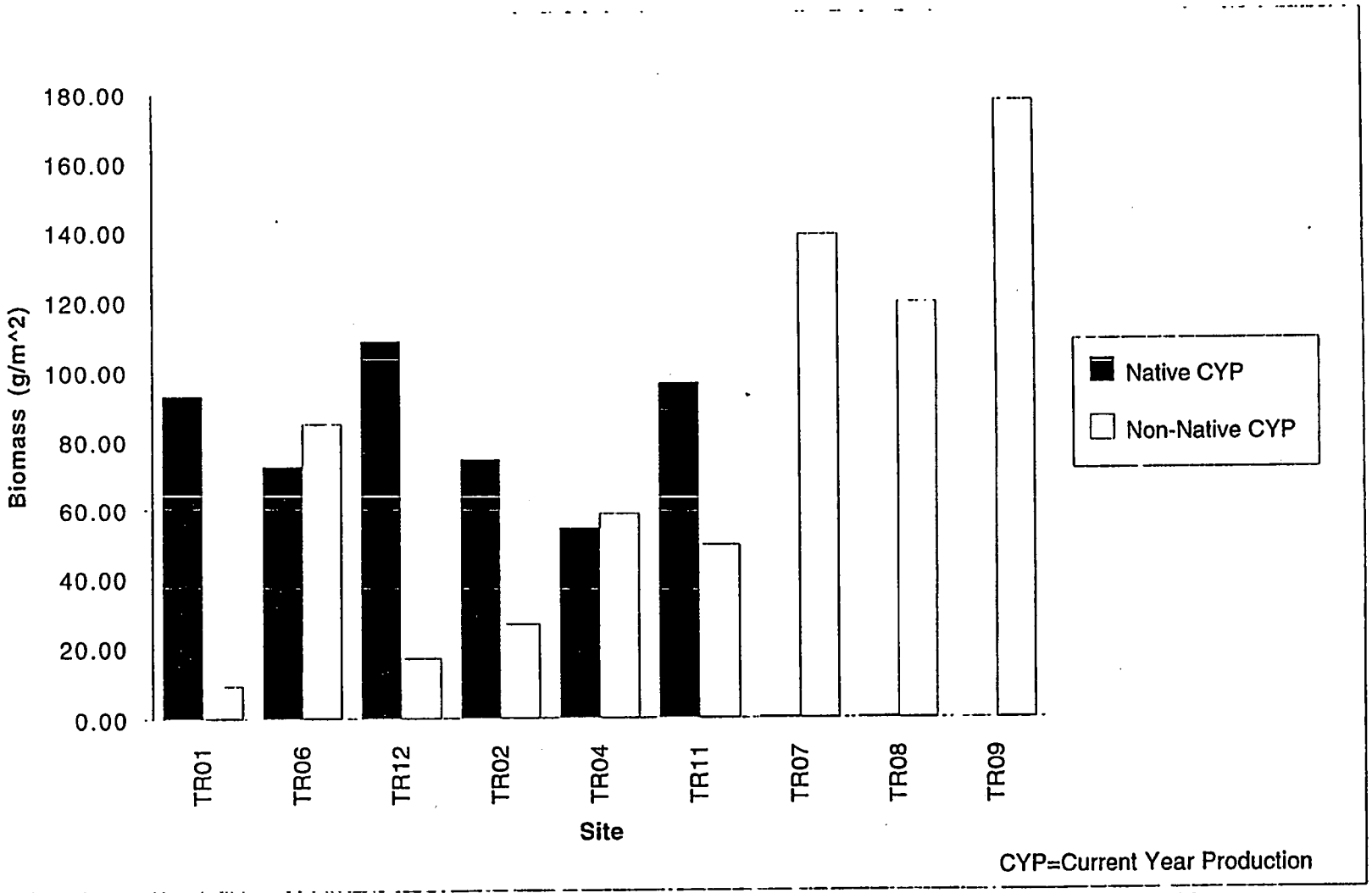


Figure B-17. 1994 Native vs. Non-Native Current Year Production Biomass by EcMP Site.

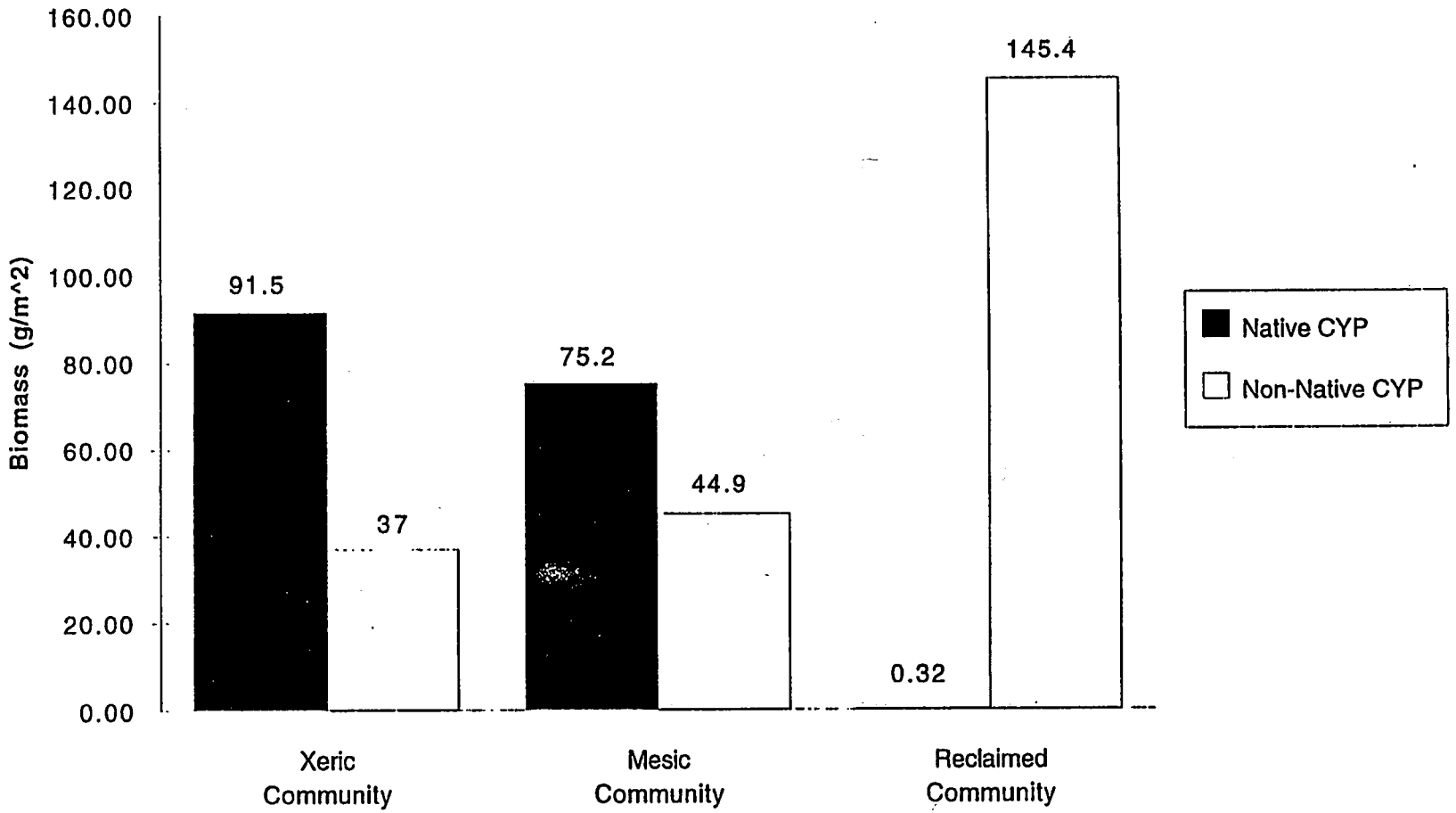


Figure B-18. 1994 Native vs. Non-Native Current Year Production Biomass by Community.

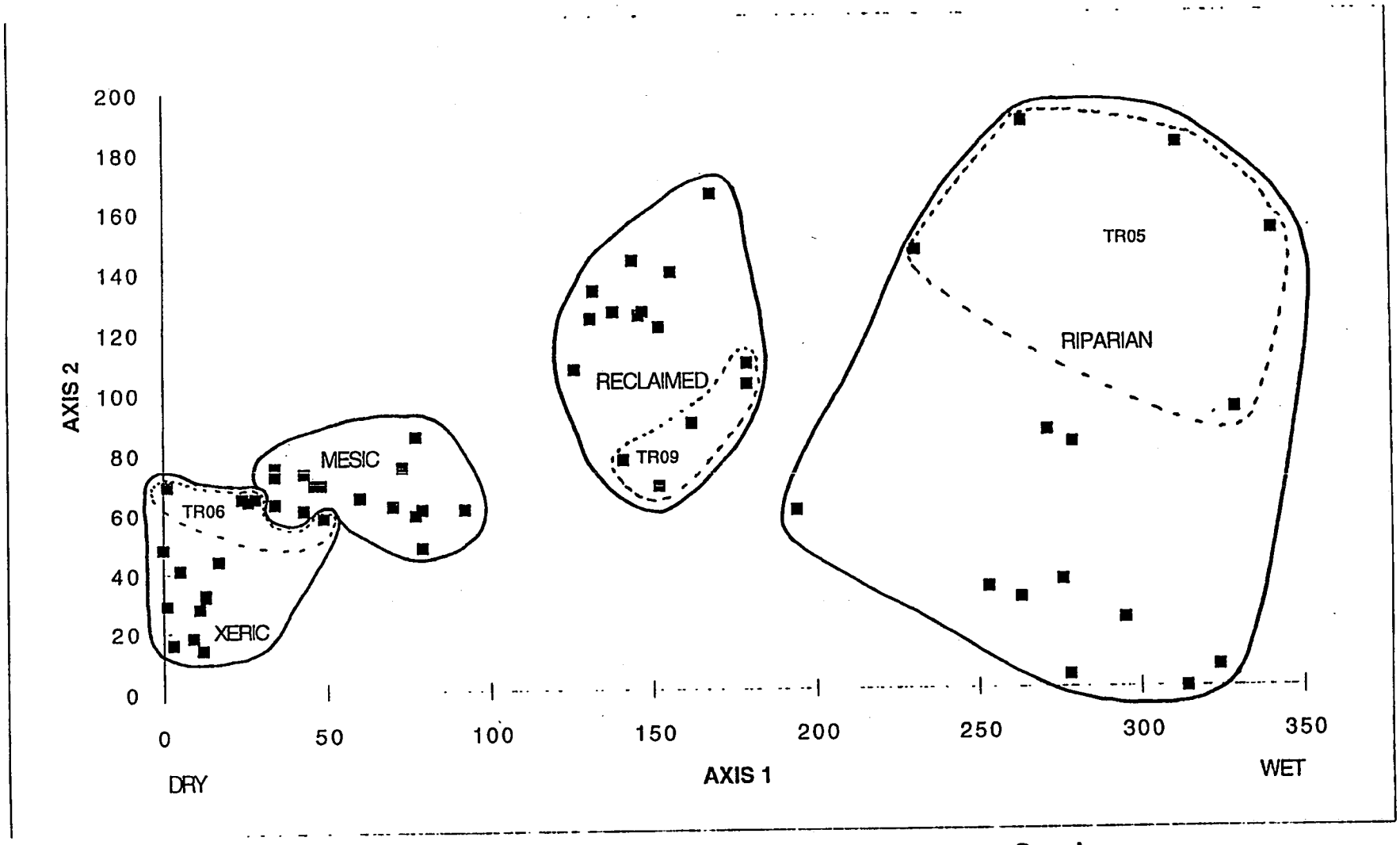


Figure B-19. Terrestrial Vegetation DECORANA Ordination by EcMP Transects - Species Presence/Absence Data, Axes 1 and 2.

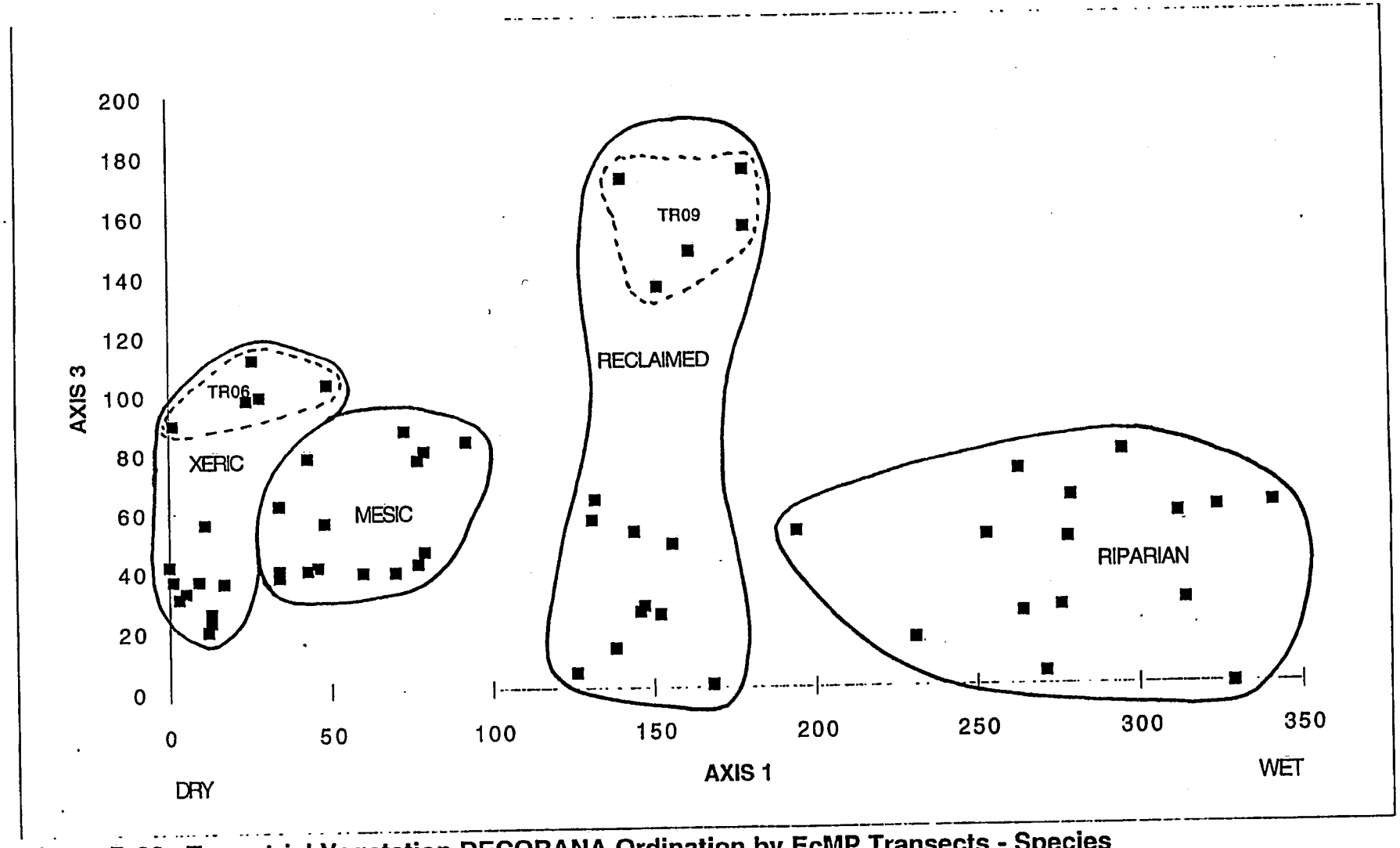


Figure B-20. Terrestrial Vegetation DECORANA Ordination by EcMP Transects - Species Presence/Absence Data, Axes 1 and 3.

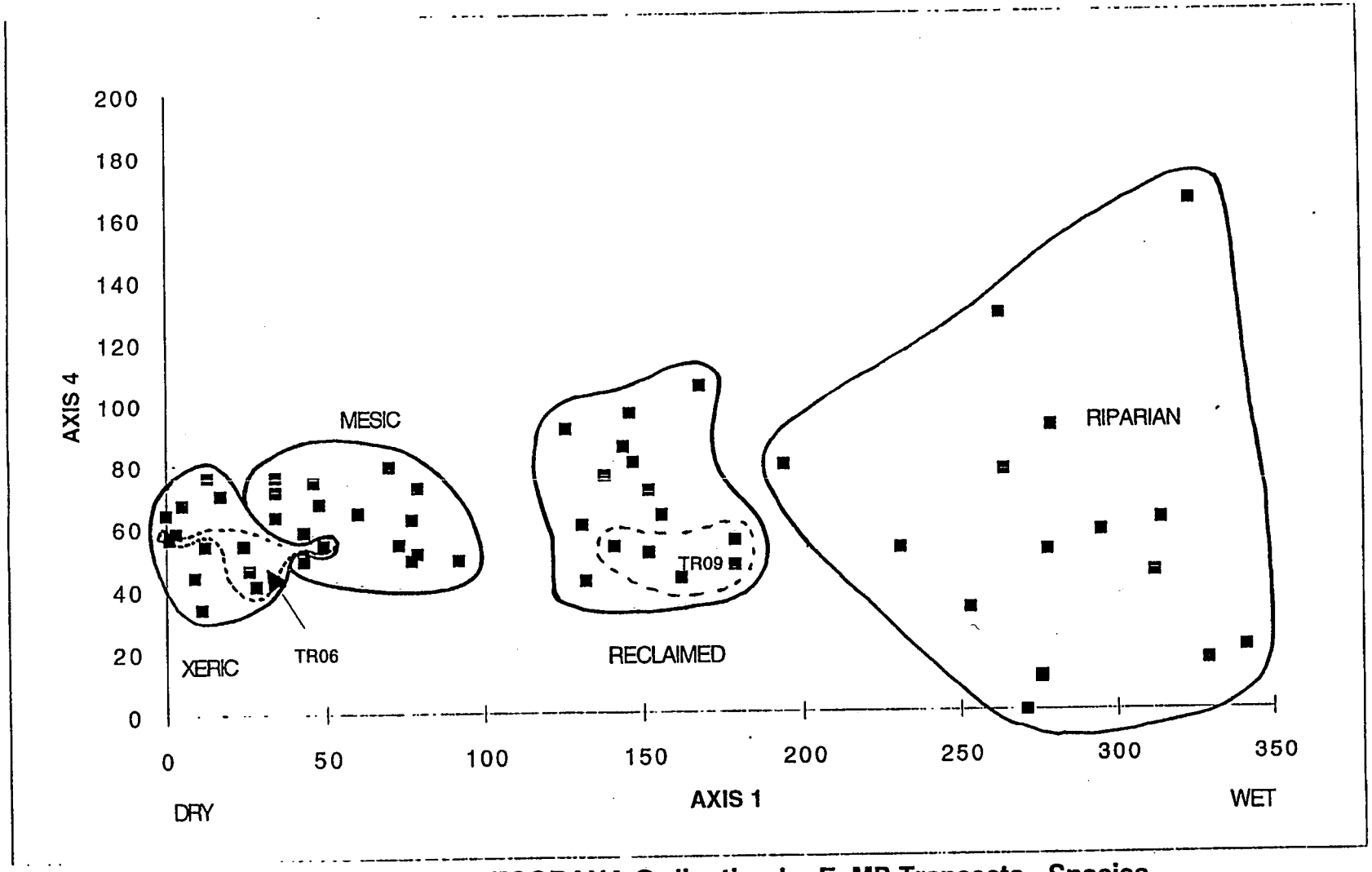


Figure B-21. Terrestrial Vegetation DECORANA Ordination by EcMP Transects - Species Presence/Absence Data, Axes 1 and 4.

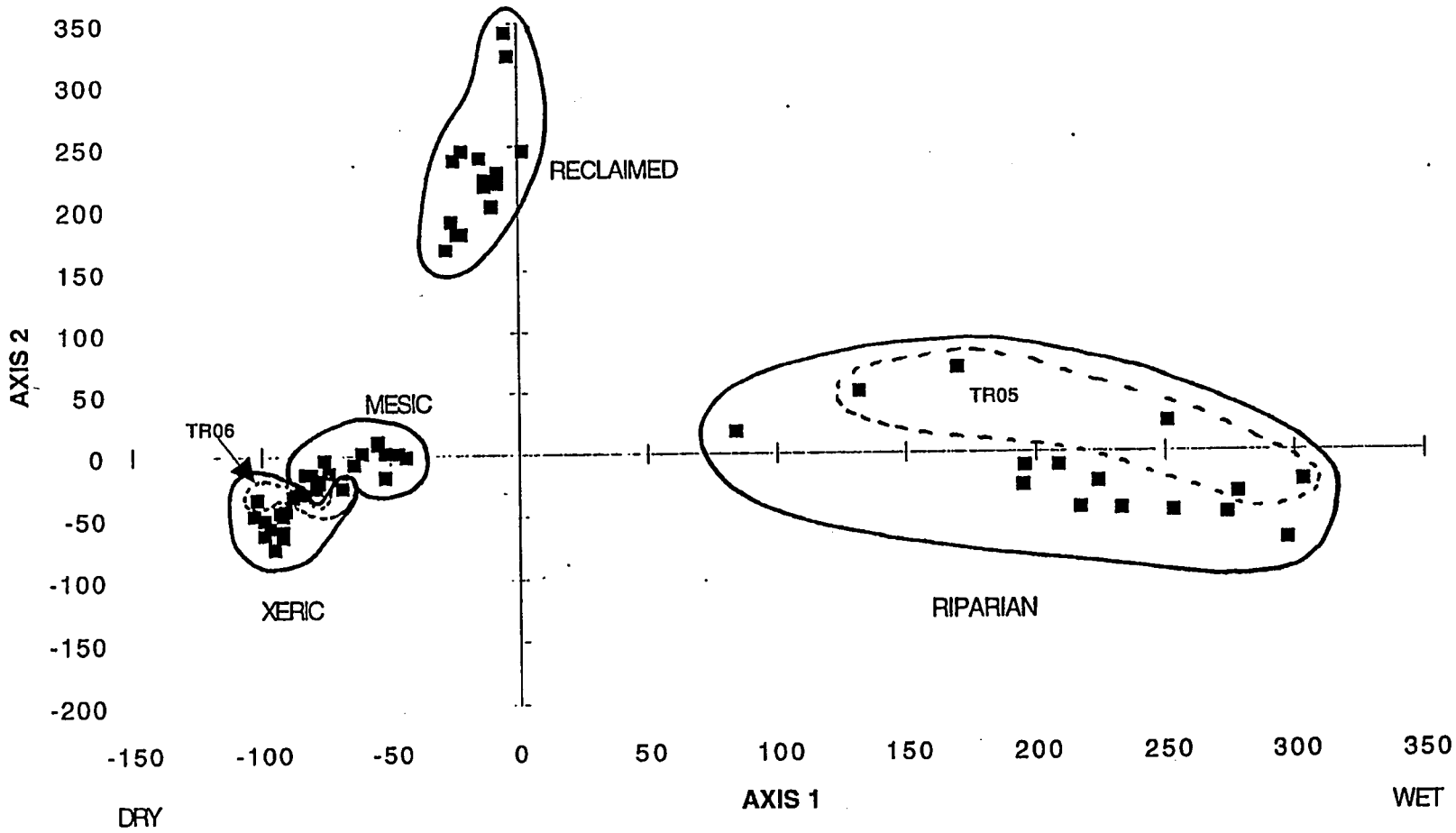


Figure B-22. Terrestrial Vegetation Ordination (Reciprocal Averaging) - Species Presence/Absence Data, Axes 1 and 2.

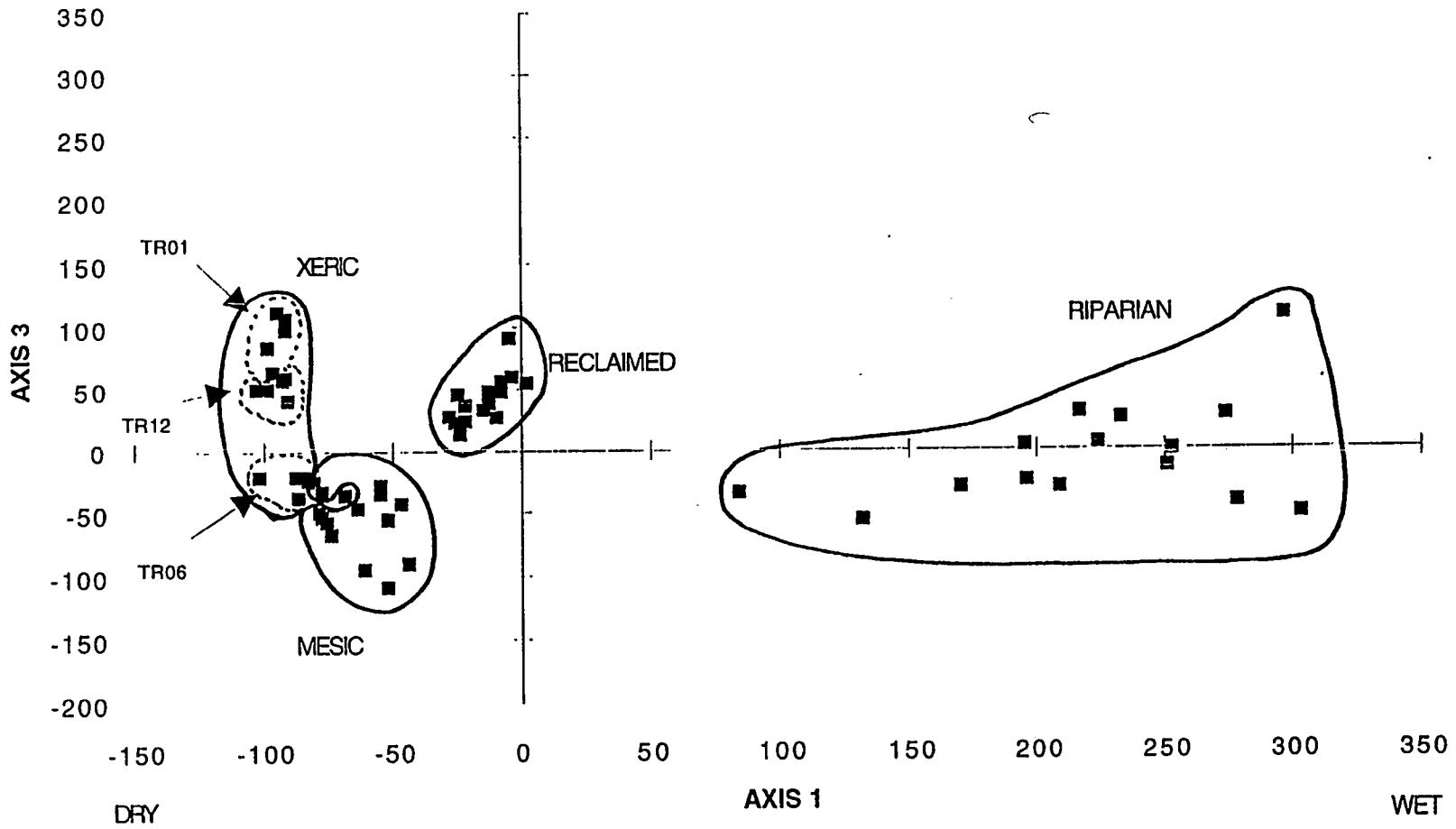


Figure B-23. Terrestrial Vegetation Ordination (Reciprocal Averaging) - Species Presence/Absence Data, Axes 1 and 3.

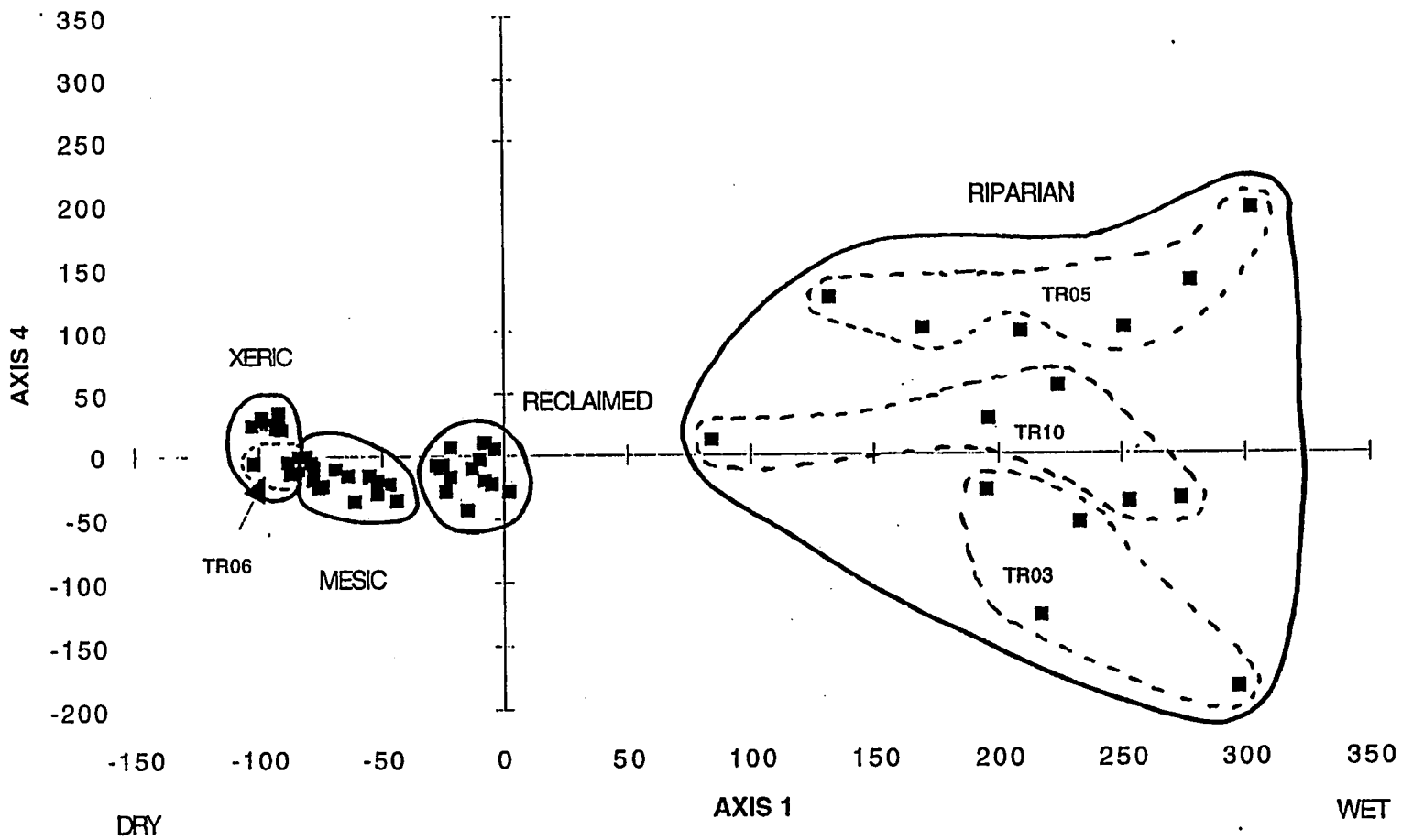


Figure B-24. Terrestrial Vegetation Ordination (Reciprocal Averaging) - Species Presence/Absence Data, Axes 1 and 4.

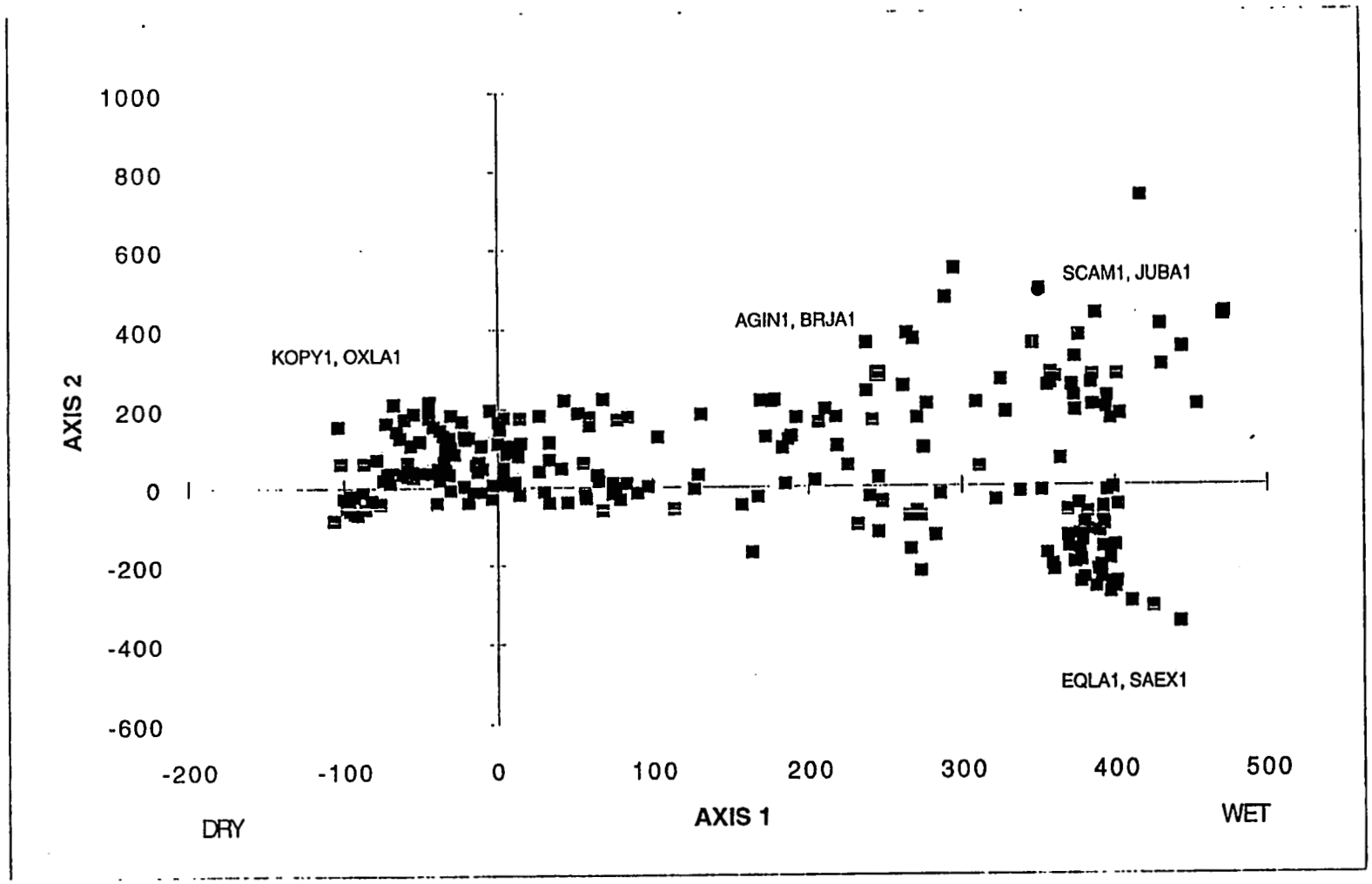


Figure B-25. Terrestrial Vegetation DECORANA Ordination by Species - Presence/Absence Data, Axes 1 and 2.

Note: Speccodes listed are examples of those typical of that part of the figure. See Table B-2 to determine scientific names from speccodes.

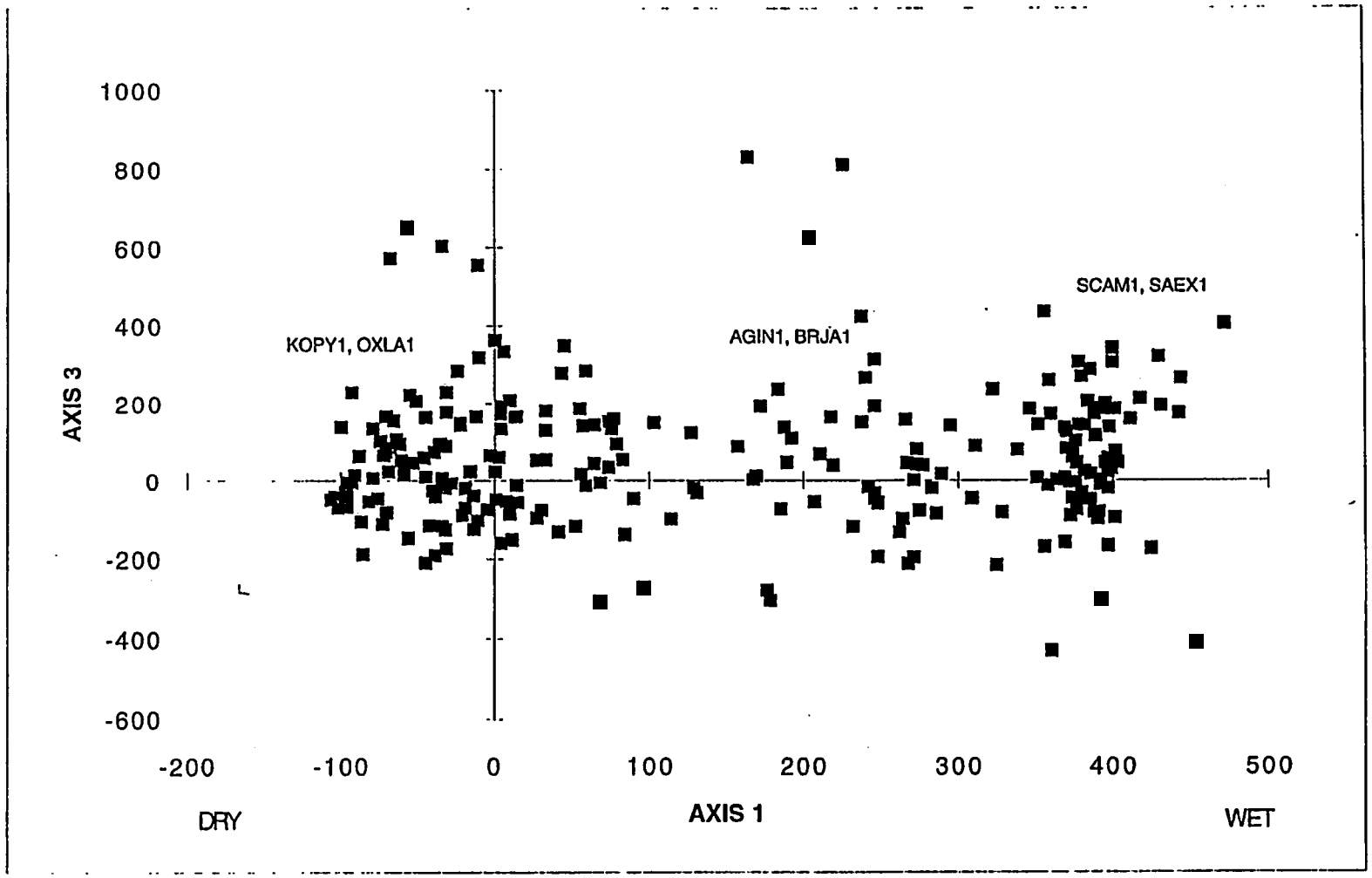


Figure B-26. Terrestrial Vegetation DECORANA Ordination by Species - Presence/Absence Data, Axes 1 and 3.

Note: Speccodes listed are examples of those typical of that part of the figure. See Table B-2 to determine scientific names from speccodes.

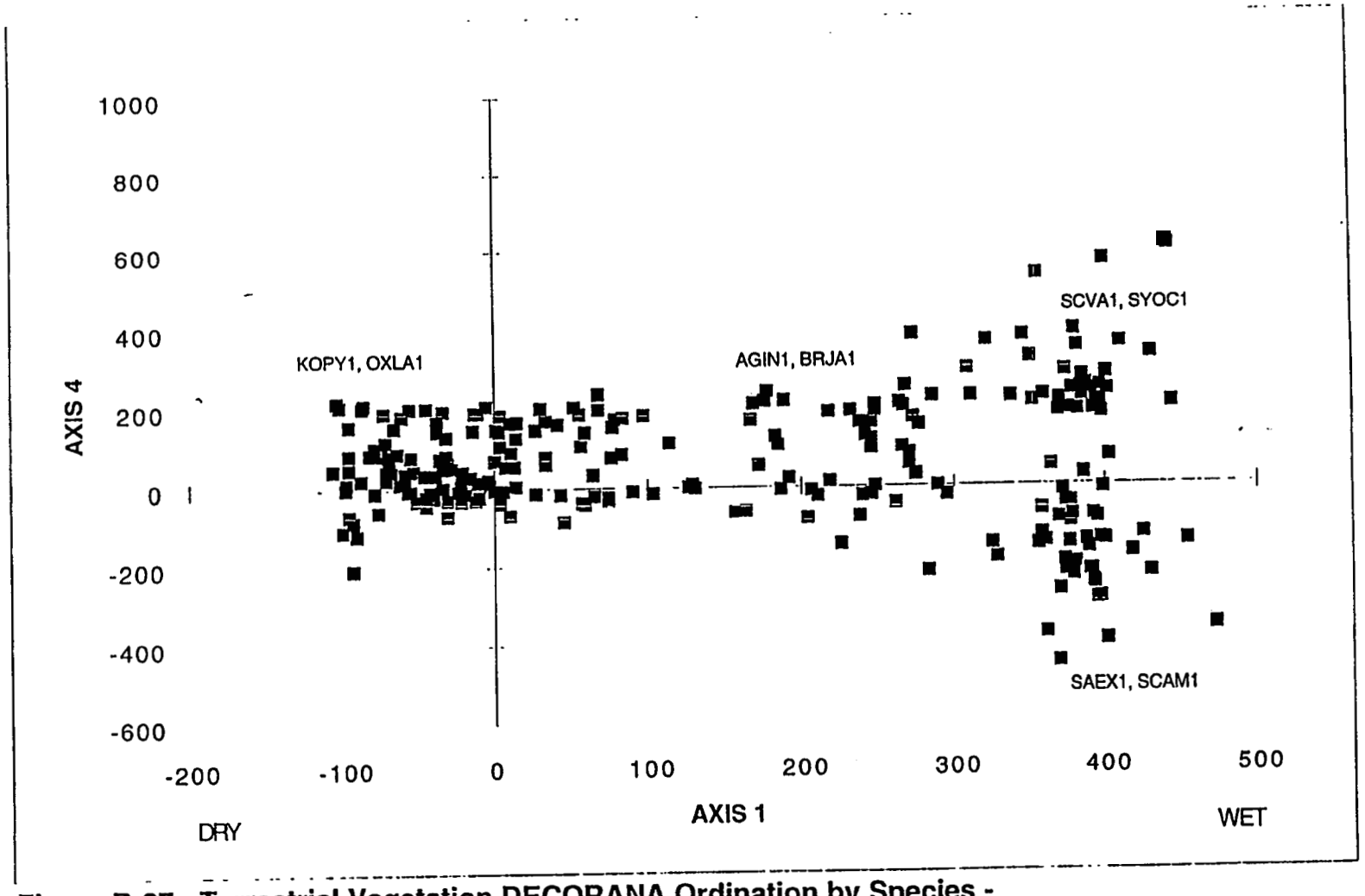


Figure B-27. Terrestrial Vegetation DECORANA Ordination by Species - Presence/Absence Data, Axes 1 and 4.

Note: Speccodes listed are examples of those typical of that part of the figure. See Table B-2 to determine scientific names from speccodes.

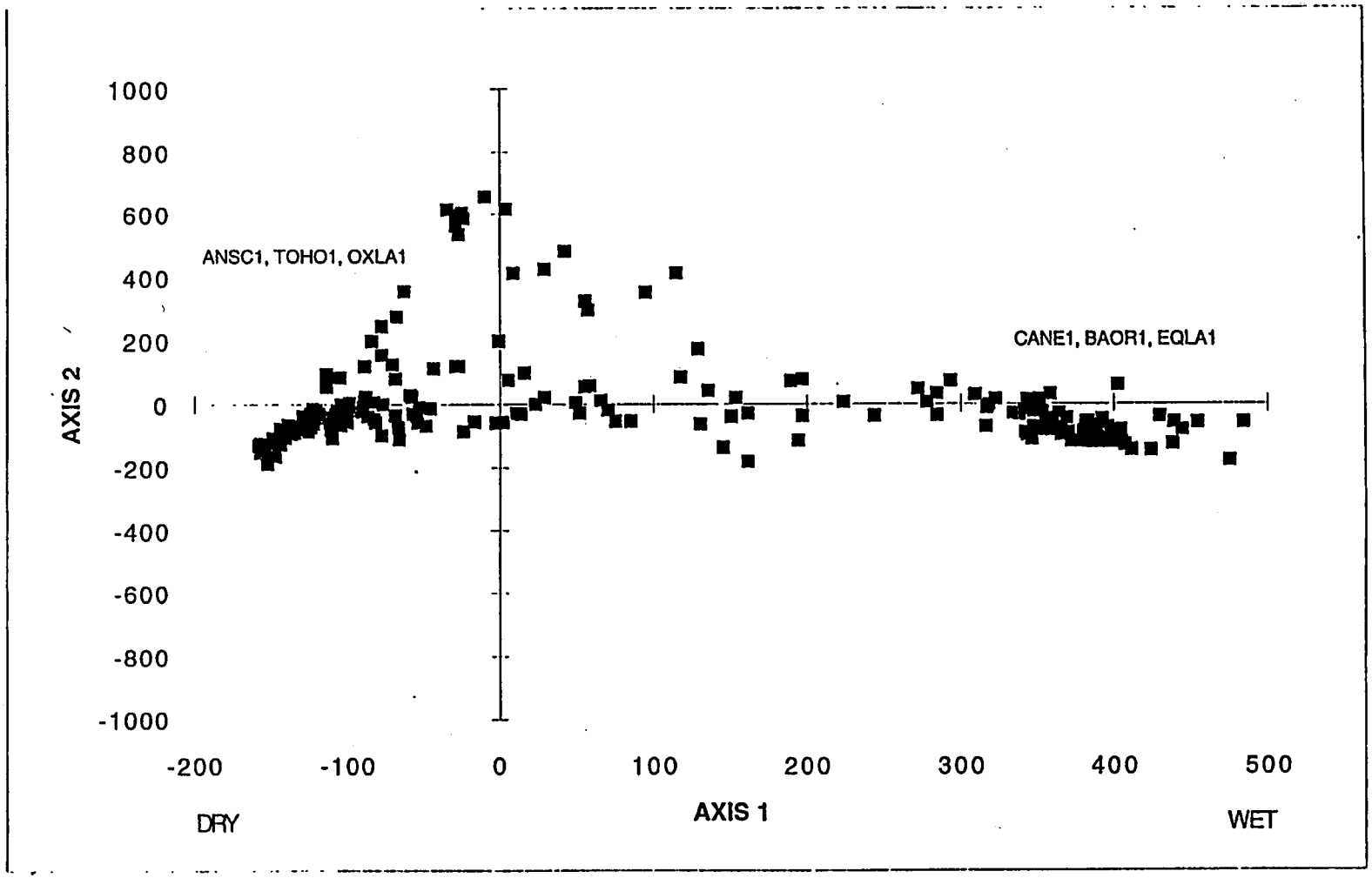


Figure B-28. Terrestrial Vegetation Ordination by Species (Reciprocal Averaging) - Presence/Absence Data, Axes 1 and 2.

Note: Speccodes listed are examples of those typical of that part of the figure. See Table B-2 to determine scientific names from speccodes.

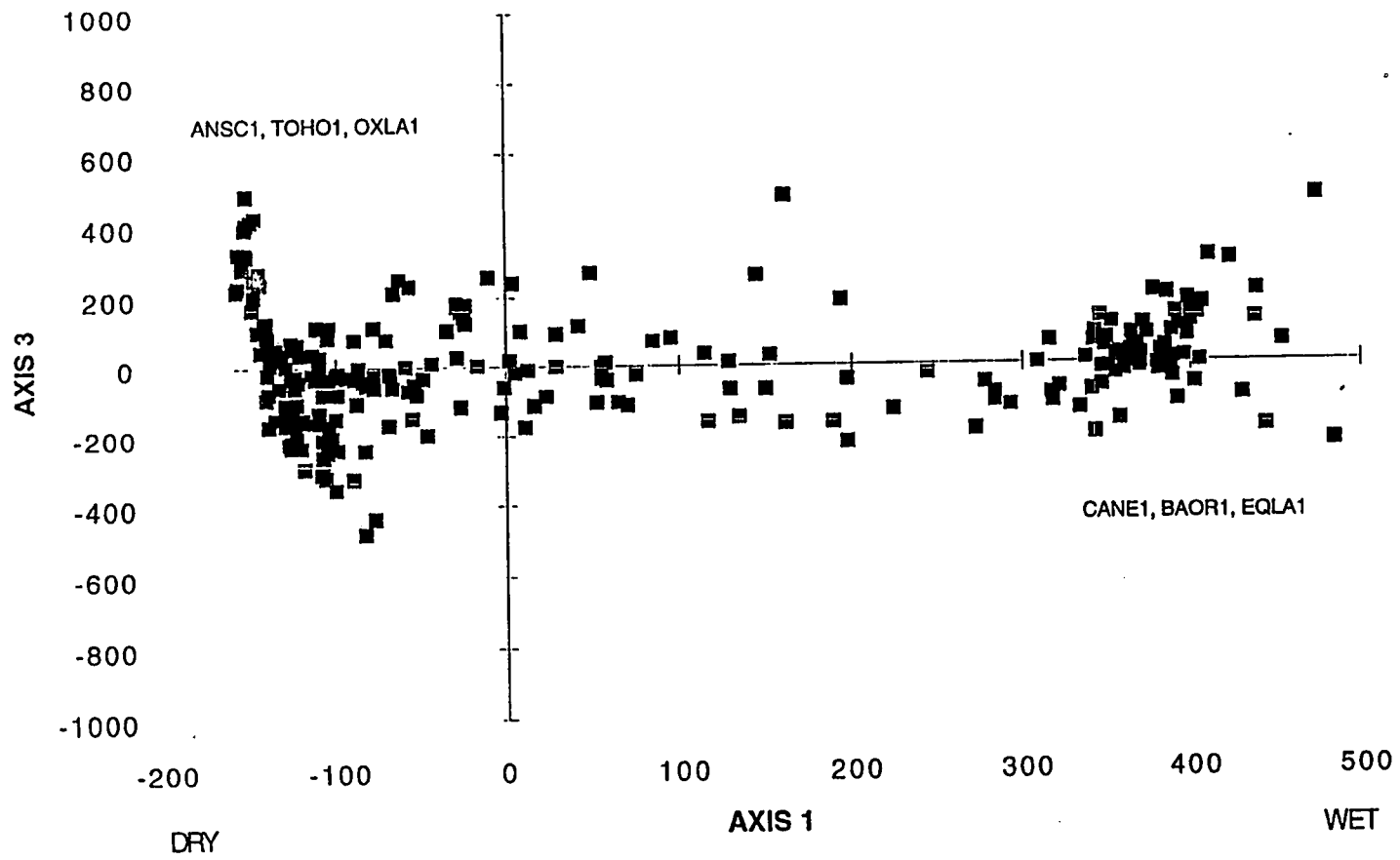


Figure B-29. Terrestrial Vegetation Ordination by Species (Reciprocal Averaging) - Presence/Absence Data, Axes 1 and 3.

Note: Speccodes listed are examples of those typical of that part of the figure. See Table B-2 to determine scientific names from speccodes.

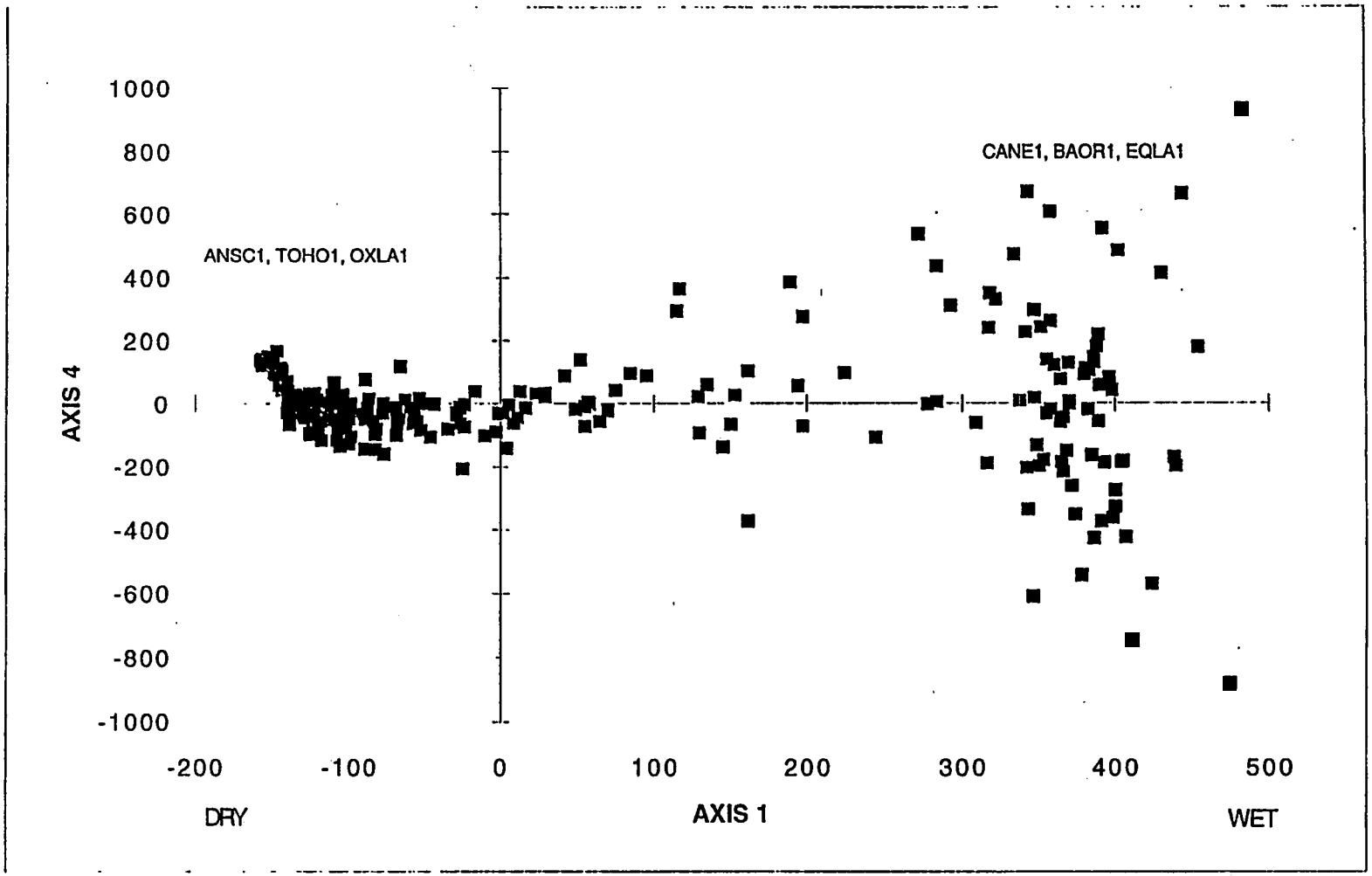


Figure B-30. Terrestrial Vegetation Ordination by Species (Reciprocal Averaging) - Presence/Absence Data, Axes 1 and 4.

Note: Speccodes listed are examples of those typical of that part of the figure. See Table B-2 to determine scientific names from speccodes.

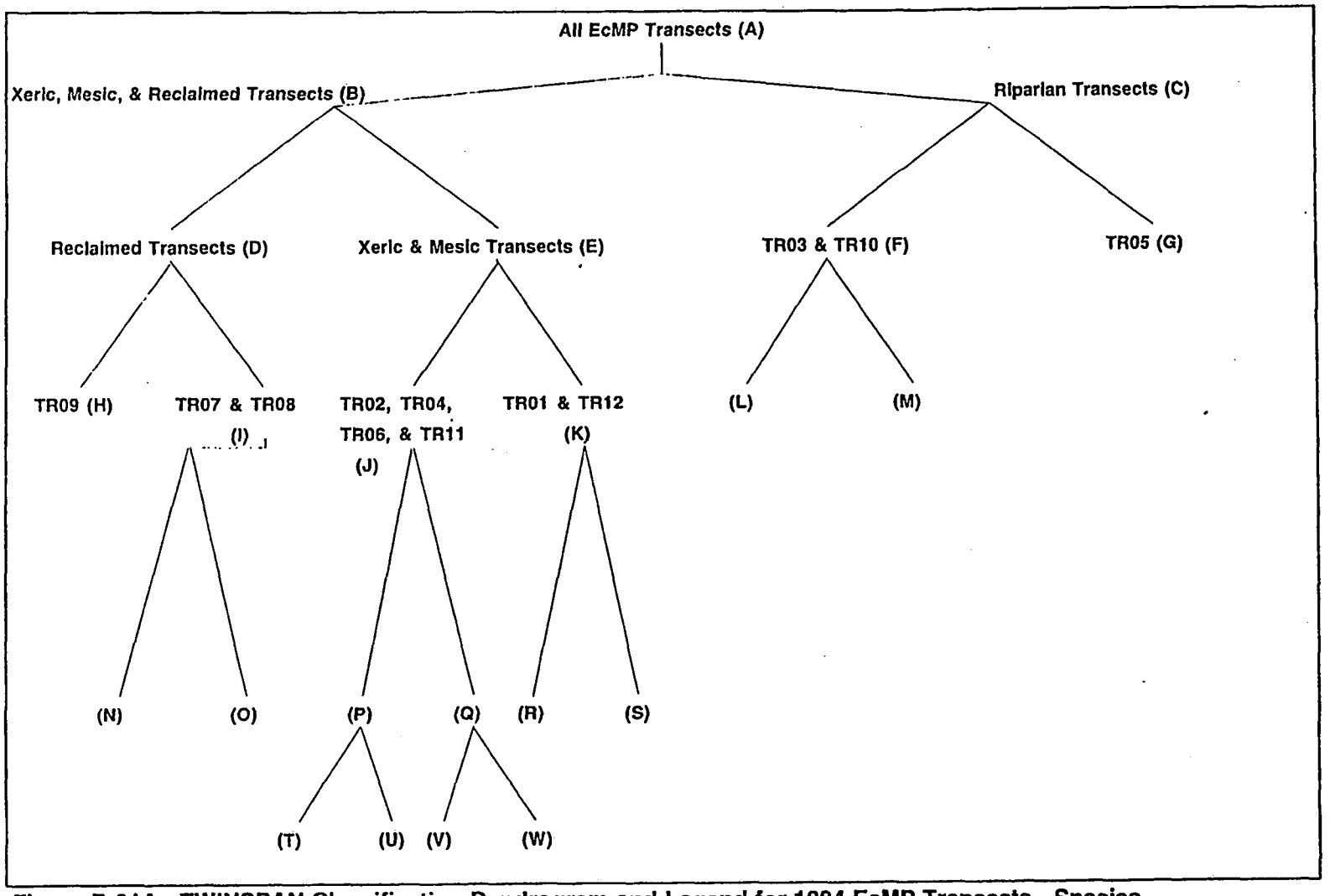


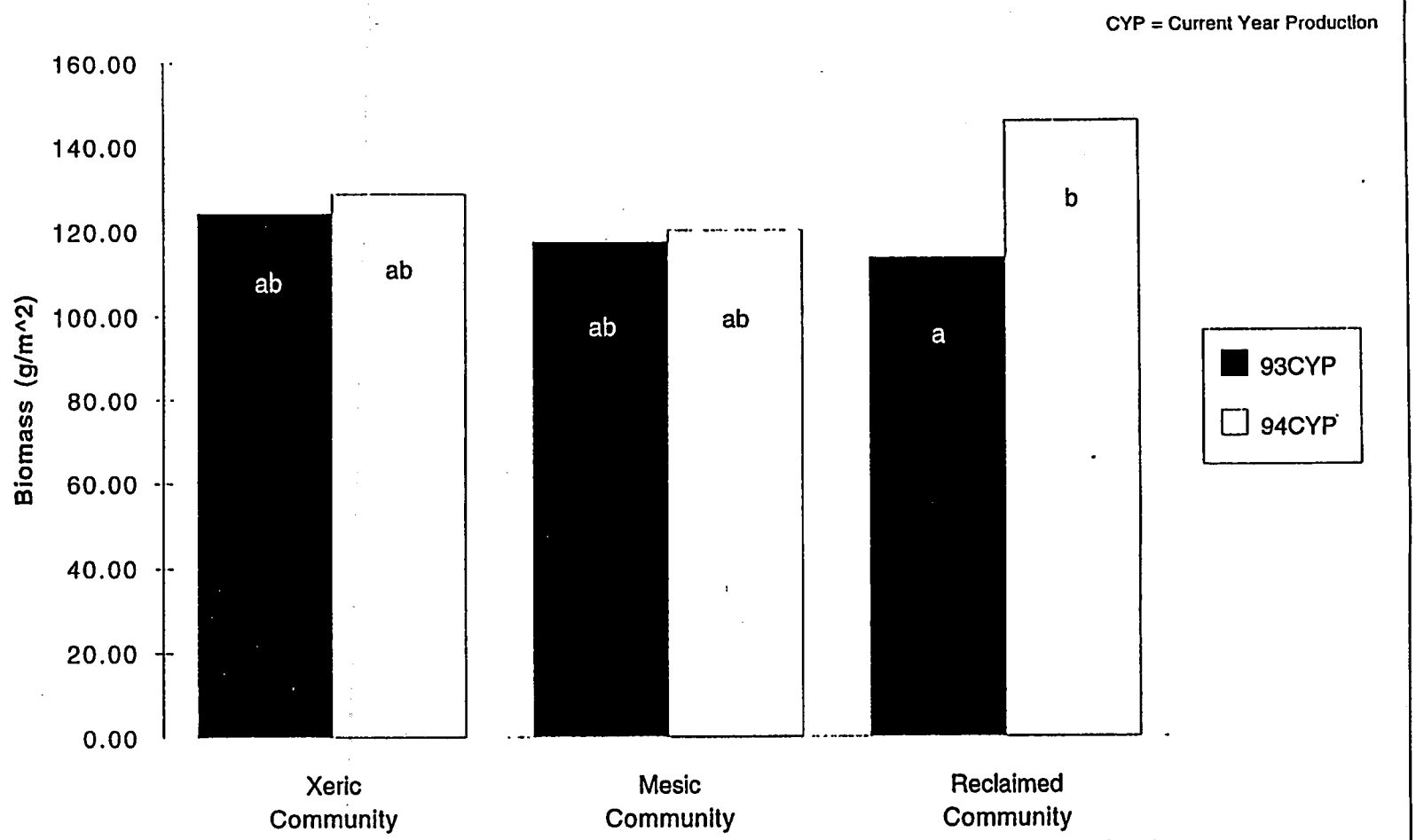
Figure B-31A. TWINSPAN Classification Dendrogram and Legend for 1994 EcMP Transects - Species Presence/Absence Data. For transects represented by letters in parentheses see legend.

Figure B-31B. TWINSPAN Classification Dendrogram and Legend for 1994 EcMP Transects - Species Presence/Absence Data.

Division	Sites and Transects				
A	TR01 T1	TR01 T2	TR01 T3	TR01 T4	TR01 T5
	TR02 T1	TR02 T2	TR02 T3	TR02 T4	TR02 T5
	TR03 T1	TR03 T2	TR03 T3	TR03 T4	TR03 T5
	TR04 T1	TR04 T2	TR04 T3	TR04 T4	TR04 T5
	TR05 T1	TR05 T2	TR05 T3	TR05 T4	TR05 T5
	TR06 T1	TR06 T2	TR06 T3	TR06 T4	TR06 T5
	TR07 T1	TR07 T2	TR07 T3	TR07 T4	TR07 T5
	TR08 T1	TR08 T2	TR08 T3	TR08 T4	TR08 T5
	TR09 T1	TR09 T2	TR09 T3	TR09 T4	TR09 T5
	TR10 T1	TR10 T2	TR10 T3	TR10 T4	TR10 T5
	TR11 T1	TR11 T2	TR11 T3	TR11 T4	TR11 T5
	TR12 T1	TR12 T2	TR12 T3	TR12 T4	TR12 T5
B	TR01 T1	TR01 T2	TR01 T3	TR01 T4	TR01 T5
	TR02 T1	TR02 T2	TR02 T3	TR02 T4	TR02 T5
	TR04 T1	TR04 T2	TR04 T3	TR04 T4	TR04 T5
	TR06 T1	TR06 T2	TR06 T3	TR06 T4	TR06 T5
	TR07 T1	TR07 T2	TR07 T3	TR07 T4	TR07 T5
	TR08 T1	TR08 T2	TR08 T3	TR08 T4	TR08 T5
	TR09 T1	TR09 T2	TR09 T3	TR09 T4	TR09 T5
	TR11 T1	TR11 T2	TR11 T3	TR11 T4	TR11 T5
	TR12 T1	TR12 T2	TR12 T3	TR12 T4	TR12 T5
C	TR03 T1	TR03 T2	TR03 T3	TR03 T4	TR03 T5
	TR05 T1	TR05 T2	TR05 T3	TR05 T4	TR05 T5
	TR10 T1	TR10 T2	TR10 T3	TR10 T4	TR10 T5
D	TR07 T1	TR07 T2	TR07 T3	TR07 T4	TR07 T5
	TR08 T1	TR08 T2	TR08 T3	TR08 T4	TR08 T5
	TR09 T1	TR09 T2	TR09 T3	TR09 T4	TR09 T5
E	TR01 T1	TR01 T2	TR01 T3	TR01 T4	TR01 T5
	TR02 T1	TR02 T2	TR02 T3	TR02 T4	TR02 T5
	TR04 T1	TR04 T2	TR04 T3	TR04 T4	TR04 T5
	TR06 T1	TR06 T2	TR06 T3	TR06 T4	TR06 T5
	TR11 T1	TR11 T2	TR11 T3	TR11 T4	TR11 T5
	TR12 T1	TR12 T2	TR12 T3	TR12 T4	TR12 T5
F	TR03 T1	TR03 T2	TR03 T3	TR03 T4	TR03 T5
	TR10 T1	TR10 T2	TR10 T3	TR10 T4	TR10 T5
G	TR05 T1	TR05 T2	TR05 T3	TR05 T4	TR05 T5

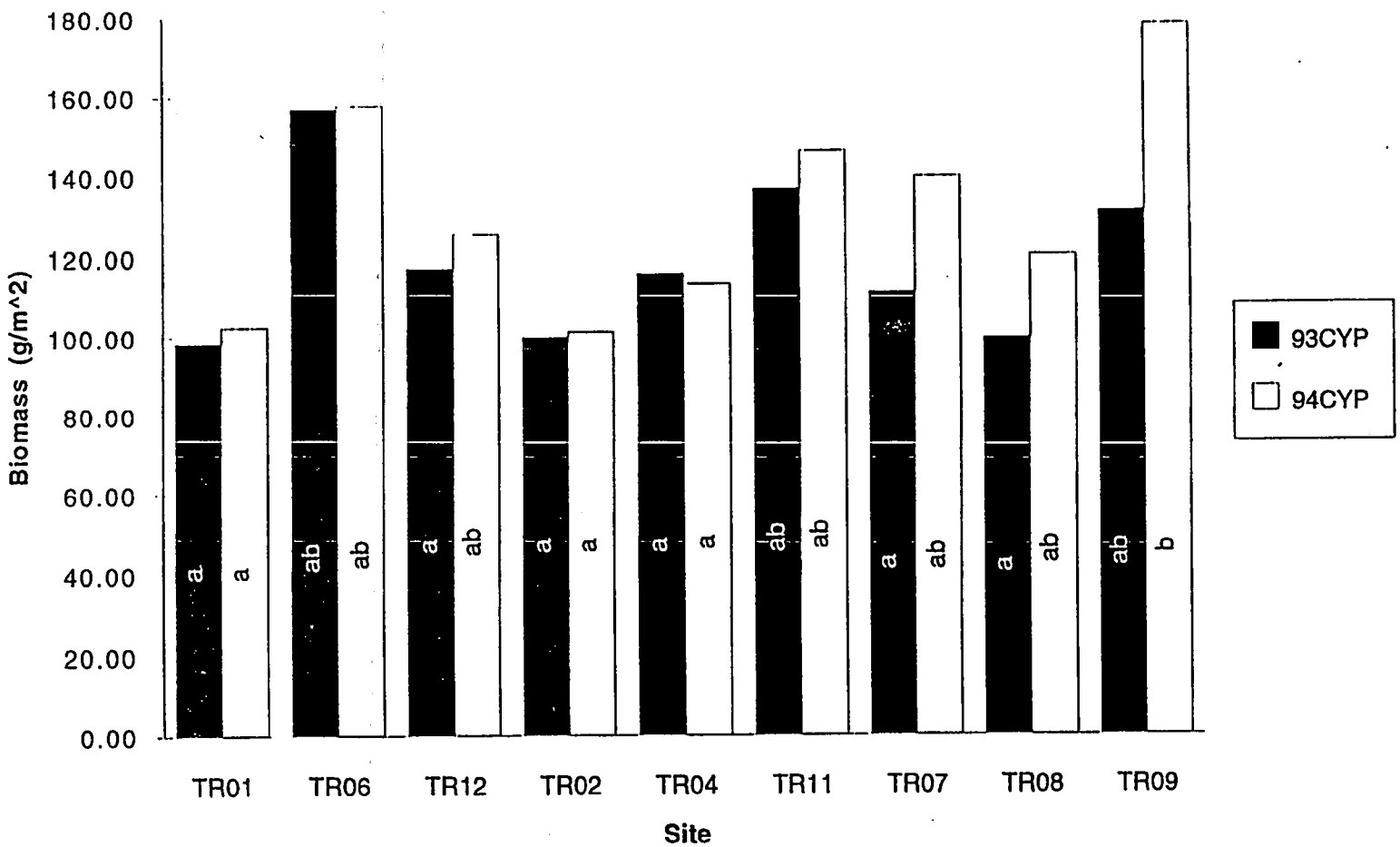
Figure B-31B. TWINSPAN Classification Dendrogram and Legend for 1994 EcMP Transects - Species Presence/Absence Data.

H	TR09 T1	TR09 T2	TR09 T3	TR09 T4	TR09 T5
I	TR07 T1	TR07 T2	TR07 T3	TR07 T4	TR07 T5
	TR08 T1	TR08 T2	TR08 T3	TR08 T4	TR08 T5
J	TR02 T1	TR02 T2	TR02 T3	TR02 T4	TR02 T5
	TR04 T1	TR04 T2	TR04 T3	TR04 T4	TR04 T5
	TR06 T1	TR06 T2	TR06 T3	TR06 T4	TR06 T5
	TR11 T1	TR11 T2	TR11 T3	TR11 T4	TR11 T5
K	TR01 T1	TR01 T2	TR01 T3	TR01 T4	TR01 T5
	TR12 T1	TR12 T2	TR12 T3	TR12 T4	TR12 T5
L	TR10 T3	TR10 T5			
M	TR03 T1	TR03 T2	TR03 T3	TR03 T4	TR03 T5
	TR10 T1	TR10 T2	TR10 T4		
N	TR07 T5				
	TR08 T1	TR08 T2	TR08 T3	TR08 T4	TR08 T5
O	TR07 T1	TR07 T2	TR07 T3	TR07 T4	
P	TR02 T2	TR02 T4	TR02 T5		
	TR04 T1	TR04 T2	TR04 T3	TR04 T4	TR04 T5
	TR11 T2	TR11 T4			
Q	TR02 T1	TR02 T3			
	TR06 T1	TR06 T2	TR06 T3	TR06 T4	TR06 T5
	TR11 T1	TR11 T3	TR11 T5		
R	TR12 T1	TR12 T2	TR12 T3	TR12 T4	TR12 T5
S	TR01 T1	TR01 T2	TR01 T3	TR01 T4	TR01 T5
T	TR04 T1	TR04 T2	TR04 T3	TR04 T4	TR04 T5
	TR11 T4				
U	TR02 T2	TR02 T4	TR02 T5		
	TR11 T2				
V	TR02 T1	TR02 T3			
	TR11 T1	TR11 T3	TR11 T5		
W	TR06 T1	TR06 T2	TR06 T3	TR06 T4	TR06 T5



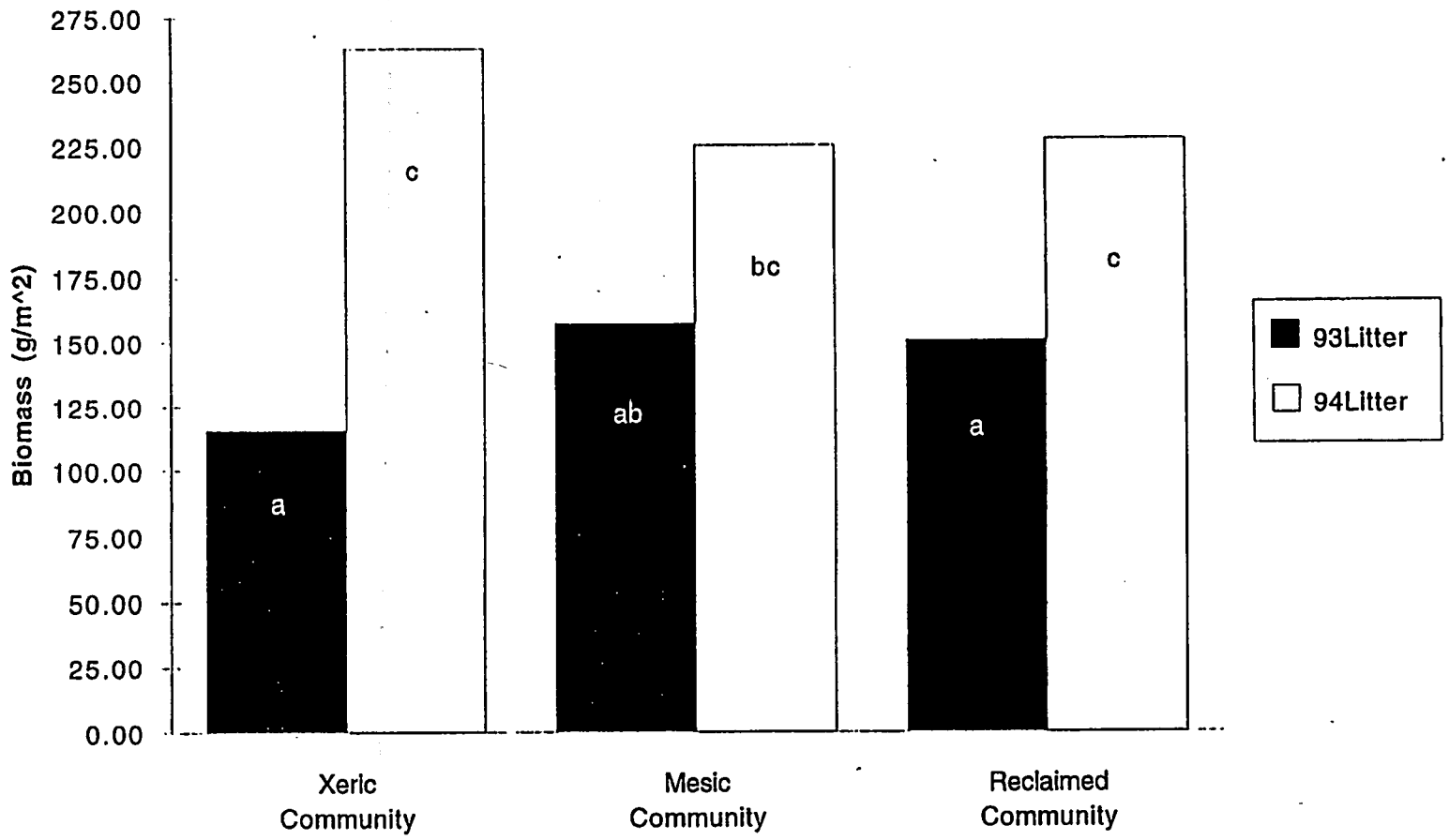
Biomass values with one or more common letters do not show significant differences at the $\alpha = 0.1$ level.

Figure B-32. 1993 and 1994 Current Year Production Biomass Amounts by Community.



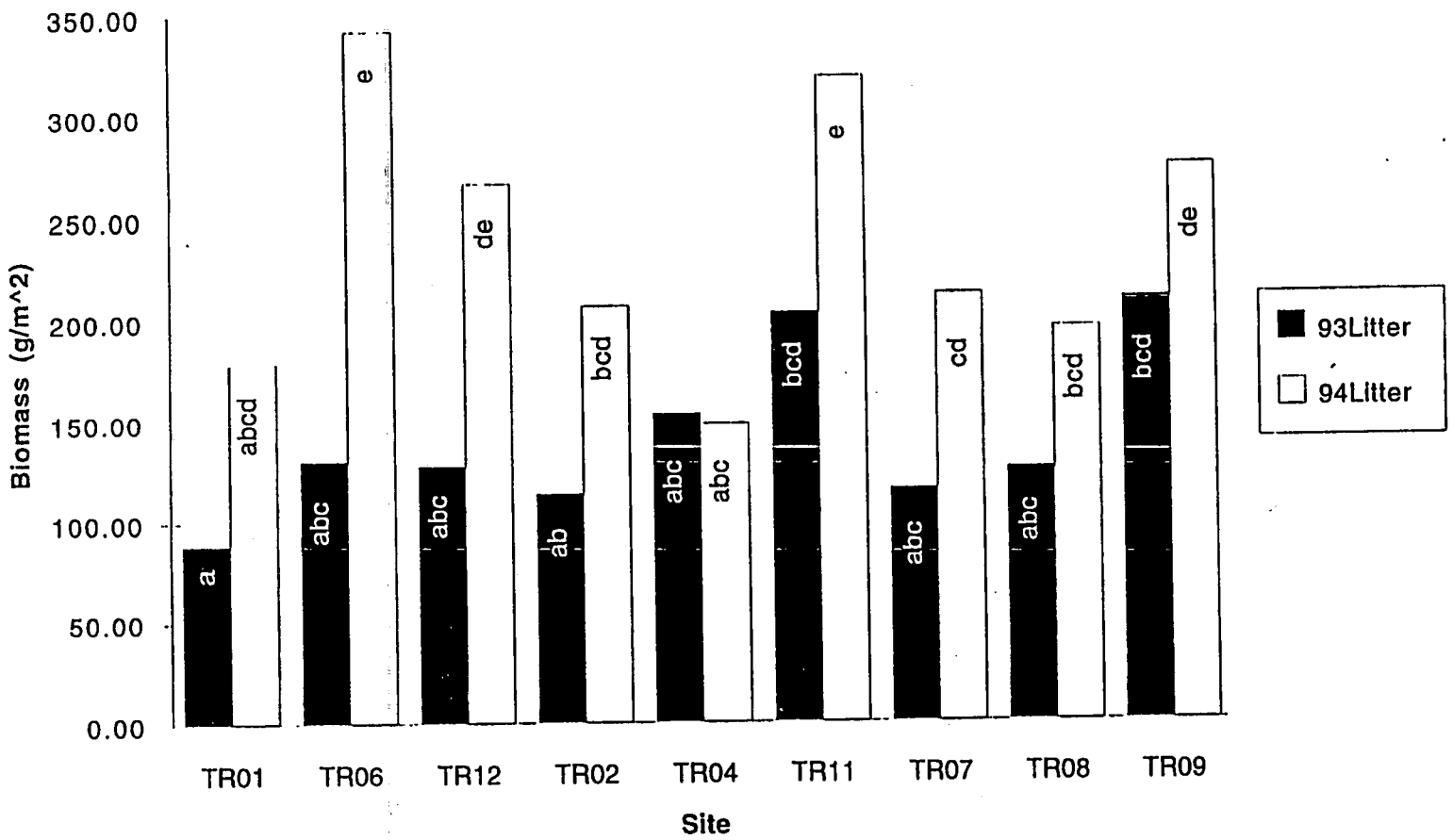
Current Year Production values with one or more common letters are not significantly different (α = 0.05 level).

Figure B-33. 1993 and 1994 Current Year Production Biomass Amounts by EcMP Site.



Biomass values with one or more common letters are not statistically significant at the $\alpha = 0.05$ level.

Figure B-34. 1993 and 1994 Litter Amounts by Community.



Biomass values with one or more common letters are not statistically different at the $\alpha = 0.05$ level.

Figure B-35. 1993 and 1994 Litter Amounts by EcMP Site.

Table B-1. Site Flora Summary.

# Families	77
# Genera	290
# Species	512
# Natives	402
#Non-natives	109
% Native	79
1 species ID'ed only to genus. No native designation.	
# Herbaceous	461
# Succulent	7
# Woody	44
# Forbs	353
# Graminoids	109
# Shrubs	22
# Trees	19
# Cacti	6
# Vines	3
# Annuals	102
# Biennials	4
# Perennials	406
# Dicots	370
# Monocots	133
# Gymnosperms	5
# Pteridophytes	4
# Endemics	4
Aster porteri Gray	
Physaria vitulifera Rydb.	
Penstemon virens Penn.	
Harbouria trachypleura (Gray) C.&R.	
Species of Concern	2
Aristida basiramea Engelm. (G5, S?)	
Carex oreocharis Holm. (G3, S?)	
T. & E. Species	0

Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
AGAVACEAE																										
Yucca glauca Nutt.	YUGL1	Y			s	f			s	f			s	f							s	f	s	f		
ANACARDIACEAE																										
Rhus aromatica Ait. var. trilobata (Nutt.) A. Gray	RHAR1	Y	s	f												f				f						
Toxicodendron rydbergii (Small ex Rydberg) Greene	TORY1	Y																		f						
APIACEAE																										
Cicuta maculata L.	CIMA1	Y													s	f										
Conium maculatum L.	COMA1	N															s	f								
Lomatium orientale Coult. & Rose	LOOR1	Y	s	f	s	f	s	f	s	f	s	f	s	f	s		s		s							
Musineon divaricatum (Pursh.) Nutt. ex T. & G.	MUDI1	Y							s		s		s													
APOCYNACEAE																										
Apocynum cannabinum L.	APCA1	Y														f		f		f						
ASCLEPIADACEAE																										
Asclepias incarnata L.	ASIN1	Y														f			s	f						
Asclepias pumila (Gray) Vail	ASPU1	Y							s	f														f		
Asclepias speciosa Torr.	ASSP1	Y													s	f		f		f						
Asclepias viridiflora Raf.	ASVI1	Y		f				f							s	f				f			s	f		
ASTERACEAE																										
Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	ACMI1	Y	s	f			s	f	s	f	s	f	s	f	s	f	s	f	s	f						
Ambrosia psilostachya DC.	AMPS1	Y	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f						
Antennaria microphylla Rydb.	ANMI1	Y	s	f			s	f																		
Artemisia campestris L.	ARCA1	Y	s	f																	s	f	s			
Artemisia dracunculus L.	ARDR1	Y				f			s	f	s	f	s	f	s	f	s	f			s	f		f		f
Artemisia frigida Willd.	ARFR1	Y	s	f	s	f	s	f	s	f	s	f	s	f	s	f			s	f	s	f				
Arnica fulgens Pursh.	ARFU1	Y										f	s	f	s	f	s		s	f						
Artemisia ludoviciana Nutt.	ARLU1	Y	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s							
Aster ericoides L.	ASER1	Y	s			f		f	s	f		f	s	f	s	f	s	f	s	f	s	f		f		
Aster occidentalis (Nutt.) T. & G.	ASOC1	Y														f										
Aster porteri Gray	ASPO1	Y	s	f				f		f			s	f			s	f			s	f	s			
Aster sp.	AST1				s						s												s			
Carduus nutans L.	CANU1	N			s	f			s	f	s	f	s	f	s	f		f	s	f			s		s	f
Centaurea diffusa Lam.	CEDI1	N	s	f			s	f	s	f					s	f										
Chrysopsis fulcrata Greene	CHFU1	Y	s	f			s	f					s	f		f					s	f				
Chrysopsis villosa Pursh.	CHVI1	Y	s	f	s	f	s	f	s	f	s	f			s	f					s	f	s	f		f
Cirsium arvense (L.) Scop.	CIAR1	N			s	f			s			f	s	f	s	f	s	f	s	f	s	f	s	f	s	f
Cichorium intybus L.	CIIN1	N																	s	f						f

menclature primarily follows Flora of the Great Plains (1991). s = Spring sampling, f = Fall sam

Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Cirsium undulatum (Nutt.) Spreng.	CIUN1	Y	s		s	f	s	f	s	f	s	f	s	f												
Conyza canadensis (L.) Cronq.	COCA1	Y													s		s	f	s	f						
Crepis occidentalis Nutt.	CROC1	Y											s													
Erigeron divergens T. & G.	ERDI1	Y			s	f		f	s	f	s	f	s		s						s	f			s	
Erigeron flagellaris Gray	ERFL1	Y				f	s	f	s	f		f		f		f										f
Erigeron sp.	ERI1				s																					
Gaillardia aristata Pursh.	GAAR1	Y	s	f			s	f																		
Grindelia squarrosa (Pursh.) Dun.	GRSQ1	Y							s	f	s	f	s	f	s	f	s	f	s	f		f	s	f		
Gutierrezia sarothrae (Pursh.) Britt. & Rusby	GUSA1	Y			s	f	s	f	s	f	s	f	s	f			s	f			s	f	s	f		
Helianthus annuus L.	HEAN1	Y											s													
Helianthus sp.	HEL1												s													
Helianthus petiolaris Nutt.	HEPE1	Y	s																							
Helianthus pumilus Nutt.	HEPU1	Y	s	f	s	f			s	f		f	s													
Kuhnia chlorolepis Woot. & Standl.	KUCH1	Y																			s	f		f		
Kuhnia eupatorioides L.	KUEU1	Y								f		f		f								f		f		
Kuhnia sp.	KUH1										s		s								s					
Lactuca oblongifolia Nutt.	LAOB1	Y														f										
Lactuca serriola L.	LASE1	N			s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s					f
Liatris punctata Hook.	LIPU1	Y	s	f	s	f	s	f	s	f	s	f	s	f								f		f		
Microseris cuspidata (Pursh.) Sch. Bip.	MICU1	Y	s		s	f	s	f	s		s		s	f					s							
Picradeniopsis oppositifolia (Nutt.) Rydb.	PIOP1	Y												f												
Ratibida columnifera (Nutt.) Woot. & Standl.	RACO1	Y		f				f	s	f	s	f	s	f				f				f				
Scorzonera laciniata L.	SCLA1	N		f	s	f	s	f	s	f	s	f	s	f					s		s	f		f		f
Senecio integerrimus Nutt.	SEIN1	Y					s		s		s		s								s					
Senecio plattensis Nutt.	SEPL1	Y	s	f			s	f	s	f	s	f	s	f	s								s	f		
Senecio spartioides T. & G.	SESP1	Y			s		s	f	s	f				f								f	s	f		
Senecio tridenticulatus Rydb.	SETR1	Y																			s	f	s			
Solidago sp.	SOL2										s	f	s													
Solidago missouriensis Nutt.	SOMI1	Y		f								f		f	s	f	s		s	f	s	f				
Solidago mollis Bart.	SOMO1	Y						f							s	f		f	s							
Solidago nemoralis Ait.	SONE1	Y					s																			
Solidago rigida L.	SORI1	Y								f																
Taraxacum officinale Weber	TAOF1	N	s		s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f					s	f
Thelesperma megapotanicum (Spreng.) O. Ktze.	THME1	Y				f											s									
Townsendia grandiflora (Nutt.)	TOGR1	Y				f																				
Townsendia hookeri Beaman	TOHO1	Y		f																						

Nomenclature primarily follows Flora of the Great Plains (1991). s = Spring sampling, f = Fall sampling.

Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Tragopogon dubius Scop.	TRDU1	N	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f
BORAGINACEAE																										
Cynoglossum officinale L.	CYOF1	N															s	f	s	f						
Lappula redowskii (Hornem.) Greene	LARE1	Y			s	f				f	s	f	s	f												
Lithospermum incisum Lehm.	LIIN1	Y				f				f				f												
Mertensia lanceolata (Pursh.) A. DC.	MELA1	Y	s	f	s		s												s							
Onosmodium molle Michx.	ONMO1	Y							s	f					s	f										
BRASSICACEAE																										
Alyssum minus (L.) Rothmaler	ALMI1	N	s	f	s	f	s	f	s	f	s	f	s	f	s	f			s	f	s	f	s	f	s	f
Arabis sp.	ARA1			f						f																
Arabis fendleri (Wats.) Greene	ARFE3	Y											s													
Arabis glabra (L.) Bernh.	ARGL1	N	s	f							s	f														
Barbarea orthoceras Ledeb.	BAOR1	N													s	f	s	f								
BRASSICACEAE sp.	BR1					f								f												
Cardaria chalepensis (L.) Hand-Mazz	CACH1	N																	s							
Camelina microcarpa Andrz.	CAMI1	N	s	f	s	f	s	f	s	f	s	f	s	f	s	f			s	f	s	f		f	s	f
Descurainia sp.	DES1											f														
Descurainia pinnata (Walt.) Britt.	DEPI1	Y	s		s	f	s	f	s	f	s	f	s	f	s	f			s	f	s	f			s	f
Descurainia richardsonii (Sweet) Schultz	DERI1	Y				f					s	f	s	f												
Descurainia sophia (L.) Webb	DESO1	N				f																				
Draba nemorosa L.	DRNE1	Y	s												s											
Draba reptans (Lam.) Fern.	DRRE1	Y	s	f	s	f	s	f	s	f		f		f												
Erysimum asperum (Nutt.) DC.	ERAS1	Y	s	f	s	f	s	f	s	f	s	f	s	f								f				
Erysimum repandum L.	ERRE1	N									s	f														
Lesquerella montana (A. Gray) Wats.	LEMO1	Y	s	f	s	f	s	f	s	f			s	f												
Lepidium sp.	LEP1							f				f	s	f					s							
Lepidium densiflorum Schrad.	LEDE1	Y										f														
Nasturtium officinale R. Br.	NAOF1	N													s	f										
Sisymbrium altissimum L.	SIAL1	N			s	f	s	f	s	f	s	f	s	f	s	f		f	s							
Thlaspi arvense L.	THAR1	N									s	f			s	f		f	s							
CACTACEAE																										
Coryphantha missouriensis (Sweet) Britt. & Rose	COMI1	Y	s		s					f	s	f	s	f												
Echinocereus viridiflorus Engelm.	ECVI1	Y	s	f	s	f	s	f	s	f	s	f	s	f												
Opuntia fragilis (Nutt.) Haw.	OPFR1	Y	s	f					s		s	f	s	f	s	f				f						
Opuntia humifusa (Raf.) Raf.	OPHU1	Y	s	f	s	f	s	f	s	f	s	f	s	f	s	f			s	f	s	f			s	f
Pediocactus simpsonii (Engelm.) Britt. & Rose	PESI1	Y			s	f	s		s																	

menclature primarily follows Flora of the Great Plains (1991). s = Spring sampling, f = Fall san

Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
CAMPANULACEAE																										
Triodanus sp.	TRI2									f		f														
CAPRIFOLIACEAE																										
Symphoricarpos occidentalis Hook.	SYOC1	Y													s	f	s	f	s	f						
CARYOPHYLLACEAE																										
Arenaria fendleri A. Gray	ARFE2	Y	s	f			s	f																		
Cerastium arvense L.	CEAR1	Y													s											
Paronychia jamesii T. & G.James	PAJA1	Y	s	f	s	f	s	f	s																	
Silene antirrhina L.	SIAN1	Y	s	f				f		f		f		f												
Silene drummondii Hook.	SIDR1	Y		f		f		f						f												
CHENOPODIACEAE																										
Chenopodium leptophyllum Nutt. ex Moq.	CHLE2	Y			s	f				f		f		f												
CLUSIACEAE																										
Hypericum perforatum L.	HYPE1	N	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s		s		s	f				
COMMELINACEAE																										
Tradescantia occidentalis (Britt.) Smyth	TROC1	Y							s		s	f	s													
CONVOLVULACEAE																										
Convolvulus arvensis L.	COAR1	N							s	f					s			f	s		s	f	s	f	s	f
Evolvulus nuttallianus R. & S.	EVNU1	Y							s	f				f												
CYPERACEAE																										
Carex eleocharis Bailey	CAEL1	Y					s		s			f							s							
Carex filifolia Nutt.	CAFI1	Y			s	f																				
Carex hellophila Mack.	CAHE1	Y	s	f	s	f		f		f		f	s	f												
Carex interior Bailey	CAIN1	Y											s													
Carex lanuginosa Michx.	CALA1	Y													s		s	f								
Carex nebraskensis Dew.	CANE1	Y													s	f	s	f	s	f						
Carex oreocharis Holm.	CAOR1	Y					s		s																	
Carex praegracilis W. Boott.	CAPR1	Y													s	f										
Carex sp.	CAR1										s						s		s							
Carex rostrata Stokes ex Willd.	CARO2	Y													s											
Carex simulata Mack.	CASI1	Y													s											
Carex stipata Muhl.	CAST1	Y																	s	f						
Eleocharis macrostachya Britt.	ELMA1	Y															s									
Eleocharis parvula (R. & S.) Link ex Bluff	ELPA1	Y													s	f	s	f	s	f						
Scirpus americanus Pers.	SCAM1	Y															s	f	s	f						
Scirpus pallidus (Britt.) Fern	SCPA1	Y													s	f	s	f	s	f						

Nomenclature primarily follows Flora of the Great Plains (1991). s = Spring sampling, f = Fall sampling.

Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Scirpus validus Vahl.	SCVA1	Y														f		f								
EQUISETACEAE																										
Equisetum arvense L.	EQAR1	Y													s		s		s							
Equisetum hyemale L.	EQHY1	Y													s											
Equisetum laevigatum A. Br.	EQLA1	Y														f			s	f						
EUPHORBIACEAE																										
Euphorbia dentata Michx.	EUDE1	Y												f												
Euphorbia robusta (Engelm.) Small	EURO1	Y					s	r	s	f																
Euphorbia serpyllifolia Pers.	EUSE1	Y																		f						
Euphorbia spathulata Lam.	EUSP1	Y								f	s	f	s	f												
FABACEAE																										
Amorpha fruticosa L.	AMFR1	Y													s	f	s	f	s	f						
Astragalus agrestis Dougl. ex G. Don	ASAG1	Y	s	f	s	f			s		s	f	s	f					s							
Astragalus crassicarpus Nutt.	ASCR1	Y					s		s		s												s	f		
Astragalus drummondii Dougl. ex Hook.	ASDR1	Y									s															
Astragalus flexuosus (Hook.)G. Don	ASFL1	Y			s					f											s					
Astragalus missouriensis Nutt.	ASMI1	Y	s																							
Astragalus parryi Gray	ASPA1	Y																					s	f		
Astragalus sericoleucus Gray	ASSE1	Y			s	f			s																	
Astragalus shortianus Nutt. ex T.&G.	ASSH1	Y	s	f	s	f	s	f	s		s		s	f												
Astragalus sp.	AST2			f					s	f																
Dalea candida Willd.	DACA1	Y											s	f										f		
Dalea purpurea Vent	DAPU1	Y		f		f	s	f	s	f			s	f												
Glycyrrhiza lepidota Pursh.	GLLE1	Y													s	f.	s	f	s	f						
Lathyrus eucosmus Butters and St. John	LAEU1	Y													s		s	f								
Lupinus argenteus Pursh.	LUAR1	Y													s	f										
Melilotus alba Medic.	MEAL1	N																f						f		
Medicago lupulina L.	MELU1	N														f	s	f	s	f		f	s	f		
Melilotus officinalis (L.) Pall.	MEOF1	N															s	f			s	f	s	f	s	
Medicago sativa L.	MESA1	N																					s		s	f
Oxytropis lambertii Pursh.	OXLA1	Y	s	f	s	f	s	f	s	f																
Psoralea tenuiflora Pursh.	PSTE1	Y	s	f	s	f	s	f	s	f	s	f	s	f	s					f			s			
Thermopsis rhombifolia var. divaricarpa Nels.	THRH1	Y													s	f	s	f	s	f						
Trifolium sp.	TRI1													f												
Vicia americana Muhl. ex Willd.	VIAM1	Y							s	f	s	f	s	f			s		s	f			s	f	s	
GERANIACEAE																										

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			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Erodium cicutarium (L.) L'Her.	ERCI1	N							s	f	s				s											
Geranium caespitosum James	GECA1	Y													s	f			s	f						
GROSSULARIACEAE																										
Ribes odoratum Wendl.	RIOD1	Y													s				s	f						
HYDROPHYLLACEAE																										
Phacelia heterophylla Pursh.	PHHE1	Y	s	f	s	f	s	f		f			s	f												
IRIDACEAE																										
Sisyrinchium montanum Greene	SIMO1	Y																		f						
JUNCACEAE																										
Juncus balticus Willd.	JUBA1	Y													s	f	s	f	s	f						
Juncus dudleyi Wieg.	JUDU1	Y													s				s							
Juncus torreyi Cov.	JUTO1	Y														f	s	f								
LAMIACEAE																										
Lycopus americanum Muhl. ex Barton	LYAM1	Y																		f						
Mentha arvensis L.	MEAR1	Y													s	f	s	f	s	f						
Monarda fistulosa L.	MOFI1	Y													s	f			s	f						
Nepeta cataria L.	NECA1	N													s	f			s	f						
Prunella vulgaris L.	PRVU1	Y													s				s	f						
Scutellaria brittonii Porter	SCBR1	Y											s													
Stachys palustris L.	STPA2	Y													s	f			s	f						
LEMNACEAE																										
Lemna minor L.	LEMI1	Y													s	f										
LILIACEAE																										
Allium textile A. Nels. & Macbr.	ALTE1	Y	s	f	s	f	s	f	s	f	s	f	s	f												
Asparagus officinalis L.	ASOF1	N																	s	f						
Leucocrinum montanum Nutt.	LEMO2	Y			s		s		s				s													
LINACEAE																										
Linum perenne L. var. lewisii (Pursh.) Eat. & Wright	LIPE1	Y			s	f			s	f	s	f			s	f			s							
MALVACEAE																										
Sphaeralcea coccinea (Pursh.) Rydb.	SPCO1	Y			s	f		f	s	f	s	f	s	f												
NYCTAGINACEAE																										
Mirabilis linearis (Pursh.) Heimerl	MILI1	Y		f		f		f		f	s	f		f												
ONAGRACEAE																										
Calylophus serrulatus (Nutt.) Raven	CASE2	Y	s	f			s	f																		
Epilobium ciliatum Raf.	EPCI1	Y													s				s	f						
Epilobium paniculatum Nutt.	EPPA1	Y															s		s	f						

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Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Gaura coccinea Pursh.	GACO1	Y		f	s	f			s	f	s	f	s	f												
Gaura parviflora Dougl.	GAPA1	Y																f		f						
Oenothera biennis L.	OEBI1	Y													s	f	s	f	s	f						
Oenothera brachycarpa Gray	OEBR1	Y			s	f						f														
Oenothera coronopifolia T. & G.	OECO1	Y					s																			
Oenothera sp.	OEN1							f																		
OROBANCHACEAE																										
Orobanche fasciculata Nutt.	ORFA1	Y	s	f		f	s	f					s	f								f				
OXALIDACEAE																										
Oxalis dillenii Jacq.	OXDI1	N													s	f										
PLANTAGINACE																										
Plantago lanceolata L.	PLLA1	N										f			s					f						
Plantago major L.	PLMA1	N																							s	
Plantago patagonica Jacq.	PLPA1	Y				f																				
POACEAE																										
Agropyron caninum (L.) Beauv.	AGCA1	Y																	s							
Agropyron cristatum (L.) Gaertn.	AGCR1	N																			s	f	s	f	s	f
Agropyron intermedium (Host) Beauv.	AGIN1	N									s										s	f	s	f	s	f
Agropyron repens (L.) Beauv.	AGRE1	N													s	f	s	f		f						
Agropyron smithii Rydb.	AGSM1	Y				f		f	s	f	s	f	s	f	s	f	s	f	s	f		f				
Agrostis stolonifera L.	AGST1	N													s	f		f	s	f						
Andropogon gerardii Vitman	ANGE1	Y	s	f	s	f	s	f	s	f			s	f												
Andropogon scoparius Michx.	ANSC1	Y	s	f		f	s	f	s	f			s	f												
Aristida purpurea Nutt. var. longiseta (Steud.) Vasey	ARFE1	Y		f		f	s	f	s	f		f		f									s	f		
Aristida sp.	ARI1				s	f					s										s					
Aristida purpurea Nutt. var. robusta (Merrill) Holmgren & Holmgren	ARLO1	Y		f		f	s	f	s	f		f	s	f								f	s	f		
Bouteloua curtipendula (Michx.) Torr.	BOCU1	Y		f	s	f		f		f		f	s	f												
Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	Y		f	s	f	s	f	s	f	s	f	s	f		f			s	f						
Bouteloua hirsuta Lag	BOHI1	Y	s	f	s	f		f		f		f		f												
Bouteloua sp.	BOU1										s															
Bromus inermis Leyss.	BRIN1	N							s	f							s	f	s	f	s	f	s	f	s	f
Bromus japonicus Thunb. ex Murr.	BRJA1	N	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f
Bromus tectorum L.	BRTE1	N		f		f		f				f		f												
Buchloe dactyloides (Nutt.) Engelm.	BUDA1	Y		f		f		f		f		f	s	f												
Dactylis glomerata L.	DAGL1	N													s	f	s									
Elymus canadensis L.	ELCA1	Y														f	s	f	s	f						

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Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Festuca pratensis Huds.	FEPR1	Y														f	s	f								
Hordeum jubatum L.	HOJU1	Y											s					f								
Koeleria pyramidata (Lam.) Beauv.	KOPY1	Y	s	f	s	f	s	f	s	f	s	f	s	f						f						
Muhlenbergia montana (Nutt.) Hitchc.	MUMO1	Y	s	f			s	f			s															
Muhlenbergia racemosa (Michx.) B. S. P.	MURA1	Y																f								
Muhlenbergia wrightii Vasey	MUWR1	Y								f				f												
Panicum virgatum L.	PAVI1	Y																	s	f						
Phleum pratense L.	PHPR1	N														f	s	f								
Poa canbyi (Scribn.) Piper	POCA1	Y			s																					
Poa compressa L.	POCO1	N	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f		f				
Poa pratensis L.	POPR1	N	s	f	s	f		f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f	s	f
Sitanion hystrix (Nutt.) Sm.	SIHY1	Y		f		f		f	s	f										f						
Sorghastrum nutans (L.) Nash	SONU1	Y		f			s	f																		
Sporobolus cryptandrus (Torr.) A. Gray	SPCR1	Y							s									f								
Sporobolus heterolepis (A. Gray) A. Gray	SPHE1	Y		f				f						f												
Sphenopholis obtusata (Michx.) Scribn.	SPOB1	Y													s	f										
Spartina pectinata Link	SPPE1	Y													s	f										
Stipa comata Trin. & Rupr.	STCO1	Y	s	f	s	f	s	f		f		f	s	f												
Stipa sp.	STI1				s								s													
Stipa neomexicana (Thur. ex Vasey.) Scribn.	STNE1	Y				f																				
Stipa robusta (Vasey) Scribn.	STRO1	Y																		f						
Stipa viridula Trin.	STVI1	Y		f					s	f		f		f		f										
Triticum aestivum L.	TRAE1	N		f								f														
POLEMONIACEAE																										
Collomia linearis Nutt.	COLI1	Y							s				s	f												
Ipomopsis spicata (Nutt.) V. Grant	IPSP1	Y	s	f																						
Microsteris gracilis (Hook.) Greene	MIGR1	Y									s															
POLYGONACEAE																										
Eriogonum alatum Torr.	ERAL1	Y	s	f	s	f	s	f	s	f																
Polygonum lapathifolium L.	POLA1	N													s	f	s									
Polygonum sawatchense Small	POSA1	Y										f														
Rumex crispus L.	RUCR1	N													s	f	s	f	s	f						
Rumex mexicanus Meisn.	RUME1	Y													s		s	f	s	f						
Rumex obtusifolius L.	RUOB1	N													s	f				f						
PORTULACACEAE																										
Talinum parviflorum Nutt.	TAPA1	Y		f																						

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Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
PRIMULACEAE																										
Androsace occidentalis Pursh.	ANOC1	Y			s																					
RANUNCULACEAE																										
Delphinium sp.	DEL1										s		s													
Delphinium nuttalianum Pritz. ex Walpers	DENU1	Y																	s							
ROSACEAE																										
Crataegus erythropoda Ashe	CRER1	Y													s	f										
Geum macrophyllum Willd.	GEMA1	Y													s	f			s	f						
Geum sp.	GEU1																		s							
Potentilla fissa Nutt.	POFI1	Y						f																		
Potentilla gracilis Dougl. ex Hook.	POGR1	Y		f																						
Potentilla hippiana Lehm.	POHI1	Y	s	f			s								s	f			s	f						
Prunus virginiana L.	PRVI1	Y													s	f			s	f						
Rosa arkansana Porter	ROAR1	Y							s	f	s	f	s	f	s	f	s	f	s	f						
Rosa woodsii Lindl.	ROWO1	Y													s	f	s	f	s	f						
RUBIACEAE																										
Galium boreale L.	GABO1	Y													s	f			s	f						
SALICACEAE																										
Populus x acuminata Rydb.	POAC1	Y													s											
Populus deltoides Marsh. var occidentalis Rydb.	PODE1	Y													s	f	s	f	s	f						
Salix amygdaloides Anderss.	SAAM1	Y													s		s	f	s	f						
Salix exigua Nutt. ssp. interior (Rowlee) Cronq.	SAEX1	Y													s	f	s	f	s	f						
Salix lutea Nutt. var. ligulifolia Ball	SALU1	Y														f										
SANTALACEAE																										
Comandra umbellata (L.) Nutt.	COUM1	Y	s	f	s	f		f		f	s		s	f	s				s							
SCROPHULARIACEAE																										
Castilleja sessiliflora Pursh.	CASE3	Y	s	f			s																			
Linaria dalmatica (L.) Mill.	LIDA1	N	s	f	s	f	s	f	s		s	f	s	f			s	f	s				s	f		f
Penstemon angustifolius Nutt.	PEAN1	Y					s		s																	
Penstemon secundiflorus Benth.	PESE1	Y			s	f							s	f												
Penstemon virens Penn.	PEVI1	Y	s	f				f		f			s	f												
Scrophularia lanceolata Pursh.	SCLA2	Y																		f						
Veronica americana (Raf.) Schwein. ex Benth.	VEAM1	Y													s	f	s	f	s	f						
Veronica anagallis-aquatica L.	VEAN1	N													s				s	f						
Verbascum blattaria L.	VEBL1	N				f			s	f		f	s	f		f	s	f	s	f						
Verbascum thapsus L.	VETH1	N			s	f			s				s	f	s	f			s	f						

·nenclature primarily follows Flora of the Great Plains (1991). s = Spring sampling, f = Fall sam

Table B-2. 1994 Species Richness Across EcMP Sites.

			XERIC SITES						MESIC SITES						RIPARIAN SITES						RECLAIMED SITES					
	SPEC-		TR01		TR06		TR12		TR02		TR04		TR11		TR03		TR05		TR10		TR07		TR08		TR09	
SCIENTIFIC NAME	CODE	NATIVE	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
SELAGINELLACEAE																										
Selaginella densa Rydb.	SEDE1	Y													s				s							
SOLANACEAE																										
Physalis virginiana P. Mill.	PHVI2	Y																		f				f		
Physalis sp.	PHY1										s				s											
Quincula lobata (Torr.) Raf.	QULO1	Y																								f
TYPHACEAE																										
Typha latifolia L.	TYLA1	Y									s				s	f	s	f	s	f						
VERBENACEAE																										
Lippia cuneifolia (Torr.) Steud.	LICU1	Y																		f						
Verbena bracteata Lag. & Rodr.	VEBR1	Y										f						f								
Verbena hastata L.	VEHA1	Y													s	f			s	f						
VIOLACEAE																										
Hybanthus verticillatus (Ort.) Baill.	HYVE1	Y								f			s	f												
Viola nephrophylla Greene	VINE1	Y													s	f			s	f						
Viola nuttallii Pursh.	VINU1	Y	s		s		s						s													
Viola sp.	VIO1																		s							
Species Richness by Site			88		89		91		107		95		106		121		79		113		42		41		27	
Mean Species Richness by Community			89						103						104						37					
Combined Species Richness by Community			133						143						163						61					
Total Species Richness (all sites combined)			271																							

Nomenclature primarily follows Flora of the Great Plains (1991). s = Spring sampling, f = Fall sampling.

Table B-3. 1994 Woody Stem and Cactus Density Mean Values by EcMP Site and Community.

Site	Cactus Density (Stems/m^2)	Woody Stem Density (Stems/m^2)
Xeric Community	0.65	0.04
TR01	0.79	*0.002
TR06	0.21	0.11
TR12	0.95	0.00
Mesic Community	0.32	0.83
TR02	0.25	1.32
TR04	0.24	0.67
TR11	0.47	0.60
Riparian Community	0.03	6.42
TR03	0.04	5.31
TR05	0.00	4.86
TR10	0.03	9.13
Reclaimed Community	0.01	*0.002
TR07	*0.008	*0.002
TR08	0.00	*0.004
TR09	0.01	0.00

* = mean value was beyond 2 significant digits
Community means based on n=15
Site means based on n=5

Table B-4. 1994 Species Restricted by Community.

Community	Family	Scientific Name	Speccode	Native
XERIC	ASTERACEAE	Antennaria microphylla Rydb.	ANMI1	Y
XERIC	ASTERACEAE	Gaillardia aristata Pursh.	GAAR1	Y
XERIC	ASTERACEAE	Helianthus petiolaris Nutt.	HEPE1	Y
XERIC	ASTERACEAE	Solidago nemoralis Ait.	SONE1	Y
XERIC	ASTERACEAE	Townsendia grandiflora (Nutt.)	TOGR1	Y
XERIC	ASTERACEAE	Townsendia hookeri Beaman	TOHO1	Y
XERIC	BRASSICACEAE	Descurainia sophia (L.) Webb	DESO1	N
XERIC	CARYOPHYLLACEAE	Arenaria fendleri A. Gray	ARFE2	Y
XERIC	CYPERACEAE	Carex filifolia Nutt.	CAFI1	Y
XERIC	FABACEAE	Astragalus missouriensis Nutt.	ASMI1	Y
XERIC	ONAGRACEAE	Calylophus serrulatus (Nutt.) Raven	CASE2	Y
XERIC	ONAGRACEAE	Oenothera coronopifolia T. & G.	OECO1	Y
XERIC	PLANTAGINACE	Plantago patagonica Jacq.	PLPA1	Y
XERIC	POACEAE	Poa canbyi (Scribn.) Piper	POCA1	Y
XERIC	POACEAE	Sorghastrum nutans (L.) Nash	SONU1	Y
XERIC	POACEAE	Stipa neomexicana (Thur. ex Vasey.) Scribn.	STNE1	Y
XERIC	POLEMONIACEAE	Ipomopsis spicata (Nutt.) V. Grant	IPSP1	Y
XERIC	PORTULACACEAE	Talinum parviflorum Nutt.	TAPA1	Y
XERIC	PRIMULACEAE	Androsace occidentalis Pursh.	ANOC1	Y
XERIC	ROSACEAE	Potentilla fissa Nutt.	POFI1	Y
XERIC	ROSACEAE	Potentilla gracilis Dougl. ex Hook.	POGR1	Y
XERIC	SCROPHULARIACEAE	Castilleja sessiliflora Pursh.	CASE3	Y
MESIC	APIACEAE	Musineon divaricatum (Pursh.) Nutt. ex T. & G.	MUDI1	Y
MESIC	ASTERACEAE	Crepis occidentalis Nutt.	CROC1	Y
MESIC	ASTERACEAE	Helianthus annuus L.	HEAN1	Y
MESIC	ASTERACEAE	Picradeniopsis oppositifolia (Nutt.) Rydb.	PIOP1	Y
MESIC	ASTERACEAE	Solidago rigida L.	SORI1	Y
MESIC	BRASSICACEAE	Arabis fendleri (Wats.) Greene	ARFE3	Y
MESIC	BRASSICACEAE	Erysimum repandum L.	ERRE1	N
MESIC	BRASSICACEAE	Lepidium densiflorum Schrad.	LEDE1	Y
MESIC	CAMPANULACEAE	Triodanus	TRI2	

Table B-4. 1994 Species Restricted by Community.

Community	Family	Scientific Name	Speccode	Native
MESIC	COMMELINACEAE	Tradescantia occidentalis (Britt.) Smyth	TROC1	Y
MESIC	CONVOLVULACEAE	Evolvulus nuttallianus R. & S.	EVNU1	Y
MESIC	CYPERACEAE	Carex interior Bailey	CAIN1	Y
MESIC	EUPHORBIACEAE	Euphorbia dentata Michx.	EUDE1	Y
MESIC	EUPHORBIACEAE	Euphorbia spathulata Lam.	EUSP1	Y
MESIC	FABACEAE	Astragalus drummondii Dougl. ex Hook.	ASDR1	Y
MESIC	FABACEAE	Trifolium	TRI1	
MESIC	LAMIACEAE	Scutellaria brittonii Porter	SCBR1	Y
MESIC	POACEAE	Muhlenbergia wrightii Vasey	MUWR1	Y
MESIC	POLEMONIACEAE	Collomia linearis Nutt.	COLI1	Y
MESIC	POLEMONIACEAE	Microsteris gracilis (Hook.) Greene	MIGR1	Y
MESIC	POLYGONACEAE	Polygonum sawatchense Small	POSA1	Y
MESIC	VIOLACEAE	Hybanthus verticillatus (Ort.) Baill.	HYVE1	Y
RECLAIMED	ASTERACEAE	Kuhnia chlorolepis Woot. & Standl.	KUCH1	Y
RECLAIMED	ASTERACEAE	Senecio tridenticulatus Rydb.	SETR1	Y
RECLAIMED	FABACEAE	Astragalus parryi Gray	ASPA1	Y
RECLAIMED	FABACEAE	Medicago sativa L.	MESA1	N
RECLAIMED	PLANTAGINACE	Plantago lanceolata L.	PLLA1	N
RECLAIMED	POACEAE	Agropyron cristatum (L.) Gaertn.	AGCR1	N
RECLAIMED	SOLANACEAE	Quincula lobata (Torr.) Raf.	QULO1	Y
RIPARIAN	ANACARDIACEAE	Toxicodendron rydbergii (Small ex Rydberg) Greene	TORY1	Y
RIPARIAN	APIACEAE	Cicuta maculata L.	CIMA1	Y
RIPARIAN	APIACEAE	Conium maculatum L.	COMA1	N
RIPARIAN	APOCYNACEAE	Apocynum cannabinum L.	APCA1	Y
RIPARIAN	ASCLEPIADACEAE	Asclepias incarnata L.	ASIN1	Y
RIPARIAN	ASCLEPIADACEAE	Asclepias speciosa Torr.	ASSP1	Y
RIPARIAN	ASTERACEAE	Aster occidentalis (Nutt.) T. & G.	ASOC1	Y
RIPARIAN	ASTERACEAE	Conyza canadensis (L.) Cronq.	COCA1	Y
RIPARIAN	ASTERACEAE	Lactuca oblongifolia Nutt.	LAOB1	Y
RIPARIAN	ASTERACEAE	Scorzonera laciniata L.	SCLA1	N

Table B-4. 1994 Species Restricted by Community.

Community	Family	Scientific Name	Speccode	Native
RIPARIAN	BORAGINACEAE	Cynoglossum officinale L.	CYOF1	N
RIPARIAN	BRASSICACEAE	Barbarea orthoceras Ledeb.	BAOR1	N
RIPARIAN	BRASSICACEAE	Cardaria chalepensis (L.) Hand-Mazz	CACH1	N
RIPARIAN	BRASSICACEAE	Nasturtium officinale R. Br.	NAOF1	N
RIPARIAN	CAPRIFOLIACEAE	Symphoricarpos occidentalis Hook.	SYOC1	Y
RIPARIAN	CARYOPHYLLACEAE	Cerastium arvense L.	CEAR1	Y
RIPARIAN	CYPERACEAE	Carex lanuginosa Michx.	CALA1	Y
RIPARIAN	CYPERACEAE	Carex nebraskensis Dew.	CANE1	Y
RIPARIAN	CYPERACEAE	Carex praegracilis W. Boott.	CAPR1	Y
RIPARIAN	CYPERACEAE	Carex rostrata Stokes ex Willd.	CARO2	Y
RIPARIAN	CYPERACEAE	Carex simulata Mack.	CASI1	Y
RIPARIAN	CYPERACEAE	Carex stipata Muhl.	CAST1	Y
RIPARIAN	CYPERACEAE	Eleocharis macrostachya Britt.	ELMA1	Y
RIPARIAN	CYPERACEAE	Eleocharis parvula (R. & S.) Link ex Bluff	ELPA1	Y
RIPARIAN	CYPERACEAE	Scirpus americanus Pers.	SCAM1	Y
RIPARIAN	CYPERACEAE	Scirpus pallidus (Britt.) Fern	SCPA1	Y
RIPARIAN	CYPERACEAE	Scirpus validus Vahl.	SCVA1	Y
RIPARIAN	EQUISETACEAE	Equisetum arvense L.	EQAR1	Y
RIPARIAN	EQUISETACEAE	Equisetum hyemale L.	EQHY1	Y
RIPARIAN	EQUISETACEAE	Equisetum laevigatum A. Br.	EQLA1	Y
RIPARIAN	EUPHORBIACEAE	Euphorbia serpyllifolia Pers.	EUSE1	Y
RIPARIAN	FABACEAE	Amorpha fruticosa L.	AMFR1	Y
RIPARIAN	FABACEAE	Glycyrrhiza lepidota Pursh.	GLLE1	Y
RIPARIAN	FABACEAE	Lathyrus eucosmus Butters and St. John	LAEU1	Y
RIPARIAN	FABACEAE	Lupinus argenteus Pursh.	LUAR1	Y
RIPARIAN	FABACEAE	Thermopsis rhombifolia var. divaricarpa Nels.	THRH1	Y
RIPARIAN	GERANIACEAE	Geranium caespitosum James	GECA1	Y
RIPARIAN	GROSSULARIACEAE	Ribes odoratum Wendl.	RIOD1	Y
RIPARIAN	IRIDACEAE	Sisyrinchium montanum Greene	SIMO1	Y
RIPARIAN	JUNCACEAE	Juncus balticus Willd.	JUBA1	Y
RIPARIAN	JUNCACEAE	Juncus dudleyi Wieg.	JUDU1	Y

Table B-4. 1994 Species Restricted by Community.

Community	Family	Scientific Name	Speccode	Native
RIPARIAN	JUNCACEAE	Juncus torreyi Cov.	JUTO1	Y
RIPARIAN	LAMIACEAE	Lycopus americanum Muhl. ex Barton	LYAM1	Y
RIPARIAN	LAMIACEAE	Mentha arvensis L.	MEAR1	Y
RIPARIAN	LAMIACEAE	Monarda fistulosa L.	MOFI1	Y
RIPARIAN	LAMIACEAE	Nepeta cataria L.	NECA1	N
RIPARIAN	LAMIACEAE	Prunella vulgaris L.	PRVU1	Y
RIPARIAN	LAMIACEAE	Stachys palustris L.	STPA2	Y
RIPARIAN	LEMNACEAE	Lemna minor L.	LEMI1	Y
RIPARIAN	LILIACEAE	Asparagus officinalis L.	ASOF1	N
RIPARIAN	ONAGRACEAE	Epilobium ciliatum Raf.	EPCI1	Y
RIPARIAN	ONAGRACEAE	Epilobium paniculatum Nutt.	EPPA1	Y
RIPARIAN	ONAGRACEAE	Gaura parviflora Dougl.	GAPA1	Y
RIPARIAN	ONAGRACEAE	Oenothera biennis L.	OEBI1	Y
RIPARIAN	OXALIDACEAE	Oxalis dillenii Jacq.	OXDI1	N
RIPARIAN	POACEAE	Agropyron caninum (L.) Beauv.	AGCA1	Y
RIPARIAN	POACEAE	Agropyron repens (L.) Beauv.	AGRE1	N
RIPARIAN	POACEAE	Agrostis stolonifera L.	AGST1	N
RIPARIAN	POACEAE	Dactylis glomerata L.	DAGL1	N
RIPARIAN	POACEAE	Elymus canadensis L.	ELCA1	Y
RIPARIAN	POACEAE	Festuca pratensis Huds.	FEPR1	Y
RIPARIAN	POACEAE	Muhlenbergia racemosa (Michx.) B. S. P.	MURA1	Y
RIPARIAN	POACEAE	Panicum virgatum L.	PAVI1	Y
RIPARIAN	POACEAE	Phleum pratense L.	PHPR1	N
RIPARIAN	POACEAE	Spartina pectinata Link	SPPE1	Y
RIPARIAN	POACEAE	Sphenopholis obtusata (Michx.) Scribn.	SPOB1	Y
RIPARIAN	POACEAE	Stipa robusta (Vasey) Scribn.	STRO1	Y
RIPARIAN	POLYGONACEAE	Polygonum lapathifolium L.	POLA1	N
RIPARIAN	POLYGONACEAE	Rumex crispus L.	RUCR1	N
RIPARIAN	POLYGONACEAE	Rumex mexicanus Meisn.	RUME1	Y
RIPARIAN	POLYGONACEAE	Rumex obtusifolius L.	RUOB1	N
RIPARIAN	RANUNCULACEAE	Delphinium nuttalianum Pritz. ex Walpers	DENU1	Y

Table B-4. 1994 Species Restricted by Community.

Community	Family	Scientific Name	Speccode	Native
RIPARIAN	ROSACEAE	Crataegus erythropoda Ashe	CRER1	Y
RIPARIAN	ROSACEAE	Geum macrophyllum Willd.	GEMA1	Y
RIPARIAN	ROSACEAE	Prunus virginiana L.	PRVI1	Y
RIPARIAN	ROSACEAE	Rosa woodsii Lindl.	ROWO1	Y
RIPARIAN	RUBIACEAE	Galium boreale L.	GABO1	Y
RIPARIAN	SALICACEAE	Populus deltoides Marsh. var occidentalis Rydb.	PODE1	Y
RIPARIAN	SALICACEAE	Populus x acuminata Rydb.	POAC1	Y
RIPARIAN	SALICACEAE	Salix amygdaloides Anderss.	SAAM1	Y
RIPARIAN	SALICACEAE	Salix exigua Nutt. ssp. interior (Rowlee) Cronq.	SAEX1	Y
RIPARIAN	SALICACEAE	Salix lutea Nutt. var. ligulifolia Ball	SALU1	Y
RIPARIAN	SCROPHULARIACEAE	Veronica americana (Raf.) Schwein. ex Benth.	VEAM1	Y
RIPARIAN	SCROPHULARIACEAE	Veronica anagallis-aquatica L.	VEAN1	N
RIPARIAN	SELAGINELLACEAE	Selaginella densa Rydb.	SEDE1	Y
RIPARIAN	VERBENACEAE	Lippia cuneifolia (Torr.) Steud.	LICU1	Y
RIPARIAN	VERBENACEAE	Verbena hastata L.	VEHA1	Y
RIPARIAN	VIOLACEAE	Viola nephrophylla Greene	VINE1	Y

Table B-5. 1994 Species Richness Summary at EcMP Sites and Communities.

Sample Site	# Families	# Species	% Native	# Annuals	# Biennials	# Perennials
Xeric Community	31	133	84	19	2	111
TR01	24	88	84	12	1	75
TR06	25	89	80	14	1	74
TR12	23	91	84	11	0	79
Mean	24.00	89.33	82.67	12.33	0.67	76.00
Mesic Community	37	143	81	27	1	113
TR02	30	107	81	17	0	90
TR04	30	95	76	23	1	70
TR11	28	106	83	17	1	86
Mean	29.33	102.67	80.00	19.00	0.67	82.00
Riparian Community	40	163	74	21	3	137
TR03	36	121	73	15	1	104
TR05	22	79	66	12	4	63
TR10	37	113	73	14	2	96
Mean	31.67	104.33	70.67	13.67	2.33	87.67
Reclaimed Community	13	61	62	9	2	50
TR07	9	42	62	7	2	33
TR08	9	41	59	7	2	32
TR09	9	27	30	7	1	19
Mean	9.00	36.67	50.33	7.00	1.67	28.00

Community values based on all 3 sites combined.
Site values are the actual number of species except where column heading is different.

Table B-5 (cont.). 1994 Species Richness Summary at EcMP Sites and Communities.

	Growth Form						Type			Form		
Sample Site	Forb	Graminoid	Cactus	Shrub	Vine	Tree	Dicots	Monocots	Pteridophytes	Herbaceous	Succulent	Woody
Xeric Community	99	27	5	2	0	0	108	30	0	126	5	2
TR01	62	21	4	1	0	0	66	22	0	83	4	1
TR06	64	20	4	1	0	0	66	23	0	84	4	1
TR12	66	22	3	0	0	0	67	24	0	88	3	0
Mean	64.00	21.00	3.67	0.67	0.00	0.00	66.33	23.00	0.00	85.00	3.67	0.67
Mesic Community	106	30	5	2	0	0	109	34	0	136	5	2
TR02	78	22	5	2	0	0	81	26	0	100	5	2
TR04	70	20	4	1	0	0	73	22	0	90	4	1
TR11	79	21	4	2	0	0	81	25	0	100	4	2
Mean	75.67	21.00	4.33	1.67	0.00	0.00	78.33	24.33	0.00	96.67	4.33	1.67
Riparian Community	108	39	2	8	1	5	117	42	4	147	2	14
TR03	80	26	2	8	0	5	90	27	4	106	2	13
TR05	48	24	0	5	0	2	54	24	1	72	0	7
TR10	77	23	2	7	1	3	85	25	3	100	2	11
Mean	68.33	24.33	1.33	6.67	0.33	3.33	76.33	25.33	2.67	92.67	1.33	10.33
Reclaimed Community	50	9	1	1	0	0	51	10	0	59	1	1
TR07	32	8	1	1	0	0	33	9	0	40	1	1
TR08	33	7	0	1	0	0	33	8	0	41	0	1
TR09	21	5	1	0	0	0	22	5	0	26	1	0
Mean	28.67	6.67	0.67	0.67	0.00	0.00	29.33	7.33	0.00	35.67	0.67	0.67

Community values based on all 3 sites combined.
Site values are the actual number of species except where column heading is different.

Table B-6. 1994 EcMP Site Summary Statistics for Biomass and Cover.

Sample Site TR01, Xeric Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	102.46	192.76	83.92	118.08
Litter	5	179.01	3541.18	138.72	276.48
Basal Cover					
Vegetation	5	19.2	10.7	14	23
Litter	5	57	7	53	60
Rock	5	21.6	12.3	16	25
Bare Ground	5	2.2	8.7	0	7
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	81.2	30.7	76	90
Shrub	5	0	0	0	0
Tree	5	0	0	0	0

Sample Site TR02, Mesic Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	101.12	225.395	76.8	114.08
Litter	5	207.1	2631.79	130.48	247.36
Basal Cover					
Vegetation	5	21.4	60.8	12	33
Litter	5	56	50.5	49	66
Rock	5	21	109	8	36
Bare Ground	5	1.6	3.3	0	4
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	88	13.5	82	91
Shrub	5	3.2	17.2	0	10
Tree	5	0	0	0	0

Sample Site TR03, Riparian Community

Basal Cover	n	Mean	Variance	Minimum	Maximum
Vegetation	5	18.2	144.2	7	34
Litter	5	74	75.5	63	84
Rock	5	6	32	1	13
Bare Ground	5	1.4	2.8	0	4
Water	5	0.4	0.8	0	2
Foliar Cover					
Foliar	5	75	546.5	39	97
Shrub	5	42.4	958.3	0	71
Tree	5	17.6	559.3	0	53

Cover means are percentages of cover. Biomass means are in g/m^2.

Table B-6 (cont.). 1994 EcMP Site Summary Statistics for Biomass and Cover.

Sample Site TR04, Mesic Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	113.17	652.828	72.08	141.12
Litter	5	148.51	155.375	139.52	169.44
Basal Cover					
Vegetation	5	40.4	274.3	24	61
Litter	5	51	219.5	32	65
Rock	5	6.2	14.7	1	11
Bare Ground	5	2.6	5.8	0	6
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	91.6	39.3	81	96
Shrub	5	0.2	0.2	0	1
Tree	5	0	0	0	0

Sample Site TR05, Riparian Community

Basal Cover	n	Mean	Variance	Minimum	Maximum
Vegetation	5	11.6	88.3	3	26
Litter	5	55.6	1063.8	5	85
Rock	5	29.2	1587.7	0	92
Bare Ground	5	0.8	3.2	0	4
Water	5	2.8	32.7	0	13
Foliar Cover					
Foliar	5	53.2	1189.7	18	98
Shrub	5	32	1419	3	95
Tree	5	27.2	1388.7	0	90

Sample Site TR06, Xeric Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	157.7	1229.25	112	198
Litter	5	342.8	2821.11	288.8	403.84
Basal Cover					
Vegetation	5	21.6	68.3	14	35
Litter	5	73.4	96.8	57	82
Rock	5	3.4	6.8	1	7
Bare Ground	5	1.6	3.8	0	5
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	89.4	38.3	84	97
Shrub	5	1.6	4.3	0	5
Tree	5	0	0	0	0

Cover means are percentages of cover. Biomass means are in g/m^2.

Table B-6 (cont.). 1994 EcMP Site Summary Statistics for Biomass and Cover.

Sample Site TR07, Reclaimed Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	139.46	855.352	114.16	189.76
Litter	5	212.37	910.492	180.24	243.52
Basal Cover					
Vegetation	5	7.4	6.3	5	11
Litter	5	73.4	48.8	65	82
Rock	5	13.8	32.2	6	20
Bare Ground	5	5.4	18.8	1	11
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	74.8	11.2	71	80
Shrub	5	0	0	0	0
Tree	5	0	0	0	0

Sample Site TR08, Reclaimed Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	120.13	783.349	103.52	169.92
Litter	5	195.62	940.977	153.6	228.16
Basal Cover					
Vegetation	5	6.8	5.7	3	9
Litter	5	71.8	25.7	64	77
Rock	5	12.6	11.8	8	16
Bare Ground	5	8.8	6.2	5	11
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	70	9	67	74
Shrub	5	0	0	0	0
Tree	5	0	0	0	0

Sample Site TR09, Reclaimed Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	177.71	271.676	149.2	189.28
Litter	5	274.37	1254.17	242.08	334.32
Basal Cover					
Vegetation	5	19.4	20.3	14	23
Litter	5	66	23.5	58	71
Rock	5	13.6	22.8	7	19
Bare Ground	5	1	3	0	4
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	95.8	11.2	91	99
Shrub	5	0	0	0	0
Tree	5	0	0	0	0

Cover means are percentages of cover. Biomass means are in g/m^2.

Table B-6 (cont.). 1994 EcMP Site Summary Statistics for Biomass and Cover.

Sample Site TR10, Riparian Community

Basal Cover	n	Mean	Variance	Minimum	Maximum
Vegetation	5	27.8	121.7	11	38
Litter	5	66.2	168.2	50	83
Rock	5	4.4	4.8	1	7
Bare Ground	5	1.6	4.3	0	5
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	71.4	550.8	33	93
Shrub	5	45	996	14	80
Tree	5	11	318	0	41

Sample Site TR11, Mesic Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	146.06	800.731	119.84	184.32
Litter	5	319.38	3667.87	269.92	420.64
Basal Cover					
Vegetation	5	25.4	207.8	14	50
Litter	5	59	135	47	74
Rock	5	14.8	149.2	3	32
Bare Ground	5	0.8	0.7	0	2
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	94.4	14.8	90	100
Shrub	5	0.6	1.8	0	3
Tree	5	0	0	0	0

Sample Site TR12, Xeric Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	5	125.62	248.209	105.36	146.72
Litter	5	266.96	2040.84	220.4	338.64
Basal Cover					
Vegetation	5	17.2	13.7	13	22
Litter	5	65.4	5.3	63	69
Rock	5	16.8	6.2	15	21
Bare Ground	5	0.6	0.8	0	2
Water	5	0	0	0	0
Foliar Cover					
Foliar	5	90.4	28.3	86	99
Shrub	5	0	0	0	0
Tree	5	0	0	0	0

Cover means are percentages of cover. Biomass means are in g/m^2.

Table B-7 . 1994 Community Summary Statistics for Biomass and Cover.

Xeric Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	15	128.592	1026.69	83.92	198
Litter	15	262.923	7200.31	138.72	403.84
Basal Cover					
Vegetation	15	19.3333	29.9524	13	35
Litter	15	65.2667	79.2095	53	82
Rock	15	13.9333	70.781	1	25
Bare Ground	15	1.46667	4.26667	0	7
Water	15	0	0	0	0
Foliar Cover					
Foliar	15	87	46	76	99
Shrub	15	0.53333	1.8381	0	5
Tree	15	0	0	0	0

Mesic Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	15	120.117	866.28	72.08	184.32
Litter	15	224.997	7229.12	130.48	420.64
Basal Cover					
Vegetation	15	29.0667	226.781	12	61
Litter	15	55.3333	127.381	32	74
Rock	15	14	117.429	1	36
Bare Ground	15	1.66667	3.38095	0	6
Water	15	0	0	0	0
Foliar Cover					
Foliar	15	91.3333	26.6667	81	100
Shrub	15	1.33333	7.38095	0	10
Tree	15	0	0	0	0

Cover means are percentages of cover. Biomass means are in g/m^2.

Table B-7 (cont.). 1994 Community Summary Statistics for Biomass and Cover.

Riparian Community

Basal Cover	n	Mean	Variance	Minimum	Maximum
Vegetation	15	19.2	148.6	3	38
Litter	10	70.1	125.211	50	84
Rock	10	5.2	17.0667	1	13
Bare Ground	15	1.26667	3.06667	0	5
Water	15	1.06667	11.2095	0	13
Foliar Cover					
Foliar	15	66.5333	750.981	18	98
Shrub	15	39.8	997.6	0	95
Tree	15	18.6	694.829	0	90

Reclaimed Community

Biomass	n	Mean	Variance	Minimum	Maximum
Current Year Production	15	145.765	1159.28	103.52	189.76
Litter	15	227.451	2116.67	153.6	334.32
Basal Cover					
Vegetation	15	11.2	45.3143	3	23
Litter	15	70.4	38.8286	58	82
Rock	15	13.3333	19.381	6	20
Bare Ground	15	5.06667	18.9238	0	11
Water	15	0	0	0	0
Foliar Cover					
Foliar	15	80.2	143.457	67	99
Shrub	15	0	0	0	0
Tree	15	0	0	0	0

Cover means are percentages of cover. Biomass means are in g/m^2.

Table B-8. 1994 % Native versus Non-native Species by Community from Basal and Foliar Cover.

	# Species	% Native	% Native Cover	% Non-Native Cover	% Relative Native Cover
Xeric Community					
Basal Cover	30	80	16.80	2.50	87
Foliar Cover	54	75	72.30	14.60	83
Mesic Community					
Basal Cover	33	67	14.70	14.40	50
Foliar Cover	58	77	47.90	43.40	52
Riparian Community					
Basal Cover	37	68	10.50	8.70	55
Foliar Cover	70	71	39.40	27.10	59
Reclaimed Community					
Basal Cover	10	30	0.20	11.00	2
Foliar Cover	19	32	1.30	78.90	2

The above calculations for % native, % native cover, % non-native cover, and % relative native cover were made for those taxa identified to species only. Those identified only to the family or genera level were not included. Calculations are based on combined site species lists to determine # species and % native values.

Table B-9. 1994 Basal and Foliar Cover Dominant Species by Community.

Basal Cover Dominant Species by Community

Community	Frequency	Relative Basal Cover (%)
Xeric Community		
Stipa comata	80.00	35.20
Andropogon scoparius	66.67	9.30
Carex heliophila	60.00	7.30
Andropogon gerardii	46.67	5.50
Poa compressa	46.67	5.20
Mesic Community		
Bromus japonicus	93.33	35.20
Bouteloua gracilis	86.67	16.60
Agropyron smithii	86.67	9.70
Bromus tectorum	26.67	5.80
Carex heliophila	33.33	5.10
Riparian Community		
Juncus balticus	53.33	22.20
Poa pratensis	60.00	17.70
Carex nebraskensis	53.33	12.10
Poa compressa	26.67	10.10
Bromus japonicus	26.67	7.30
Reclaimed Community		
Bromus inermis	100.00	51.80
Agropyron intermedium	93.33	43.50
9 other species	NA	0.63

Foliar Cover Dominant Species by Community

Community	Absolute Foliar Cover (%)	Relative Foliar Cover (%)
Xeric Community		
Stipa comata	32.20	37.00
Andropogon gerardii	6.80	7.80
Carex heliophila	5.60	6.40
Andropogon scoparius	3.93	4.50
Arenaria fendleri	3.67	4.20
Mesic Community		
Bromus japonicus	29.13	31.90
Agropyron smithii	18.13	19.90
Bouteloua gracilis	6.53	7.20
Carex heliophila	4.13	4.50
Bromus tectorum	3.93	4.30
Riparian Community		
Juncus balticus	14.87	22.40
Cirsium arvense	7.20	10.80
Poa compressa	6.20	9.30
Carex nebraskensis	5.93	8.90
Poa pratensis	3.00	4.50
Reclaimed Community		
Bromus inermis	44.67	55.70
Agropyron intermedium	30.07	37.50
Alyssum minus	1.60	2.00

Frequency based on n = 15. Top five cover species listed only.

Absolute Foliar Cover = Mean number of hits for each species converted to a percentage.

Relative Foliar Cover = Mean cover value of given species expressed as a proportion of the total coverage for all species.

Frequency = Probability of getting a hit for that species.

Table B-10. 1994 Basal Cover Dominant Species at at EcMP Sites.

Xeric Community		
Sample Site	Frequency	Relative Basal Cover (%)
TR01		
Andropogon scoparius	100.00	22.90
Andropogon gerardii	60.00	7.30
Carex heliophila	80.00	7.30
Muhlenbergia montana	80.00	7.30
Aster porteri	80.00	6.30
TR06		
Stipa comata	100.00	56.50
Bouteloua gracilis	80.00	10.20
Poa pratensis	20.00	9.30
Poa compressa	20.00	7.40
Carex heliophila	60.00	5.60
TR12		
Stipa comata	100.00	45.30
Carex heliophila	40.00	9.30
Andropogon gerardii	60.00	8.10
Bouteloua curtipendula	60.00	5.80
Andropogon scoparius	80.00	4.70

Riparian Community		
Sample Site	Frequency	Relative Basal Cover (%)
TR03		
Juncus balticus	80.00	36.30
Poa pratensis	80.00	14.30
Carex nebraskensis	60.00	12.10
Barbarea orthoceras	80.00	9.90
Salix exigua	20.00	5.50
TR05		
Festuca pratensis	40.00	15.50
Juncus balticus	20.00	15.50
Carex nebraskensis	40.00	12.10
Agrostis stolonifera	40.00	8.60
Poa compressa	20.00	8.60
TR10		
Poa pratensis	80.00	25.90
Poa compressa	60.00	17.30
Juncus balticus	60.00	15.80
Bromus japonicus	40.00	13.70
Carex nebraskensis	60.00	12.20

Frequency=Probability of getting a hit for a given species (n=5).

Relative Basal Cover=mean cover value (n=5) of given species expressed as a proportion of the total coverage for all species.

Top five cover species listed only.

Table B-10 (cont.) 1994 Basal Cover Dominant Species at EcMP Sites.

Mesic Community		
Sample Site	Frequency	Relative Basal Cover (%)
TR02		
Bouteloua gracilis	100.00	29.90
Agropyron smithii	80.00	19.60
Bouteloua hirsuta	80.00	11.20
Bromus japonicus	80.00	10.30
Bouteloua curtipendula	60.00	5.60
TR04		
Bromus japonicus	100.00	55.00
Bouteloua gracilis	80.00	15.30
Bromus tectorum	40.00	8.40
Agropyron smithii	80.00	5.40
Poa compressa	80.00	3.00
TR11		
Bromus japonicus	100.00	24.40
Carex heliophila	80.00	15.00
Agropyron smithii	100.00	7.90
Bouteloua gracilis	80.00	7.10
Bromus tectorum	40.00	6.30
Poa pratensis	60.00	6.30

Reclaimed Community		
Sample Site	Frequency	Relative Basal Cover (%)
TR07		
Bromus inermis	100.00	43.20
Agropyron intermedium	100.00	37.80
All others combined		18.90
TR08		
Bromus inermis	100.00	70.60
Agropyron intermedium	80.00	29.40
No others		
TR09		
Agropyron intermedium	100.00	50.50
Bromus inermis	100.00	48.50
Convolvulus arvensis	20.00	1.00
No others		

Frequency=Probability of getting a hit for a given species (n=5).

Relative Basal Cover=mean cover value (n=5) of given species expressed as a proportion of the total coverage for all species.

Top five cover species listed only.

Table B-11. 1994 Foliar Cover Dominant Species by EcMP Site.

Xeric Community		
Sample Site	Foliar Cover (%)	Relative Foliar Cover (%)
TR01		
Andropogon gerardii	9.40	11.60
Andropogon scoparius	8.40	10.30
Aster porteri	8.40	10.30
Muhlenbergia montana	6.80	8.40
Arenaria fendleri	5.40	6.70
TR06		
Stipa comata	55.80	62.40
Linaria dalmatica	7.20	8.10
Poa pratensis	5.20	5.80
Poa compressa	4.80	5.40
Bouteloua gracilis	2.40	2.70
TR12		
Stipa comata	35.60	39.40
Andropogon gerardii	10.20	11.30
Carex heliophila	9.40	10.40
Arenaria fendleri	5.60	6.20
Alyssum minus	5.00	5.50

Mesic Community		
Sample Site	Foliar Cover (%)	Relative Foliar Cover (%)
TR02		
Agropyron smithii	29.00	33.00
Bromus japonicus	18.40	20.90
Bouteloua gracilis	11.80	13.40
Bouteloua curtipendula	4.80	5.50
Carex heliophila	3.60	4.10
TR04		
Bromus japonicus	44.60	48.70
Agropyron smithii	14.40	15.70
Bouteloua gracilis	6.20	6.80
Bromus tectorum	4.20	4.60
Scorzonera laciniata	2.80	3.10
TR11		
Bromus japonicus	24.40	25.80
Agropyron smithii	11.00	11.70
Carex heliophila	8.80	9.30
Stipa comata	8.20	8.70
Bromus tectorum	7.60	8.10

Relative Foliar Cover = mean cover value (n=5) of a given species expressed as a proportion of the total coverage for all species.

Top five cover species listed only.

Frequency = Probability of getting a hit for a given species (n=5).

Table B-11 (cont.). 1994 Foliar Cover Dominant Species by EcMP Site.

Riparian Community		
Sample Site	Foliar Cover (%)	Relative Foliar Cover (%)
TR03		
Juncus balticus	27.80	37.10
Cirsium arvense	7.40	9.90
Carex nebraskensis	7.20	9.60
Glycyrrhiza lepidota	3.60	4.80
Poa pratensis	3.60	4.80
TR05		
Circium arvense	9.00	16.90
Festuca pratensis	7.80	14.70
Poa compressa	6.40	12.00
Juncus balticus	5.20	9.80
Agrostis stolonifera	4.40	8.30
TR10		
Juncus balticus	11.60	16.20
Poa compressa	11.40	16.00
Carex nebraskensis	6.80	9.50
Cirsium arvense	5.20	7.30
Poa pratensis	5.00	7.00

Reclaimed Community		
Sample Site	Foliar Cover (%)	Relative Foliar Cover (%)
TR07		
Bromus inermis	36.20	48.40
Agropyron intermedium	28.40	38.00
Melilotus officinalis	3.20	4.30
Alyssum minus	2.40	3.20
Agropyron smithii	1.20	1.60
TR08		
Bromus inermis	53.60	76.60
Agropyron intermedium	14.40	20.60
Cirsium arvense	0.40	0.60
Convolvulus arvensis	0.40	0.60
Melilotus alba	0.40	0.60
TR09		
Agropyron intermedium	47.20	49.50
Bromus inermis	44.20	46.10
Alyssum minus	2.40	2.50
Convolvulus arvensis	0.80	0.84
Agropyron cristatum	0.60	0.63

Relative Foliar Cover = mean cover value (n=5) of a given species expressed as a proportion of the total coverage for all species.

Top five cover species listed only.

Frequency = Probability of getting a hit for a given species (n=5).

Table B-11 (cont.). 1994 Foliar Cover Dominant Species by EcMP Site.

Riparian Community		
Sample Site	Shrub Cover (%)	Relative Shrub Cover (%)
TR03		
Amorpha fruticosa	24.80	58.50
Salix exigua	11.20	26.40
Symphoricarpos occidentalis	3.60	8.50
Prunus virginiana	0.80	0.20
Rosa woodsia	0.80	0.20
TR05		
Salix exigua	15.20	47.50
Populus deltoides	6.40	20.00
Amorpha fruticosa	5.80	18.10
Symphoricarpos occidentalis	3.80	11.90
Salix amygdaloides	0.60	0.20
TR10		
Salix exigua	15.80	35.10
Amorpha fruticosa	15.40	34.20
Symphoricarpos occidentalis	5.80	12.90
Prunus virginiana	3.40	7.60
Rosa arkansana	2.20	4.90

Riparian Community		
Sample Site	Tree Cover (%)	Relative Tree Cover (%)
TR03		
Populus deltoides	15.80	89.80
Salix exigua	1.20	6.80
Amorpha fruticosa	0.60	3.40
TR05		
Salix exigua	16.00	58.80
Populus deltoides	6.80	25.00
Salix amygdaloides	2.40	8.80
Amorpha fruticosa	2.00	7.40
TR10		
Populus deltoides	8.20	74.50
Salix amygdaloides	1.60	14.50
Salix exigua	1.20	10.90

Relative Foliar Cover = mean cover value (n=5) of a given species expressed as a proportion of the total coverage for all species.

Top five cover species listed only.

Frequency = Probability of getting a hit for a given species (n=5).

Table B-12. 1994 Native vs. Non-native Current Year Production Biomass at EcMP Sites and Communities.

Sample Site	Native CYP (g/m^2)	Non-Native CYP (g/m^2)	% Native CYP
Xeric Community	91.54	37.04	71.19
TR01	93.28	9.18	91.04
TR06	72.68	85.01	46.09
TR12	108.67	16.94	86.51
Mesic Community	75.18	44.94	62.58
TR02	74.51	26.61	73.68
TR04	54.47	58.70	48.13
TR11	96.55	49.52	66.10
Reclaimed Community	0.32	145.44	0.22
TR07	0.54	138.91	0.39
TR08	0.42	119.71	0.35
TR09	0.00	177.71	0.00

CYP = Current Year Production
Community means based on n=75
Site means based on n=25
% Native CYP = Native CYP/(Native CYP+Non-native CYP)

Table B-13. 1994 Leading Biomass Producers by EcMP Site.

Xeric Community		
Sample Site	Frequency	Total CYP(g/m^2)
TR01		
Aster porteri	0.84	12.78
Andropogon gerardii	0.40	11.82
Chrysopsis villosa	0.92	11.12
Liatris punctata	0.80	8.43
Arenaria fendleri	0.80	7.94
Stipa comata	0.60	6.93
Andropogon scoparius	0.32	5.94
Muhlenbergia montana	0.40	5.46
Carex heliophila	0.80	4.34
Poa compressa	0.16	4.03
TR06		
Linaria dalmatica	0.92	51.47
Stipa comata	0.92	47.10
Poa compressa	0.32	10.86
Alyssum minus	0.08	9.84
Sisymbrium altissimum	0.12	3.63
Bouteloua gracilis	0.76	3.54
Agropyron smithii	0.16	3.39
Stipa neomexicana	0.12	3.25
Carex heliophila	0.40	3.12
Carduus nutans	0.08	2.88
TR12		
Stipa comata	1.00	55.71
Liatris punctata	0.60	14.54
Alyssum minus	0.72	8.67
Carex heliophila	0.96	5.30
Andropogon gerardii	0.28	5.20
Bouteloua curtipendula	0.68	4.88
Andropogon scoparius	0.24	4.59
Poa compressa	0.16	3.61
Psoralea tenuiflora	0.40	3.29
Arenaria fendleri	0.56	3.13

Mesic Community		
Sample Site	Frequency	Total CYP(g/m^2)
TR02		
Agropyron smithii	96.00	34.19
Bromus japonicus	84.00	10.06
Bouteloua gracilis	60.00	6.66
Scorzonera laciniata	64.00	5.97
Centaurea diffusa	4.00	4.69
Bouteloua curtipendula	28.00	4.56
Bouteloua hirsuta	36.00	4.00
Alyssum minus	32.00	3.78
Artemisia frigida	16.00	3.57
Chrysopsis villosa	20.00	3.15
TR04		
Bromus japonicus	100.00	34.37
Agropyron smithii	100.00	22.45
Carex eleocharis	16.00	8.61
Bouteloua gracilis	76.00	6.94
Scorzonera laciniata	64.00	4.69
Poa compressa	16.00	4.42
Linaria dalmatica	20.00	4.26
Aster ericoides	28.00	3.28
Poa pratensis	20.00	2.59
Alyssum minus	16.00	2.46
TR11		
Agropyron smithii	88.00	22.24
Bromus japonicus	92.00	14.61
Carex heliophila	68.00	13.26
Carduus nutans	28.00	12.98
Stipa comata	52.00	11.23
Artemisia ludiviciana	52.00	10.51
Andropogon gerardii	28.00	9.44
Grindelia squarrosa	12.00	7.86
Poa compressa	8.00	5.31
Bromus tectorum	40.00	5.07

Values listed are based on an n=25. There were 25 quadrats per site. Only the top 10 bic ıroducers per site are listed. Frequency = Probability of getting a hit for a given species.

Table B-13 (cont.). 1994 Leading Biomass Producers by EcMP Site.

Reclaimed Community		
Sample Site	Frequency	Total CYP(g/m^2)
TR07		
Bromus inermis	80.00	81.81
Agropyron intermedium	88.00	51.20
Alyssum minus	56.00	2.91
Melilotus officinalis	20.00	1.47
Poa pratensis	4.00	0.48
Chrysopsis villosa	8.00	0.45
Cirsium arvense	20.00	0.43
Medicago lupulina	52.00	0.32
Tragopogon dubius	8.00	0.16
Camelina microcarpa	16.00	0.08
TR08		
Bromus inermis	100.00	100.51
Agropyron intermedium	100.00	16.86
Medicago lupulina	48.00	0.96
Alyssum minus	28.00	0.93
Vicia americana	28.00	0.21
Aristida purpurea var.robusta	4.00	0.18
Cirsium arvense	8.00	0.14
Melilotus alba	8.00	0.11
Convolvulus arvensis	8.00	0.06
Linaria dalmatica	4.00	0.06
TR09		
Agropyron intermedium	100.00	96.37
Bromus inermis	80.00	74.62
Convolvulus arvensis	56.00	4.00
Cirsium arvense	4.00	1.20
Alyssum minus	44.00	1.02
Agropyron cristatum	4.00	0.29
Tragopogon dubius	4.00	0.11
Camelina microcarpa	4.00	0.06
Bromus japonicus	12.00	0.03

Values listed are based on an n=25. There were 25 quadrats per site. Only the top 10 biomass producers per site are listed. Frequency = Probability of getting a hit for a given species.

Table B-14. Terrestrial Vegetation DECORANA Ordination by EcMP Transect - Based on Species Presence/Absence Data.

Sample Site	Community	AXIS 1	AXIS 2	AXIS 3	AXIS 4
TR01 T1	Xeric	12	14	20	54
TR01 T2	Xeric	11	28	56	34
TR01 T3	Xeric	3	16	31	58
TR01 T4	Xeric	1	29	37	56
TR01 T5	Xeric	9	18	37	44
TR02 T1	Mesic	34	72	38	76
TR02 T2	Mesic	46	69	41	74
TR02 T3	Mesic	34	63	40	71
TR02 T4	Mesic	70	62	39	79
TR02 T5	Mesic	77	59	42	62
TR03 T1	Riparian	271	86	4	0
TR03 T2	Riparian	253	34	50	33
TR03 T3	Riparian	278	4	49	51
TR03 T4	Riparian	263	30	72	128
TR03 T5	Riparian	324	7	59	164
TR04 T1	Mesic	79	61	46	72
TR04 T2	Mesic	48	69	56	67
TR04 T3	Mesic	77	85	77	49
TR04 T4	Mesic	92	61	83	49
TR04 T5	Mesic	73	75	87	54
TR05 T1	Riparian	231	146	16	52
TR05 T2	Riparian	329	93	0	16
TR05 T3	Riparian	264	189	24	77
TR05 T4	Riparian	312	181	57	44
TR05 T5	Riparian	341	152	60	20
TR06 T1	Xeric	49	58	103	54
TR06 T2	Xeric	26	64	112	46
TR06 T3	Xeric	28	65	99	41
TR06 T4	Xeric	1	69	90	57
TR06 T5	Xeric	24	65	98	54
TR07 T1	Reclaimed	156	139	48	63
TR07 T2	Reclaimed	152	121	24	71
TR07 T3	Reclaimed	126	107	5	91
TR07 T4	Reclaimed	131	124	56	60
TR07 T5	Reclaimed	132	133	63	42
TR08 T1	Reclaimed	144	143	52	85
TR08 T2	Reclaimed	146	125	25	96
TR08 T3	Reclaimed	138	126	13	76
TR08 T4	Reclaimed	168	165	1	105
TR08 T5	Reclaimed	147	126	27	80
TR09 T1	Reclaimed	179	102	155	47
TR09 T2	Reclaimed	179	109	174	55
TR09 T3	Reclaimed	152	68	135	51

Table B-14 (cont.). Terrestrial Vegetation DECORANA Ordination by EcMP Transect - Based on Species Presence/Absence Data.

TR09 T4	Reclaimed	141	77	171	53
TR09 T5	Reclaimed	162	89	147	43
TR10 T1	Riparian	314	0	28	61
TR10 T2	Riparian	276	36	26	11
TR10 T3	Riparian	279	82	63	91
TR10 T4	Riparian	295	23	78	57
TR10 T5	Riparian	194	60	52	79
TR11 T1	Mesic	34	75	62	63
TR11 T2	Mesic	60	65	39	64
TR11 T3	Mesic	43	61	40	58
TR11 T4	Mesic	79	48	80	51
TR11 T5	Mesic	43	73	78	49
TR12 T1	Xeric	13	32	26	76
TR12 T2	Xeric	5	41	33	67
TR12 T3	Xeric	0	48	42	64
TR12 T4	Xeric	13	33	23	76
TR12 T5	Xeric	17	44	36	70

Table B-15. Terrestrial Vegetation Ordination by EcMP Transect - Reciprocal Averaging Method - Species Presence/Absence Data.

Sample Site	Community	AXIS 1	AXIS 2	AXIS 3	AXIS 4
TR01 T1	Xeric	-92	-61	107	35
TR01 T2	Xeric	-97	-58	64	27
TR01 T3	Xeric	-95	-75	112	26
TR01 T4	Xeric	-99	-64	84	31
TR01 T5	Xeric	-92	-66	98	35
TR02 T1	Mesic	-81	-15	-25	0
TR02 T2	Mesic	-76	-4	-57	-25
TR02 T3	Mesic	-83	-15	-24	-12
TR02 T4	Mesic	-55	11	-28	-17
TR02 T5	Mesic	-55	9	-34	-16
TR03 T1	Riparian	209	-11	-31	98
TR03 T2	Riparian	195	-27	3	-29
TR03 T3	Riparian	233	-46	25	-54
TR03 T4	Riparian	217	-45	30	-127
TR03 T5	Riparian	297	-71	108	-184
TR04 T1	Mesic	-47	1	-43	-23
TR04 T2	Mesic	-74	-14	-67	-24
TR04 T3	Mesic	-52	2	-109	-30
TR04 T4	Mesic	-44	-2	-90	-35
TR04 T5	Mesic	-61	2	-95	-36
TR05 T1	Riparian	132	50	-56	126
TR05 T2	Riparian	278	-33	-43	138
TR05 T3	Riparian	170	69	-30	101
TR05 T4	Riparian	251	24	-14	101
TR05 T5	Riparian	303	-24	-52	195
TR06 T1	Xeric	-69	-26	-36	-11
TR06 T2	Xeric	-87	-31	-38	-14
TR06 T3	Xeric	-84	-31	-21	-1
TR06 T4	Xeric	-102	-35	-21	-6
TR06 T5	Xeric	-88	-33	-21	-5
TR07 T1	Reclaimed	-10	201	27	-3
TR07 T2	Reclaimed	-13	222	48	-11
TR07 T3	Reclaimed	-28	167	28	-7
TR07 T4	Reclaimed	-26	189	23	-10
TR07 T5	Reclaimed	-22	179	37	7
TR08 T1	Reclaimed	-22	246	24	-17
TR08 T2	Reclaimed	-13	218	39	-10
TR08 T3	Reclaimed	-25	238	46	-7
TR08 T4	Reclaimed	-4	323	60	5
TR08 T5	Reclaimed	-8	220	56	10
TR09 T1	Reclaimed	2	246	55	-29
TR09 T2	Reclaimed	-5	342	91	-23
TR09 T3	Reclaimed	-15	240	33	-43

Table B-15 (cont.). Terrestrial Vegetation Ordination by EcMP Transect - Reciprocal Averaging Method - Species Presence/Absence Data.

TR09 T4	Reclaimed	-24	179	13	-28
TR09 T5	Reclaimed	-8	228	48	-20
TR10 T1	Riparian	274	-50	28	-36
TR10 T2	Riparian	224	-24	5	54
TR10 T3	Riparian	196	-11	-25	28
TR10 T4	Riparian	253	-48	0	-38
TR10 T5	Riparian	84	18	-34	12
TR11 T1	Mesic	-79	-26	-50	-6
TR11 T2	Mesic	-64	-7	-46	-16
TR11 T3	Mesic	-78	-20	-33	-9
TR11 T4	Mesic	-52	-18	-55	-20
TR11 T5	Mesic	-78	-22	-53	-19
TR12 T1	Xeric	-92	-48	59	24
TR12 T2	Xeric	-99	-52	50	28
TR12 T3	Xeric	-103	-48	50	25
TR12 T4	Xeric	-93	-46	58	22
TR12 T5	Xeric	-91	-44	41	21

Table B-16. 1994 DECORANA Ordination by Species Presence/Absence Data.

SPECCODE	AXIS1	AXIS 2	AXIS 3	AXIS 4
ACMI1	248	-42	-59	0
AGCA1	369	-62	-158	-450
AGCR1	183	100	236	127
AGIN1	172	127	192	53
AGRE1	358	286	-14	-125
AGSM1	246	23	-33	163
AGST1	386	205	16	26
ALMI1	127	-4	124	1
ALTE1	-55	26	45	80
AMFR1	358	260	-13	-61
AMPS1	129	31	-20	8
ANGE1	-59	28	31	37
ANMI1	-96	-40	-68	158
ANOC1	-68	211	572	40
ANSC1	-69	35	25	63
APCA1	401	281	-95	-395
ARCA1	97	0	-271	184
ARDR1	131	186	-31	-3
ARFE1	-36	131	93	74
ARFE2	-96	-38	-45	50
ARFE3	45	-39	350	-86
ARFR1	27	39	51	-15
ARFU1	189	130	48	219
ARGL1	10	5	207	-68
ARLO1	7	105	-55	55
ARLU1	74	10	35	-25
ASAG1	57	-31	140	-38
ASCR1	-34	97	-117	195
ASDR1	-19	126	-20	-16
ASER1	242	168	-17	129
ASFL1	-5	196	-76	208
ASIN1	382	-115	141	348
ASMI1	-91	-71	14	-118
ASOC1	400	-262	306	569
ASOF1	397	-187	-166	-287
ASPA1	169	219	12	211
ASPO1	27	182	-95	148
ASPU1	52	188	-118	207
ASSE1	-10	47	319	-23
ASSH1	-64	126	106	88
ASSP1	376	-47	102	193
ASVI1	232	-100	-119	192
BAOR1	403	181	45	71
BOCU1	-53	35	47	45
BOGR1	-3	5	64	10
BOHI1	-39	46	73	33
BRIN1	238	242	152	162
BRJA1	187	120	138	-6
BRTE1	-12	63	166	-29
BUDA1	-32	33	-18	51
CACH1	400	-154	343	-141
CAEL1	-13	40	-125	193
CAFI1	-34	32	604	2
CAHE1	-59	33	15	25
CAIN1	-31	103	228	-71

Table B-16. 1994 DECORANA Ordination by Species Presence/Absence Data.

CALA1	322	-36	235	369
CAMI1	65	14	143	-22
CANE1	399	-6	30	-10
CANU1	246	24	191	120
CAOR1	-73	165	-113	193
CAPR1	356	-174	436	533
CARO2	356	-174	436	533
CASE2	-97	-36	-29	12
CASE3	-98	-54	-44	1
CASI1	443	-350	175	605
CAST1	338	-16	78	223
CEAR1	356	-174	436	533
CEDI1	114	-58	-99	112
CHFU1	68	-61	-7	199
CHLE2	-31	183	176	65
CHVI1	64	31	43	32
CIAR1	271	173	0	55
CIIN1	246	-117	315	-22
CIMA1	388	-261	173	252
CIUN1	-32	111	90	81
COAR1	218	178	164	188
COCA1	385	279	288	274
COLI1	-42	154	-116	-10
COMA1	418	734	212	-172
COMI1	4	22	134	-8
COUM1	33	-42	55	171
CRER1	359	-202	260	228
CROC1	45	-39	350	-86
CYOF1	395	225	44	-84
DACA1	68	223	-306	238
DAGL1	374	327	-44	-217
DAPU1	-68	36	84	41
DENU1	271	-65	-197	83
DEPI1	76	-3	134	75
DERI1	4	51	192	-38
DESO1	-68	211	572	40
DRNE1	273	-218	41	384
DRRE1	-72	34	66	118
ECVI1	-59	62	32	25
ELCA1	356	255	-170	-151
ELMA1	472	439	405	-358
ELPA1	384	262	205	244
EPCI1	398	-250	136	180
EPPA1	328	188	-81	-184
EQAR1	395	-14	199	-290
EQHY1	378	-248	142	-78
EQLA1	379	-142	-48	-230
ERAL1	-74	18	103	86
ERAS1	-35	66	95	-4
ERCI1	90	-17	-46	-11
ERDI1	79	-33	94	172
ERFL1	14	-20	-12	127
ERRE1	33	69	130	79
EUDE1	-45	216	10	-44
EURO1	-56	39	-147	202
EUSE1	271	-65	-197	83

Table B-16. 1994 DECORANA Ordination by Species Presence/Absence Data.

EUSP1	1	146	-50	150
EVNU1	-21	123	-88	41
FEPR1	388	436	-81	-142
GAAR1	-96	-38	-45	50
GABO1	369	-130	6	187
GACO1	-22	130	144	6
GAPA1	351	498	7	323
GECA1	377	-160	44	-45
GEMA1	391	-237	188	242
GLLE1	385	205	-50	224
GRSQ1	207	165	-56	-11
GUSA1	59	179	-14	140
HEAN1	-31	-9	-174	-27
HEPE1	-100	-30	139	-109
HEPU1	-34	45	6	50
HOJU1	289	477	18	1
HYPE1	167	-26	2	170
HYVE1	4	38	-160	185
IPSP1	-93	-67	-7	-83
JUBA1	386	205	16	26
JUDU1	369	-65	135	-84
JUTO1	374	190	80	289
KOPY1	-16	-14	25	29
KUCH1	178	221	-304	242
KUEU1	84	179	-139	179
LAEU1	346	362	185	378
LAOB1	443	-350	175	605
LARE1	-24	168	284	-7
LASE1	211	196	68	-24
LEDE1	43	221	278	-17
LEMI1	400	-262	306	569
LEMO1	-71	34	74	43
LEMO2	-66	144	155	155
LICU1	271	-65	-197	83
LIDA1	33	115	182	60
LIIN1	-55	188	223	-6
LIPE1	55	60	187	187
LIPU1	-28	85	-8	51
LOOR1	83	10	54	84
LUAR1	356	-174	436	533
LYAM1	425	-311	-173	-124
MEAL1	268	375	-213	253
MEAR1	364	68	0	48
MELA1	56	-21	16	106
MELU1	262	254	-133	-43
MEOF1	246	288	-48	95
MESA1	204	17	626	-81
MICU1	-14	56	-40	148
MIGR1	59	158	283	-43
MILI1	-46	37	60	34
MOFI1	374	-196	62	-41
MUDI1	15	111	-57	167
MUMO1	-82	-35	-55	87
MURA1	454	203	-409	-144
MUWR1	-38	145	-191	144
NAOF1	411	-299	159	359

Table B-16. 1994 DECORANA Ordination by Species Presence/Absence Data.

NECA1	370	-157	82	216
OEBI1	394	198	184	212
OEBR1	6	86	334	-6
OECO1	-104	155	-43	221
ONMO1	286	-20	-86	227
OPFR1	157	-47	88	-63
OPHU1	74	-18	154	-31
ORFA1	-38	19	-41	169
OXDI1	380	-236	270	392
OXLA1	-79	70	133	102
PAJA1	-79	-41	6	-10
PAVI1	309	213	-48	295
PEAN1	-87	60	-107	207
PESE1	-45	177	164	-20
PESI1	-61	173	51	182
PEVI1	-70	11	-82	81
PHHE1	-51	117	206	-31
PHPR1	325	271	-217	-147
PHVI2	248	-38	-196	192
PIOP1	-31	103	228	-71
PLLA1	393	-101	-302	-251
PLMA1	226	53	811	-145
PLPA1	0	166	364	-4
POAC1	361	276	-430	-377
POCA1	-11	-12	556	16
POCO1	192	176	108	21
PODE1	373	228	-91	-193
POFI1	-86	-57	-187	213
POGR1	-93	-25	230	-207
POHI1	267	-160	46	202
POLA1	431	306	194	332
POPR1	219	103	40	12
POSA1	43	221	278	-17
PRVI1	392	-157	-11	191
PRVU1	370	-133	126	-267
PSTE1	3	7	61	145
QULO1	164	-169	830	-61
RACO1	10	90	-86	166
RHAR1	283	-127	-20	-216
RIOD1	391	-207	-82	-218
ROAR1	277	209	40	156
ROWO1	392	-56	3	-75
RUCR1	372	254	-3	-15
RUME1	376	380	-4	-147
RUOB1	397	-273	56	211
SAAM1	377	-124	-74	-95
SAEX1	390	-117	-100	-218
SALU1	360	-216	171	-144
SCAM1	430	407	320	-223
SCBR1	11	12	-150	90
SCLA1	13	80	164	54
SCLA2	400	-154	343	-141
SCPA1	397	170	-20	-139
SCVA1	444	350	264	207
SEDE1	378	-192	307	241
SEIN1	41	47	-132	161

Table B-16. 1994 DECORANA Ordination by Species Presence/Absence Data.

SEPL1	-4	-31	-76	21
SESP1	-11	106	-103	192
SETR1	176	217	-278	217
SIAL1	77	172	160	155
SIAN1	-40	-41	-25	-25
SIDR1	-88	-12	63	22
SIHY1	-22	3	148	-31
SIMO1	271	-65	-197	83
SOMI1	275	98	-78	28
SOMO1	248	-42	-58	207
SONE1	-102	61	-70	209
SONU1	-96	-20	-39	84
SORI1	-45	206	-209	205
SPCO1	0	111	25	69
SPCR1	264	389	-100	211
SPHE1	-76	-44	-47	-59
SPOB1	356	-174	436	533
SPPE1	356	-174	436	533
STCO1	-62	33	96	11
STNE1	-57	108	653	-6
STPA2	401	-248	185	283
STRO1	369	-62	-158	-450
STVI1	30	-13	-77	202
SYOC1	382	-67	24	188
TAOF1	240	-25	266	-24
TAPA1	-96	-61	-4	-68
THAR1	311	51	89	228
THME1	238	364	424	-75
THRH1	392	-79	1	-248
TOGR1	-57	108	653	-6
TOHO1	-106	-86	-50	46
TORY1	397	-187	-166	-287
TRAE1	-19	-41	-71	-14
TRDU1	103	128	149	-16
TRI1	-45	216	10	-44
TRI2	-32	126	-126	130
TROC1	14	175	165	4
TYLA1	352	-14	145	213
VEAM1	402	-52	76	237
VEAN1	380	-97	-31	-199
VEBL1	273	-77	80	172
VEBR1	295	550	140	-25
VEHA1	389	-216	116	-159
VETH1	266	-76	156	99
VIAM1	185	9	-73	107
VINE1	397	-176	22	249
VINU1	-71	24	166	23
YUGL1	4	176	173	105

Table B-17. 1994 Reciprocal Averaging Ordination by Species Presence/Absence Data.

SPECCODE	AXIS 1	AXIS 2	AXIS 3	AXIS 4
AC MI1	75	-53	-26	42
AG CA1	358	-61	26	261
AG CR1	-24	586	180	-76
AG IN1	-27	538	160	-63
AG RE1	318	-1	-111	351
AG SM1	70	-18	-113	-25
AG ST1	369	-44	-15	127
AL MI1	-29	121	26	-28
AL TE1	-134	-81	31	15
AM FR1	317	-11	-90	240
AM PS1	-17	-56	4	37
AN GE1	-135	-88	47	26
AN MI1	-152	-141	320	133
AN OC1	-141	-84	-92	-28
AN SC1	-140	-96	90	44
AP CA1	392	-49	-112	555
AR CA1	-63	354	250	10
AR DR1	-27	122	-117	-13
AR FE1	-125	-34	-50	-15
AR FE2	-152	-141	316	133
AR FE3	-83	-46	-241	-96
AR FR1	-87	-39	-4	14
AR FU1	11	-28	-174	-44
AR GL1	-100	-55	-147	-49
AR LO1	-105	87	84	14
AR LU1	-54	-58	-53	17
AS AG1	-67	-72	-60	-49
AS CR1	-123	-16	67	34
AS DR1	-118	-35	-292	-116
AS ER1	58	60	-41	0
AS FL1	-114	97	-24	-42
AS IN1	366	-89	49	-217
AS MI1	-147	-166	427	168
AS OC1	411	-146	301	-746
AS OF1	398	-93	75	43
AS PA1	-35	615	107	-82
AS PO1	-89	10	79	77
AS PU1	-84	201	-41	-55
AS SE1	-110	-40	-133	-47
AS SH1	-138	-89	5	17
AS SP1	355	-59	23	-34
AS VI1	49	4	268	-17
BA OR1	396	-73	14	82
BO CU1	-132	-82	17	11
BO GR1	-104	-66	-35	-11
BO HI1	-126	-70	-32	-9
BR IN1	29	425	94	34
BR JA1	5	77	-19	-7
BR TE1	-112	-58	-157	-49
BU DA1	-122	-62	-41	-11
CA CH1	405	-122	2	-183
CA EL1	-110	-61	2	21
CA FI1	-124	-72	-163	-63
CA HE1	-135	-91	52	28
CA IN1	-126	-57	-231	-94

Table B-17. 1994 Reciprocal Averaging Ordination by Species Presence/Absence Data.

CA LA1	278	5	-56	-2
CA MI1	-69	81	-24	-21
CA NE1	390	-77	13	57
CA NU1	65	10	-106	-58
CA OR1	-144	-77	45	42
CA PR1	346	-113	133	-611
CA RO2	346	-113	133	-611
CA SE2	-153	-144	323	136
CA SE3	-153	-160	394	149
CA SI1	475	-179	469	-880
CA ST1	284	-35	-85	3
CE AR1	346	-113	133	-611
CE DI1	-24	-86	127	-5
CH FU1	-57	-31	233	-22
CH LE2	-123	-44	-199	-70
CH VI1	-71	125	79	-13
CI AR1	129	177	9	21
CI IN1	55	324	-3	-74
CI MA1	386	-121	198	-428
CI UN1	-123	-58	-104	-33
CO AR1	8	414	102	-62
CO CA1	366	-50	-9	-44
CO LI1	-129	-52	-157	-46
CO MA1	402	62	-63	484
CO MI1	-104	-36	-170	-71
CO UM1	-78	-96	115	1
CR ER1	343	-99	86	-338
CR OC1	-83	-46	-241	-96
CY OF1	383	-55	-4	104
DA CA1	-78	246	-27	-32
DA GL1	343	12	-203	670
DA PU1	-140	-97	77	39
DE NU1	135	45	-149	60
DE PI1	-58	23	-69	-63
DE RI1	-105	-42	-248	-92
DE SO1	-141	-84	-92	-28
DR NE1	161	-183	480	-375
DR RE1	-141	-99	90	41
EC VI1	-136	-85	22	17
EL CA1	322	16	-72	330
EL MA1	484	-60	-229	934
EL PA1	364	-28	-6	78
EP CI1	400	-122	144	-328
EP PA1	284	32	-109	433
EQ AR1	389	-78	-46	217
EQ HY1	372	-116	112	-262
EQ LA1	370	-87	23	-4
ER AL1	-142	-103	123	55
ER AS1	-124	-46	-28	-15
ER CI1	-46	-13	-197	-106
ER DI1	-53	-9	-81	-86
ER FL1	-94	-25	-30	-34
ER RE1	-90	-7	-322	-143
EU DE1	-127	-67	-220	-33
EU RO1	-134	-67	39	24
EU SE1	135	45	-149	60

Table B-17. 1994 Reciprocal Averaging Ordination by Species Presence/Absence Data.

EU SP1	-107	-17	-259	-99
EV NU1	-119	-28	-149	-58
FE PR1	358	31	-165	607
GA AR1	-152	-141	316	133
GA BO1	349	-79	48	-132
GA CO1	-118	-45	-155	-58
GA PA1	293	72	-120	310
GE CA1	368	-96	41	-150
GE MA1	391	-121	142	-375
GL LE1	360	-44	-24	120
GR SQ1	16	99	-113	-15
GU SA1	-78	155	-60	-28
HE AN1	-125	-52	-144	-46
HE PE1	-157	-153	325	141
HE PU1	-124	-56	-59	-26
HO JU1	189	73	-165	386
HY PE1	2	-58	15	-34
HY VE1	-104	0	-192	-93
IP SP1	-150	-163	416	149
JU BA1	369	-44	-15	127
JU DU1	347	-70	-17	17
JU TO1	353	-25	117	-178
KO PY1	-110	-83	29	7
KU CH1	-29	599	181	-36
KU EU1	-68	275	-24	-59
LA EU1	309	29	0	-62
LA OB1	475	-179	469	-880
LA RE1	-120	-47	-232	-84
LA SE1	23	0	-88	31
LE DE1	-83	6	-476	-145
LE MI1	411	-146	301	-746
LE MO1	-141	-101	88	46
LE MO2	-140	-82	-22	6
LI CU1	135	45	-149	60
LI DA1	-88	24	-104	-14
LI IN1	-135	-66	-151	-40
LI PE1	-69	-35	-168	-101
LI PU1	-121	-18	35	13
LO OR1	-49	-68	-35	1
LU AR1	346	-113	133	-611
LY AM1	438	-126	124	-173
ME AL1	115	414	33	292
ME AR1	338	-34	13	9
ME LA1	-66	-111	215	116
ME LU1	95	352	79	88
ME OF1	42	481	118	89
ME SA1	-10	656	256	-103
MI CU1	-112	-59	-35	1
MI GR1	-77	0	-434	-158
MI LI1	-129	-76	4	5
MO FI1	365	-97	82	-185
MU DI1	-99	0	-239	-106
MU MO1	-145	-128	270	111
MU RA1	444	-83	-187	663
MU WR1	-127	-45	-126	-23
NA OF1	424	-147	291	-571

Table B-17. 1994 Reciprocal Averaging Ordination by Species Presence/Absence Data.

NE CA1	350	-85	69	-199
OE BI1	382	-58	32	-21
OE BR1	-106	-28	-317	-133
OE CO1	-158	-131	220	134
ON MO1	197	-37	-42	-74
OP FR1	-3	-59	-132	-90
OP HU1	-59	28	0	-13
OR FA1	-126	-49	54	32
OX DI1	378	-120	205	-544
OX LA1	-146	-105	105	56
PA JA1	-145	-123	244	94
PA VI1	224	8	-130	97
PE AN1	-149	-106	169	97
PE SE1	-129	-60	-164	-48
PE SI1	-139	-63	-77	-16
PE VI1	-141	-103	128	70
PH HE1	-133	-79	-58	-6
PH PR1	272	48	-190	538
PH VI2	57	296	10	4
PI OP1	-126	-57	-231	-94
PL LA1	386	-77	-5	148
PL MA1	4	617	240	-141
PL PA1	-108	-32	-306	-117
PO AC1	334	-28	-135	471
PO CA1	-110	-66	-158	-56
PO CO1	13	-32	-13	37
PO DE1	347	-24	-68	297
PO FI1	-148	-116	252	107
PO GR1	-155	-145	282	132
PO HI1	145	-137	260	-139
PO LA1	439	-58	203	-198
PO PR1	29	22	-2	20
PO SA1	-83	6	-476	-145
PR VI1	393	-105	103	-186
PR VU1	358	-84	14	-21
PS TE1	-100	-49	-25	-26
QU LO1	-25	602	143	-208
RA CO1	-99	-19	-80	1
RH AR1	194	-114	188	55
RI OD1	389	-101	87	-58
RO AR1	161	-28	-166	101
RO WO1	381	-81	-25	109
RU CR1	341	-18	-81	227
RU ME1	351	14	-14	242
RU OB1	399	-122	180	-364
SA AM1	355	-54	-36	138
SA EX1	380	-86	-6	90
SA LU1	342	-92	63	-202
SC AM1	430	-40	-96	411
SC BR1	-102	-17	-203	-78
SC LA1	-99	4	-19	-14
SC LA2	405	-122	2	-183
SC PA1	388	-66	-22	180
SC VA1	454	-59	58	179
SE DE1	374	-117	82	-352
SE IN1	-89	122	-33	-50

Table B-17. 1994 Reciprocal Averaging Ordination by Species Presence/Absence Data.

SE PL1	-104	-58	115	28
SE SP1	-114	54	38	3
SE TR1	-29	564	175	-29
SI AL1	-55	-36	-146	-58
SI AN1	-126	-86	74	17
SI DR1	-148	-128	207	90
SI HY1	-110	-106	114	66
SI MO1	135	45	-149	60
SO MI1	153	20	30	26
SO MO1	85	-53	70	96
SO NE1	-157	-123	230	121
SO NU1	-154	-134	284	131
SO RI1	-129	-39	-109	0
SP CO1	-107	-28	-208	-80
SP CR1	117	86	-162	364
SP HE1	-144	-125	242	105
SP OB1	346	-113	133	-611
SP PE1	346	-113	133	-611
ST CO1	-137	-94	43	26
ST NE1	-139	-79	-169	-69
ST PA2	407	-131	168	-422
ST RO1	358	-61	26	261
ST VI1	-82	-57	-53	-81
SY OC1	364	-72	33	-59
TA OF1	55	54	-38	-8
TA PA1	-152	-163	407	149
TH AR1	244	-38	-29	-108
TH ME1	52	-27	-105	140
TH RH1	386	-83	-12	129
TO GR1	-139	-79	-169	-69
TO HO1	-152	-187	490	128
TO RY1	398	-93	75	43
TR AE1	-111	-81	118	28
TR DU1	-44	114	10	-3
TR I1	-127	-67	-220	-33
TR I2	-125	-29	-216	-98
TR OC1	-100	-14	-350	-129
TY LA1	316	-70	66	-190
VE AM1	404	-83	137	-184
VE AN1	370	-88	-6	8
VE BL1	150	-41	-69	-69
VE BR1	197	80	-223	275
VE HA1	385	-106	46	-166
VE TH1	130	-61	-71	-94
VI AM1	-1	200	-62	-32
VI NE1	400	-113	118	-275
VI NU1	-141	-106	89	46
YU GL1	-107	85	-79	-51

Table B-18. 1993 and 1994 Biomass Comparisons by Community and EcMP Site.

Site	93CYP	94CYP	93Litter	94Litter
Xeric Community	124.16	128.59	115.77	262.92
TR01	98.43	102.46	88.69	179.01
TR06	156.93	157.70	130.69	342.80
TR12	117.12	125.62	127.94	266.96
Mesic Community	117.87	120.12	157.05	225.00
TR02	99.76	101.12	114.03	207.10
TR04	115.64	113.17	153.55	148.51
TR11	136.71	146.06	203.58	319.38
Reclaimed Community	113.62	145.77	150.48	227.45
TR07	110.77	139.46	115.81	212.37
TR08	99.20	120.13	125.92	195.62
TR09	130.90	177.71	209.70	274.37

Community values based on n=75.
Site values based on n=25.
All values given in g/m^2.

APPENDIX C: SMALL MAMMALS

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MICHELLE FINK

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TRAPPING SUMMARY

BACKGROUND

Small mammals are a valuable component of ecological investigations and contaminant pathways analyses because they are numerous and easily captured, they occupy small home ranges and so reflect habitat quality or contamination on a small scale, and they live in close contact with surface soils and thus are maximally exposed to surficial contaminants. Small mammal species at the Site consume a variety of food including leafy tissue, seeds, and invertebrates. Additionally, they are a primary prey species for many predators including raptors and coyotes and could be responsible for the spread of bioaccumulated contaminants through the food chain.

The 1994 trapping season was the second full season of data collection at 12 permanent sites. Comparisons across seasons and years are now possible.

OBJECTIVES

The primary objective of this study module is to assess the dynamics of small mammal populations at the Site and the relationship of these populations to specific habitat characteristics. This objective will be accomplished by collecting data for common and rare species of small mammals in order to gain an understanding of their population characteristics and movement patterns at the Site. Data on biotic, abiotic, and habitat preference variables were collected to assess their influence on these populations. There is also an interest in the extent to which anthropogenic disturbance, if any, of preferred habitat affects long-term health and success of these populations. As the relationships between habitat and populations become better defined, information will be available to managers who are interested in project impacts to natural environments, and this information will become the basis of mitigation strategies.

HYPOTHESES

All of the hypotheses discussed below were listed in the EcMP Program Plan (EcMP 1993).

1) H_0: Populations of small mammals do not vary significantly year-to-year, on a seasonally adjusted basis, within a given study site.
   H_A: Populations of small mammals vary significantly year-to-year, on a seasonally adjusted basis, within a given study site.

Because only 2 years of data have been collected, long-term trends cannot be projected. However, some preliminary comparisons can be made.

2) H_0: Recruitment levels do not vary significantly from year-to-year, on a seasonally adjusted basis, within a given study site.
   H_A: Recruitment levels vary significantly from year-to-year, on a seasonally adjusted basis, within a given study site.

As in Hypothesis 1, it would be difficult to project trends with only 2 years of data, but some preliminary comparisons can be made.

3) H_0: Small mammal populations do not correlate with proximity to water sources.
   H_A: Small mammal populations correlate with proximity to water sources.

Maps of all EcMP sites and transects (Terrestrial Vegetation and Small Mammal) are being updated. The Global Positioning System (GPS) used for mapping the EcMP sites uses more current technology than the system used to map the Site. As a result, they are not always compatible and accurate distances from trap sites to water sources cannot be determined via GIS methods. However, the Site has been re-mapped and the data are being verified. When these digitized data are received and the maps updated, this hypothesis may be tested.

4) H_0: Small mammal populations do not correlate with proximity to human activities.
H_A: Small mammal populations correlate with proximity to human activities.
Testing this hypothesis is dependent upon the maps discussed in Hypothesis 3.

METHODS

Field Methods

The Spring sampling session occurred from April 19, 1994 to May 5, 1994 and the Fall sampling occurred from October 4, 1994 to October 20, 1994. Both sampling sessions followed the procedures presented in the EcMP Program Management/Technical Performance Report, 1993, Appendix 16 and occurred on all twelve permanent terrestrial sites using Longworth live traps so that all 1994 data are comparable to the Fall 1993 data. The Spring 1993 data were collected from nine of the twelve sites using Sherman live traps which do not capture as many species or as many individuals as the Longworth traps (EcMP 1994).

The same methods were used and the same information was collected from each capture during the 1994 and 1993 sampling sessions. This allows for direct comparisons between seasons and years. Each capture was identified to species (where possible), weighed, sexed, aged, marked, and measured for tail, ear, foot, and total body length. Reproductive condition was also noted. Any noteworthy comments, such as traps that were closed but empty and the dye color used that day, were recorded on the datasheet.

Field identifications of small mammals were made using Hall (1981) as the primary source. Secondary identification sources are Armstrong (1972) and Leichleitner (1969). The authority for nomenclature was Jones, et. al. (1992).

Analytical Methods

Recaptures were not included in any analyses conducted to estimate population sizes and recruitment levels. Some individuals were also found to be "trap happy;" sometimes the same individual would be trapped repeatedly in the same area. Occasionally animals would escape before they could be processed in the field. Animals that were not processed were noted and each field in the database for that record was flagged with "ND," "U," or "999" to designate missing data values, depending on the field type and width. These animals were not included in calculations of sex and age ratios.

Populations were inferred from trap-night success or the number of captures per 100 trap-nights. A trap-night is one trap set out for one night so 100 traps set out for three consecutive nights would result in 300 trap-nights. Calculation the number of captures per 100 trap-nights is done for convenience because the number resulting from the calculation can be directly converted to percent success. If there are 13.5 Deer Mice per 100 captures at a particular site, this is equal to 13.5% of the traps contained a Deer Mouse at that site.

DATABASE STATUS

A total of 718 records were entered into the EcMP database for the Spring trapping session and a total of 1097 records were entered into the EcMP database for the Fall trapping session. All records have been verified and edited according to EcMP data management procedures.

RESULTS AND DISCUSSION

Throughout this Appendix, common names of all small mammal species will be capitalized for emphasis. This practice does not necessarily follow any particular convention.

Spring 1994

Populations and Distributions

A total of 423 individuals (excluding recaptures) of nine species were captured in the course of the exercise (Tables C-1 to C-5; Figure C-1). Table C-5 shows a breakdown of captures by species and community types. The most individuals and fewest number of species were captured at riparian sites and the most species were captured at xeric grassland sites. The fewest individuals were captured at reclaimed grassland sites. At all sites, except one reclaimed grassland site, the Deer Mouse (*Peromyscus maniculatus*) was the most commonly trapped species (Tables C-1 to C-4) and occupied 8.5% of all traps (Table C-5 and Figure C-1). During the spring trapping session, one new species was documented for the Site, the Plains Pocket Mouse (*Perognathus flavescens*). One individual of this species was trapped once at a xeric grassland site. The other *Perognathus* species captured, *P. flavus* (Silky Pocket Mouse), was also unique to the same xeric grassland site.

The most common species caught was the Deer Mouse which comprised 72% of the total capture. The Deer Mouse was trapped in all community types and at all sites but one reclaimed grassland site. The Meadow Vole (*Microtus pennsylvanicus*) was captured in all community types but the reclaimed grassland and comprised 7.8% of the catch. In previous non-EcMP work at the Site (Baseline and Operable Unit reports), the Deer Mouse comprised 66% of the capture and the Meadow Vole comprised 27% of the capture. At the Rocky Mountain Arsenal, located about 16 km northeast of Denver, the Deer Mouse was the most common species captured during the Spring of 1986 and comprised 57% of the capture (Shell 1989). The Deer Mouse was present in all community types sampled at the Rocky Mountain Arsenal and was the most common in all community types except streamside meadow sites, where the Western Harvest Mouse was the most common species, and cattail/rush sites, where the Meadow Vole was the most common species. A total of seven species were documented during the Shell (1989) study at the Rocky Mountain Arsenal, six of which are common at Rocky Flats. These data are summarized in Table C-6. The Rocky Mountain Arsenal is farther removed from the mountains than Rocky Flats and its flora and fauna show a stronger prairie influence. Its land use history is similar to that of Rocky Flats in that it has been removed from agricultural use for several decades. Use of the Rocky Mountain Arsenal has since changed to the manufacture of chemical and incendiary munitions; production, storage and demilitarization of chemical agents; production of pesticides and herbicides; and, finally, cleanup (Shell 1989).

At Rocky Flats, Thirteen-lined Ground Squirrels (*Spermophilus tridecemlineatus*) comprised 7.1% of the catch and were found only at the grassland sites and most frequently at the mesic grassland sites. Twenty-nine Prairie Vole (*Microtus ochrogaster*) individuals were captured (6.9% of total captures), primarily in riparian and xeric grassland communities. The Western Harvest Mouse (*Reithrodontomys megalotis*) was captured in all community types (2.8% of total captures) and the Plains Harvest Mouse (*R. montanus*) was captured in all grassland community types and comprised 1.9% of the catch. Four Hispid Pocket Mice (*Chaetodipus hispidus*) were captured (0.9% of the catch): two in the xeric grassland community and two in the reclaimed grassland community. As mentioned above, one each of the Plains Pocket Mouse and the Silky Pocket Mouse were captured (0.2%) at the same xeric grassland site. In previous non-EcMP work, the Prairie Vole and the Plains Harvest Mouse each contributed 3% to the catch and the Western Harvest Mouse, the Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*), the Mexican Woodrat (*Neotoma mexicana*) and the Thirteen-lined Ground Squirrel each contributed less than 1% to the catch.

Habitat Preferences

Total small mammal populations, as inferred from trap-night success, were lowest at reclaimed grassland sites (4%) and highest at riparian sites (15%). However, riparian, mesic grassland (14%) and xeric grassland (13%) community population numbers were all very similar (Table C-5). Trap-night success for deer mice was highest in riparian and mesic grassland communities at 11% and lowest at reclaimed sites at 3%. Xeric grassland community trap success for the Deer Mouse was 10%. Overall, trap success was 12% (423 individuals in 3600 trap-nights). These percentages are higher than the Spring capture percentages from 1993. The primary difference is in the type of trap used. Longworth live traps have been used by EcMP staff since Fall 1993 and have demonstrated the ability to capture not only more individuals but more species than the Sherman traps. This finding was documented in the 1994 EcMP Annual Report.

At the Rocky Mountain Arsenal (Shell 1989), the highest trap-night success was reported at the weedy forb sites where the Deer Mouse was the only species captured. Communities dominated by shrubs (sand sagebrush and rubber rabbitbrush) and yuccas, which most closely resemble the EcMP xeric community, had the greatest number of species captured (seven). Cattail/rush sites also had high small mammal populations and were dominated by the Meadow Vole. Four species of small mammals were captured at these sites (Table C-6).

Age and Sex Distributions

Age and sex distribution data for the Deer Mouse are presented in Tables C-7 to C-11. Figures C-2 and C-3 present the ratios calculated from those data for all communities. The Deer Mouse was the only species captured in sufficient numbers to compare age and sex distribution across community types, seasons, and years. However, these data are available for some additional species in some community types.

Sex ratios are expressed in number of males per 100 females. The ratio was highest in the reclaimed grassland community at 150 males per 100 females and lowest in the xeric grassland community at 102.5 males per 100 females. For all communities combined, there were 109 males per 100 females.

Age ratios are expressed in terms of number of young per 100 females. The ratio ranged from 0 in mesic grassland and riparian communities to 37.5 in reclaimed grassland communities. For all communities combined, there were 4.35 young per 100 females.

Fall 1994

Populations and Distributions

A total of 661 individuals (excluding recaptures) of 11 species were captured during the fall trapping exercise (Tables C-12 to C-16; Figure C-4). As in the spring trapping session, the most individuals were captured in the riparian community complex and the fewest individuals were captured in the reclaimed community. The fewest number of species (5) were captured in the riparian community complex and the reclaimed grassland community. The most number of species were captured in the xeric grassland community.

One new species was documented for the Site: the House Mouse (*Mus musculus*). The individual was captured at the reclaimed grassland site TR08. It is suspected that this species also occurs near buildings on plantsite, although to date, only the Deer Mouse has been documented in those areas.

The Deer Mouse was the most commonly captured species in all community types and at all sites except one reclaimed grassland site, TR07, (Tables C-12 to C-15) where the Western Harvest Mouse was the most commonly captured species (Table C-14). The Deer Mouse constituted 73% of the individuals (484 of 661) captured and occupied 54% of all traps. The Western Harvest Mouse constituted 8.5% of the overall catch and was common at all community types. The Meadow Vole constituted 7.8% of the overall catch and occurred primarily in riparian complexes (49 of 254) but one capture was also recorded at a mesic site. The Prairie Vole comprised 7.3 % of the catch and was captured in all community types but not all sites. Five Plains Pocket Mice were captured at TR06, a xeric site, and one Western Harvest Mouse was captured at the same site. Site TR06 differs floristically from the other two xeric sites, as well as in its fauna. One Silky Pocket Mouse died in the trap at a mesic site and was kept as a voucher. During the fall of 1993, four Silky Pocket Mice were captured at TR06.

At the Rocky Mountain Arsenal (Shell 1989), as at Rocky Flats, the Deer Mouse was the most common species captured during the Fall of 1986 and comprised 79% of the total capture. It was present in all community types sampled and was the most common species in all community types except native perennial grassland sites where the Northern Grasshopper Mouse was the most common species captured. The Northern Grasshopper Mouse has not been documented at Rocky Flats. Of the other species captured at the Rocky Mountain Arsenal during the Shell (1989) study, all are also common at Rocky Flats except Ord's Kangaroo Rat, which has not been documented (Table C-17).

Habitat Preferences

Total small mammal populations, as inferred from trap-night success, were highest in the riparian community complex (28%), and the mesic grassland community (25%), and lowest in the reclaimed grassland community (5.7%). Success in xeric grasslands was 14%. Success was higher in the Fall than in the Spring as expected but the ranking of success at the sites is the same.

As in the Spring, small mammal populations at the Rocky Mountain Arsenal (Shell 1989) were highest in areas dominated by weedy forbs and these populations were composed almost entirely of the Deer Mouse. Sites dominated by shrubs (sand sagebrush and rubber rabbitbrush) and yucca again showed the greatest species diversity (four species) and the highest small mammal populations next to the weedy forb sites (Table C-17). Like the EcMP studies, the highest diversity was found at the sites dominated by shrubs and yucca.

The Deer Mouse, the most ubiquitous small mammal species on the Site, was most common in the mesic community. In the riparian community complex, the Meadow Vole contributed to the trap success which was highest overall. Trap success for the Deer Mouse was lowest in the reclaimed grassland community (3.1%). At the reclaimed site TR09, located in the southeast corner of the Site, only two Deer Mice were captured for a success rate of 0.7% but constituted 100% of the catch. The highest success rate (24.3%) was at site TR03 (71% of the catch), the Rock Creek riparian site and TR02 (90% of the catch), the Rock Creek mesic site.

Age and Sex Distributions

Age and sex data are shown in Tables C-18 to C-22. Ratios calculated from these data are presented in Figures C-5 and C-6.

As in spring, sex ratios are presented in terms of number of males per 100 females and only the Deer Mouse was captured in sufficient numbers to compare across community types. The number of males per 100 females averaged 97. The highest ratio was found in the reclaimed

grassland communities (320 males per 100 females) and the lowest in mesic grassland communities (93 males per 100 females).

Young per 100 females averaged 56. The highest ratio was found in the reclaimed grassland communities (120 young per 100 females) and the lowest in the xeric grassland community (61 young per 100 females). The data suggest that young are dispersing out of the riparian and xeric areas to the mesic and reclaimed areas.

1993 and 1994 Comparisons

Populations and Distributions

Comparison of means was conducted using one-way ANOVA (α=0.05) and mean separation was conducted using Tukey HSD (Honestly Significant Differences) Intervals, a conservative test, unless otherwise noted. To test Hypothesis 1, the total number of captures of all species (excluding recaptures) for each year were compared (Table C-23; Figure C-7). Additionally, the number of captures for each season (Spring and Fall) of each year were compared. Overall, there was no significant difference in the mean total number of individuals captured in 1993 and the mean total number of individuals captured in 1994. The only significant difference in number of captures (excluding recaptures) occurred between Spring and Fall 1993 (Spring ave. =21.13, Fall ave. =59.25, p=0.03). Using the less conservative LSD (Least Significant Differences) Intervals for mean separation, there were significantly more captures in Fall 1993 and 1994 than in Spring 1993 (p=0.03) but Spring 1994 did not differ significantly in terms of individuals captured than any of the other sampling sessions. These differences may be partially explained by the use of an inferior trap during the Spring 1993 sampling session. Therefore, there is not enough evidence to suggest that populations vary significantly from year to year.

For both seasons of both years, riparian and mesic sites had significantly higher numbers ($p<0.001$) of captures than the reclaimed and xeric sites. There were no significant differences in the number of captures between reclaimed and xeric sites or between riparian and mesic sites. TR03, the Rock Creek riparian site had significantly more ($p<0.001$) individuals captured than all the reclaimed sites (TR07, TR08, TR09) as well as the Woman Creek xeric site TR12. TR09 had significantly fewer individuals than TR02 (the Rock Creek mesic site), TR05 (the Walnut Creek mesic site), and TR03. These data are shown in Table C-24 and Figures C-7 to C-10.

Habitat Preferences

As inferred from trap-night success, habitat preferences were consistent for all trapping sessions. Riparian sites consistently had the highest success rate in terms of the percent of successful traps (23% overall) and reclaimed grassland sites consistently had the lowest percent of successful traps (6% overall). Mesic and xeric grassland sites ranked second and third (17% overall and 11% overall, respectively). Success rates at riparian sites were significantly higher (p=0.0001) than at reclaimed grassland or xeric grassland sites. Success rates at mesic grassland and xeric grassland sites did not differ significantly. Reclaimed grassland sites had significantly (p=0.001) lower success rates than mesic grassland and riparian community complex sites (Table C-24 and Figure C-8). Table C-25 summarizes small mammal captures by species at all communities for both years. Figures C-12 through C-20 summarize captures by species and community for both years and seasons.

Age and Sex Distributions

During both years, the Deer Mouse sex ratio (males per 100 females) was higher in the spring than in the Fall for all communities combined although the difference was small in 1994 (Table C-26; Figures C-21 and C-22). The ratio was higher in the Fall than in the Spring for mesic

grassland community in 1993; reclaimed grassland community in 1994, and; riparian community complex in 1994. The highest Deer Mouse sex ratio was 320 and was found in the reclaimed grassland during the Fall 1994 sampling session. The lowest Deer Mouse sex ratio was 88 and was found in the reclaimed grassland during the Fall 1993 sampling session.

In order to test Hypothesis 2, the number of juvenile Deer Mice per 100 females was compared across seasons and years. As expected, the Deer Mouse age ratio (young per 100 females) was higher in the Fall than in the Spring The one exception was during the 1993 sampling session on the mesic sites. These differences however, were not statistically significant. Recruitment levels did not differ significantly either between seasons or years. Riparian sites consistently have one of the lowest age ratios for all sampling suggesting that juveniles disperse out of these areas into adjacent grasslands. The data are presented in Table C-25 and Figure C-22.

HABITAT CHARACTERIZATION

BACKGROUND

The Small Mammal Habitat Characterization study was conducted to determine if there are any statistically significant differences in vegetation cover, shrub and succulent densities, and species richness between trap stations for which there were captures (successful) during the Small Mammal trapping exercise and those for which there were no captures (unsuccessful).

OBJECTIVES

The primary objective of characterizing small mammal habitats at the Site is to uncover patterns of habitat heterogeneity which may be due to topography, vegetation, or anthropogenic disturbance. This information may be used when restoring habitat disturbed by clean-up activities at the Site.

HYPOTHESES

Some of the hypotheses discussed below are different than those listed in the EcMP Plan.

1) H_0: Vegetation species and trap success are not associated.
   H_A: Vegetation species and trap success are associated.

2) H_0: Canopy species and trap success are not associated.
   H_A: Canopy species and trap success are associated.

3) H_0: Small mammals and plant community type are not associated.
   H_A: Small mammals and plant community type are associated.

4) H_0: Physical characteristics do not differ significantly between successful and unsuccessful trap stations.
   H_A: Physical characteristics differ significantly between successful and unsuccessful trap stations.

5) H_0: Shrub and cactus densities do not differ significantly between successful and unsuccessful traps.
   H_A: Shrub and cactus densities differ significantly between successful and unsuccessful traps.

6) H_0: Vegetation species richness does not differ significantly between successful and unsuccessful traps.
   H_A: Vegetation species richness differs significantly between successful and unsuccessful traps.

METHODS

Field Methods

Ten successful and ten unsuccessful trap stations from each of the 12 sites sampled were chosen for habitat characterization. Because the Deer Mouse (*Peromyscus maniculatus*) was the only small mammal species present in high enough numbers to compare, successful sites were randomly chosen, where possible, from among trapsites where only the Deer Mouse was captured. Unsuccessful sites were randomly chosen from among trapsites which never had a capture over the 3-day trapping period and for which the trap was never closed and empty, where possible. During trapping, the two primary habitat types present in the immediate vicinity of the trap were recorded for every trapsite regardless of success or species captured.

At each of the 20 trapsites chosen as described above, slope angle (degrees) and slope aspect (degrees) were measured. The trapsite's position on the moisture gradient as indicated by the plant species present was recorded. Hydric sites are characterized by the presence of *Juncus* and *Typha* species and are in direct contact with water throughout the year. Humid sites are those that are in wet meadow or ecotonal situations. Mesic sites are characterized by sod-forming grasses and xeric sites are characterized by bunch-forming grasses. Burrowing opportunities, low, medium or high, were estimated for each trap station based on the presence of burrows and on the soil texture. The distance to the edge of the nearest contiguous woodland or shrubland associated with a riparian complex was measured and the predominant species present in the canopy was recorded. Each plant species located within a 3-m radius of the trap station was recorded and the number of cactus individuals and woody stems by species were tallied.

Analytical Methods

Several statistical analyses were conducted on the 1994 habitat characterization data. Three were tests of association, between vegetation species and trap success, between canopy species and trap success, and between mammal species captured and plant community type. Another test compared the physical characteristics of successful versus unsuccessful trapsites. The last analysis looked at possible correlation between these same physical characteristics. Steel and Torrie (1980) was consulted for these statistical methods.

Association tests used a Chi square test on 2x2 contingency tables that express presence or absence of the two features of concern. A corrected Chi square equation is recommended for use on 2x2 contingency tables. However, this corrected equation is highly sensitive to low numbers. Only the tests of association between the vegetation species and trap success produced sufficient numbers to use the corrected equation. For this test, Spring and Fall 1994 were calculated separately and then compared to data from Fall of 1993. The other two association tests used the non-corrected equation. Caution is therefore given during interpretation of the results for canopy species with trap success, and mammal species with community type associations. For these two tests, Spring and Fall 1994 data were combined.

Comparison of the physical characteristics found at successful versus unsuccessful trapsites were done using Student's T-test on sample means. The exact equation used varied according to whether variances and/or sample sizes equalled. The characteristics tested were: distance to the nearest canopy edge, in meters (DCE), slope angle, in degrees (ANG), and slope aspect, in

degrees (ASP). Comparisons were made of successful and unsuccessful trapsites within each sample site, and then within areas classified by soil moisture and burrowing opportunities (see field methods for definitions). No attempt was made to compare **among** sites or soil classifications because of the high degree of inherent heterogony from site to site. Spring and Fall 1994 were compared separately.

The three physical characteristics, DCE, ANG, and ASP, may provide redundant information. To test this hypothesis, Pearson's Correlation Coefficient was calculated on pair-wise combinations of the three characteristics. Data from both Spring and Fall 1994 were combined for this procedure.

Comparisons of shrub and cactus densities found at successful versus unsuccessful sites were conducted using a Student's T-test on sample means. Where the sample sizes were unequal, it was assumed that the variances were equal which determined the equation used for the comparison. The same tests were performed to compare the number of plant species present at successful versus unsuccessful sites.

RESULTS AND DISCUSSION

Association Between Vegetation Species and Trap Success

For Spring 1994, 4 out of 248 (1.6%) plant species demonstrated significant associations with trap success (Table C-27). Two, *Draba reptans* and *Salix exigua*, were associated with successful trapsites (p= 0.05), while the other two, *Artemisia ludoviciana* and *Lactuca serriola* were significantly associated with unsuccessful trapsites (p= 0.05). The Fall 1994 data set produced 9 out of 224 (4%) species with significant associations (Table C-27). *Artemisia frigida, Erigeron flagellaris, Gutierrezia sarothrae, Nepeta cataria,* and *Senecio plattensis* were associated with successful trapsites (p= 0.05). *Convolvulus arvensis, Plantago lanceolata, Sporobolus cryptandrus,* and *Taraxacum officinale* were associated with unsuccessful trapsites (p= 0.05).

For comparison, Fall 1993 data were also tested (Table C-27). Three out of 182 (1.6%) species surfaced; *Sisymbrium altissimum* was significantly associated with successful trapsites (p= 0.05) and *Agrostis hyemalis* and *Monarda fistulosa* were associated with unsuccessful trapsites (p= 0.05).

Because the Deer Mouse has a varied diet and eats insects and other small invertebrates as well as various plant parts (Fitzgerald, et al. 1994), one would not expect to find many positive associations between particular plant species and successful trapsites. The plant species listed in Table C-27 have little in common and the associations appear to be stochastic. One purpose of the EcMP is to define a baseline and to attempt to define ranges of variation. Table C-27 clearly shows that considerable variation in plant species occurs in Deer Mouse habitat and that these mice are successful in a wide range of habitats as already indicated in the section of this appendix which discusses the capture information. These associations may prove more useful in studies of rare species or species with particular habitat affinities.

Association Between Canopy Species and Trap Success

No significant association emerged.

Association Between Mammal Species Captured and Community Types

Due to the low numbers involved, habitat types were pooled into general community types; grassland, shrubland, woodland, wetland, and disturbed. The only significant result found was that *Microtus pennsylvanicus* (Meadow Vole) captures were **negatively** associated with

grasslands ($X^2 = 5.64$, df = 1, $p < 0.025$). In other words, given the great abundance of grassland habitat on the Site, Meadow Voles occurred significantly less in grasslands than would have been expected. These results are consistent with the capture results which show that the Meadow Vole, although the most common small mammal species at the site next to the Deer Mouse, occurred almost exclusively in riparian habitats (Tables C-5 and C-16).

Comparison of Successful versus Unsuccessful Trapsite Physical Characteristics

Four out of the 12 sample sites showed significant differences in physical characteristics. Mean slope angle at successful trapsites (3°)is significantly greater than at unsuccessful sites (2°) located at the reclaimed sites TR08 and TR09 which are located on gently sloping terrain and at TR11 which is on a south-facing slope. However, this small difference probably has little biological significance. Slope aspect is significantly lower at successful trapsites at TR07.

When trapsites were grouped by soil moisture and burrowing opportunity characteristics, only the combination of mesic soil and "medium" burrowing opportunities demonstrated a significant difference (P= 0.05), and then only with slope aspect. Aspect was lower in successful trapsites than in unsuccessful trapsites.

Correlation of Physical Characteristics

For both Spring and Fall, 1994, all three characteristics displayed significant correlations to each other (Table C-28). This would indicate that measuring all three characteristics may be redundant.

Comparison of Shrub and Cactus Density at Successful and Unsuccessful Trap Stations

There were no significant differences between shrub and cactus densities at successful and unsuccessful trap stations for the Deer Mouse.

Comparison of Vegetation Species Richness at Successful and Unsuccessful Trap Stations

There were no significant differences between vegetation species richness at successful and unsuccessful trap stations for the Deer Mouse.

PREBLE'S MEADOW JUMPING MOUSE TRAPPING SUMMARY

BACKGROUND

The Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*) (PMJM) is a state species of concern. A private party (Biodiversity Legal Foundation) has petitioned the U.S. Fish and Wildlife Service to federally list the PMJM as threatened or endangered under the Endangered Species Act. PMJM populations have declined precipitously over the past few decades throughout its range (Compton and Hugie 1993) and Rocky Flats is known to have a viable population. Surveys for PMJM were conducted at the Site in the summers of 1992 and 1993 by a subcontractor. Several captures were recorded and habitat was noted, however, individuals were not marked and there is no way to estimate population size from the data. Captures were made in each of the three major watersheds on plantsite. The subcontractor had identified some of the mice captured in the Rock Creek drainage as *Zapus princeps* (Stoecker 1992 and Stoecker 1993), a larger member of the genus that occurs commonly at higher elevations. The EcMP 1994 work set out to determine if the two species are sympatric and, if they are, the elevation and habitat of sympatry. After fairly extensive trapping of the Rock Creek drainage by EcMP personnel, only *Z. h. preblei*

were found. The subcontractor had collected two specimens during trapping and assigned a specimen to each species. The EcMP mammalogist examined these specimens and determined that one had been misidentified and that both specimens were *Z. h. preblei.* Concurrence was obtained from Dr. David Armstrong, a University of Colorado mammalogist.

OBJECTIVES

As mentioned above, one of the objectives of the 1994 PMJM work was to confirm the capture of *Z. princeps* and the possible sympatry with *Z. h. preblei.* Secondly, the work was designed to confirm the occurrence of PMJM in all drainages at the plantsite and to determine the viability of those populations. Additionally, a sitewide survey of all areas containing known suitable habitat was conducted in order to increase the known range of PMJM at the Site.

HYPOTHESES

1) *Zapus hudsonius preblei* and *Z. princeps* have overlapping ranges.

2) *Z.h. preblei* populations occur on plantsite in the same locations as in previous years.

3) *Z.h. preblei* populations occur on plantsite in locations where they have not been previously captured but which contain suitable habitat.

METHODS

Field Methods

Because the objective of this exercise was to confirm previous captures and species identifications, trapping for the PMJM was conducted only in riparian areas. Future studies may include trapping seeps and hillsides between the riparian areas and the seeps.

Trapping began in the lower Walnut Creek drainage on July 12, 1994, in an area where PMJM had been previously captured. Twenty-five Sherman live traps were placed in each location for three days. Most, but not all, sites were pre-baited for four days using either a sweet horse feed or a mixture of peanuts, oatmeal, and raisins, or a combination of the two baits. The final area to be trapped was in lower Rock Creek and the final trapping day was September 20, 1994.

Each capture was identified to species, aged and sexed. For each PMJM, head and body length, tail length, hind foot length, ear length and weight were recorded. Each individual was marked and the reproductive condition and any unusual characteristics were noted. Each capture was released and no vouchers were collected.

Field identifications were made using Hall (1981). Specimens from the Front Range located at local museums were examined and the range of variation in size and pelage was noted.

The habitat in the vicinity of each capture site was characterized. Endpoints in addition to those measured for the EcMP small mammal habitat characterization were recorded in order to ascertain habitat preferences. Additional variables measured were the distance of the trap station to an embankment, litter cover, the position of the trap relative to the canopy edge (inside, outside, or the edge), and the primary community types in a 3-m radius of the trap station (up to four).

Analytical Methods

Recaptures were not included in any analyses in order to estimate population sizes and recruitment levels, and to eliminate redundancy in morphological characteristics.

DATABASE STATUS

The database contains 34 records of 23 PMJM individuals captured in 1994. An additional 31 records are of captures from 1991, 1992, and 1993. The database is not part of the EcMP database; instead, the data were entered into a QuattroPro file. Future data will be entered into the EcMP database.

RESULTS AND DISCUSSION

Populations and Distributions

The majority of the captures during 1994 were in the Rock Creek drainage (18 out of 23 captures). Surveys were unable to confirm the occurrence of PMJM in Woman Creek but new sites were identified in Walnut Creek. In addition, three captures of two individuals occurred on the Pond A-1 margin and four captures of three individuals were recorded above Pond A-1. Capture locations are shown in Figure C-23. There are fewer capture locations than capture sites.

All captures occurred in or very near riparian habitats. The two individuals captured on the Pond A-1 margin were the first captures recorded for a pond margin habitat type. It is believed that they occupy those areas where grass seed is plentiful late in the season. More intensive trapping of these areas throughout the PMJM active period may be done during 1995.

Habitat Preferences

In an effort to obtain an understanding of the PMJM's habitat needs, environmental and floristic characteristic related to successful trap stations were measured. Environmental characteristics measured included distance to the edge of the nearest canopy cover (Table C-29), distance to nearest embankment (Table C-30), distance to the nearest stream channel (Table C-31), and soil moisture, burrowing opportunities, litter cover, and the position of the trap station in relation to the canopy edge (Table C-32).

Canopy cover was defined in this exercise as a large, continuous patch of tree or shrub cover usually in association with a riparian area. Table C-29 shows that 89% of the sites where a PMJM was captured were within 5 m of canopy cover and that 93% were 10 m or less from canopy cover. There is one outlier on the table that is located on a side drainage 150 m away from canopy cover and this site has a high abundance of species of *Juncus* (rushes) and *Carex* (sedges). *Symphoricarpos occidentalis* (snowberry) and *Amorpha fruticosa* (leadplant) also occur in the vicinity of this site. These four plant species may provide cover or a food source for the PMJM and compensate for the lack of typical riparian canopy species.

This study was designed specifically to capture PMJM so traps were placed in riparian areas where the mouse is most likely to occur. Approximately 36,000 trap-nights in other habitat types onsite (from EcMP sampling) have resulted in no PMJM captures. The distance of the trap station to the edge of the nearest stream channel is shown in Table C-32. Seventy-three percent of successful trap stations were located less than 10 m from a stream channel and none were greater than 35 m away from a stream channel. The results of an analysis of the distance to an embankment are similar (Table C-30): 46 of the 55 successful sites (84%) are located 5 m or less from an embankment and none are greater than 40 m away from an embankment. These

embankments may provide hibernating or nesting sites for PMJM and may be important for its success.

Soil moisture, as indicated by the vegetation present, was humid at the majority of successful trap stations (49%). Humid sites are dominated by marsh or riparian vegetation. PMJM were not captured at xeric sites, which are characterized by the predominance of bunchgrasses, and were rarely captured at hydric sites (sites with standing water throughout most of the year). Burrowing opportunities were estimated using soil texture and the presence or absence of burrows. All successful sites were located in areas where the burrowing opportunities were considered medium or high with the majority (65%) located in areas of high burrowing opportunities. Litter cover may provide nesting sites for PMJM and the ground area it covered was visually estimated. Litter cover was considered low if less than 25%, medium if from 25% to 50% and high if greater than 50%. The position of the traps in relation to the canopy cover is somewhat subjective because the majority of the traps were located along the edge of the canopy as it is very difficult to place them within thick canopy cover. However, 64% of the successful trap stations were located along the edge of the canopy and only 5% were located within the canopy.

At each successful site, the primary plant species of the canopy cover was recorded. At 91% of the sites, either *Salix exigua* or *Amorpha fruticosa* were the primary canopy species (Table C-33). Other species which comprised the majority of the canopy cover were *Prunus virginiana*, *Symphoricarpos occidentalis*, and *Salix amygdaloides*.

As shown in Table C-34, two weedy species, *Cirsium arvense* and *Bromus japonicus*, were the most frequently occurring plant species at all sites. *C. arvense* occurred at 97% of the PMJM sites and *B. japonicus* occurred at 77% of the sites. At a minimum, this information indicates that PMJM are not deterred by the presence of these two weedy plants.

At each PMJM site, the four main community types and the amount of foliar cover for each were recorded. Bottomland shrubland community (*Salix* spp. and *A. fruticosa*) was the primary community type at 68% of the sites with an average of 62% cover. The second most frequently occurring primary community type was mesic mixed grassland (*Agropyron smithii* and *Poa pratensis*) and the third most frequently occurring primary community type was short upland shrubland (*S. occidentalis* and associated). All four community types, their frequencies and their total percent cover are shown in Table C-35.

These data suggest that it is perhaps the juxtaposition of several community types which provide food and cover to the PMJM that is important to the mouse, and not necessarily the occurrence of a single habitat type. The presence of tall plant species which may provide cover for PMJM also appear to be important components of their habitat, as does the presence of soft soil or litter for nest-building. These are all important factors to consider in plans to create suitable habitat for PMJM recovery or for conducting a search for populations either across the plantsite or the state.

Age and Sex Distributions

Only data from 1994 were used to calculate age and sex ratios of the Mouse at the Site. Data from previous years were not used because recapture information was not collected. Because the sample size is rather small, it is imperative to use caution when interpreting these results. All that can be stated with certainty is that PMJM are reproducing and that the population at this time appears viable.

Of the 23 1994 captures, two escaped before they could be processed. These two individuals were adults but sex information was not obtained so they were not included in the calculations of the age and sex ratios. Of the 21 individuals processed, there were 6 juveniles, 12 males and 9 females to yield approximately 133 males per 100 females and 67 young per 100 females. These

ratios are most similar to those for the Deer Mouse in riparian sites during the Fall of 1994 which were approximately 119 males per 100 females and 55 young per 100 females (Table C-21).

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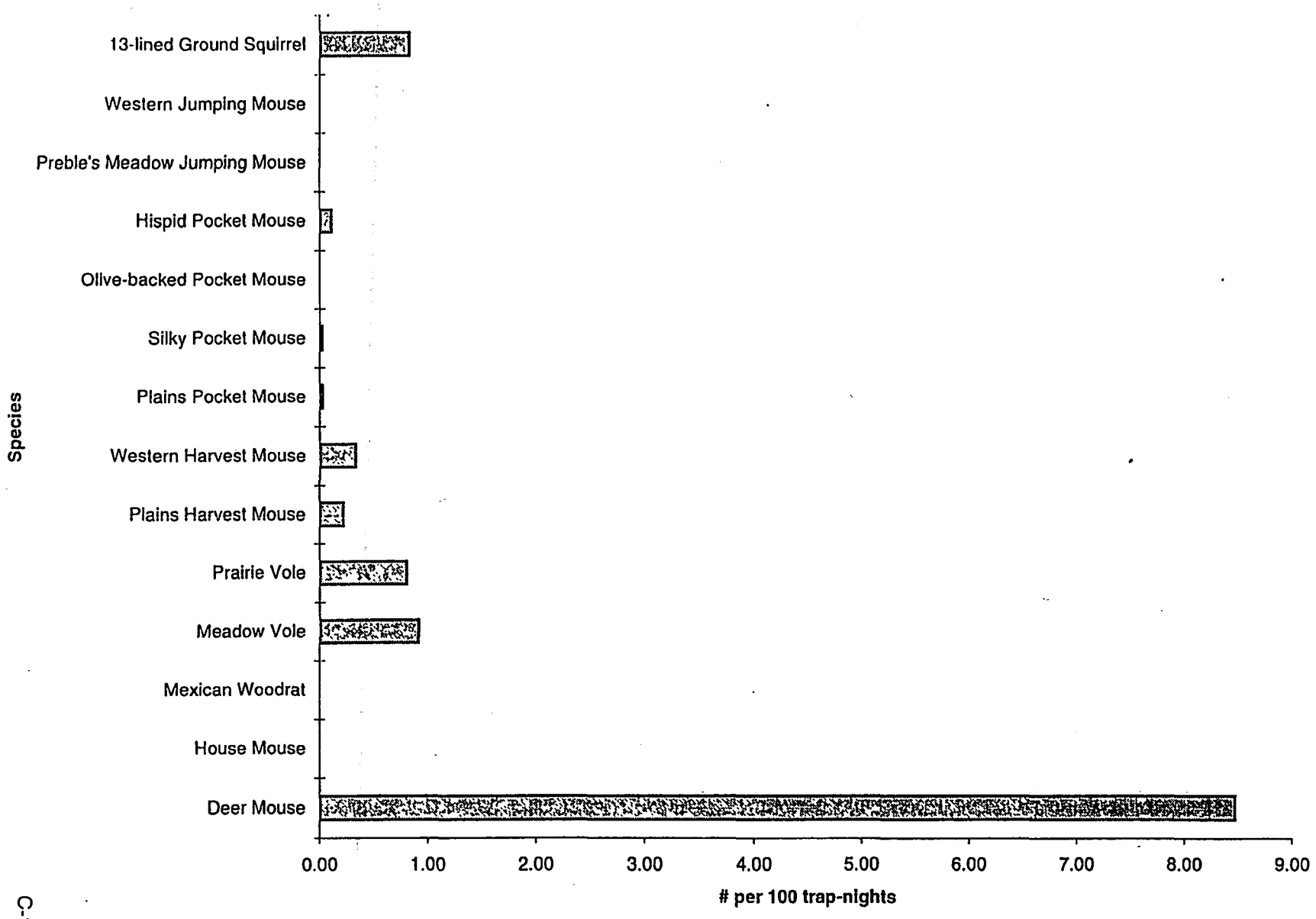


Figure C-1. Spring Capture Summary, All Communities, 1994.

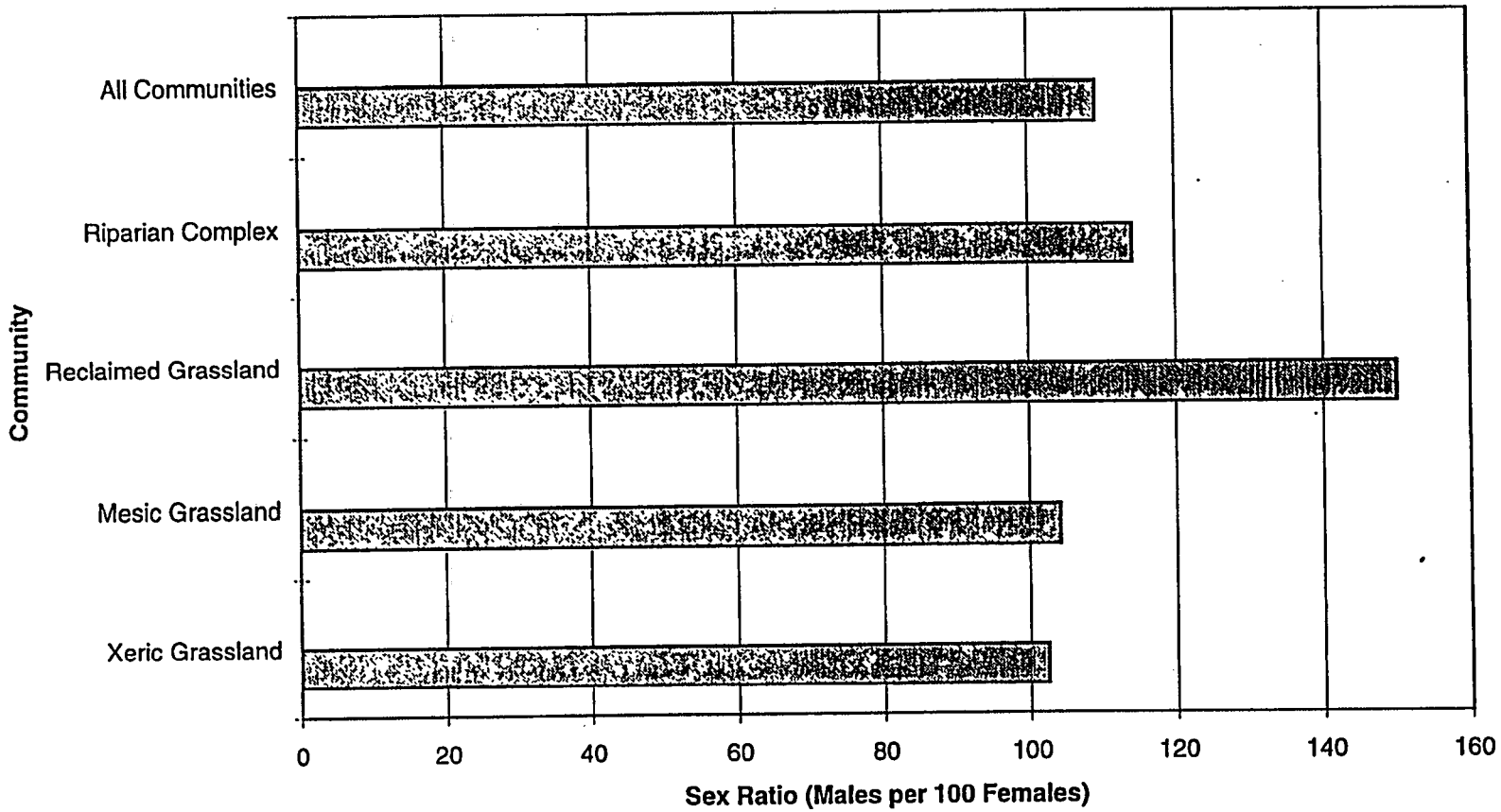


Figure C-2. Deer Mouse Sex Ratio, Spring 1994.

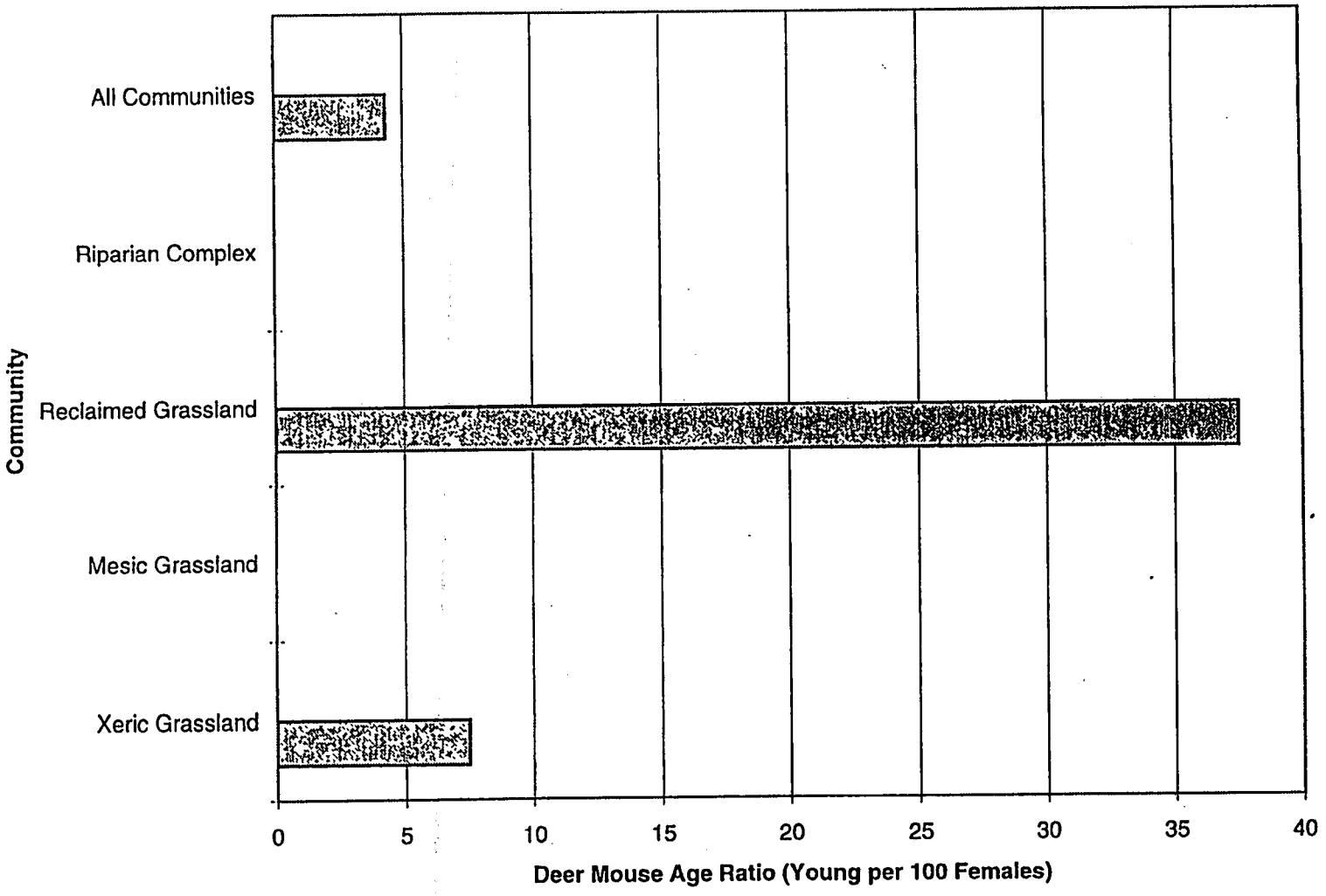


Figure C-3. Deer Mou `ge Ratio, Spring 1994.

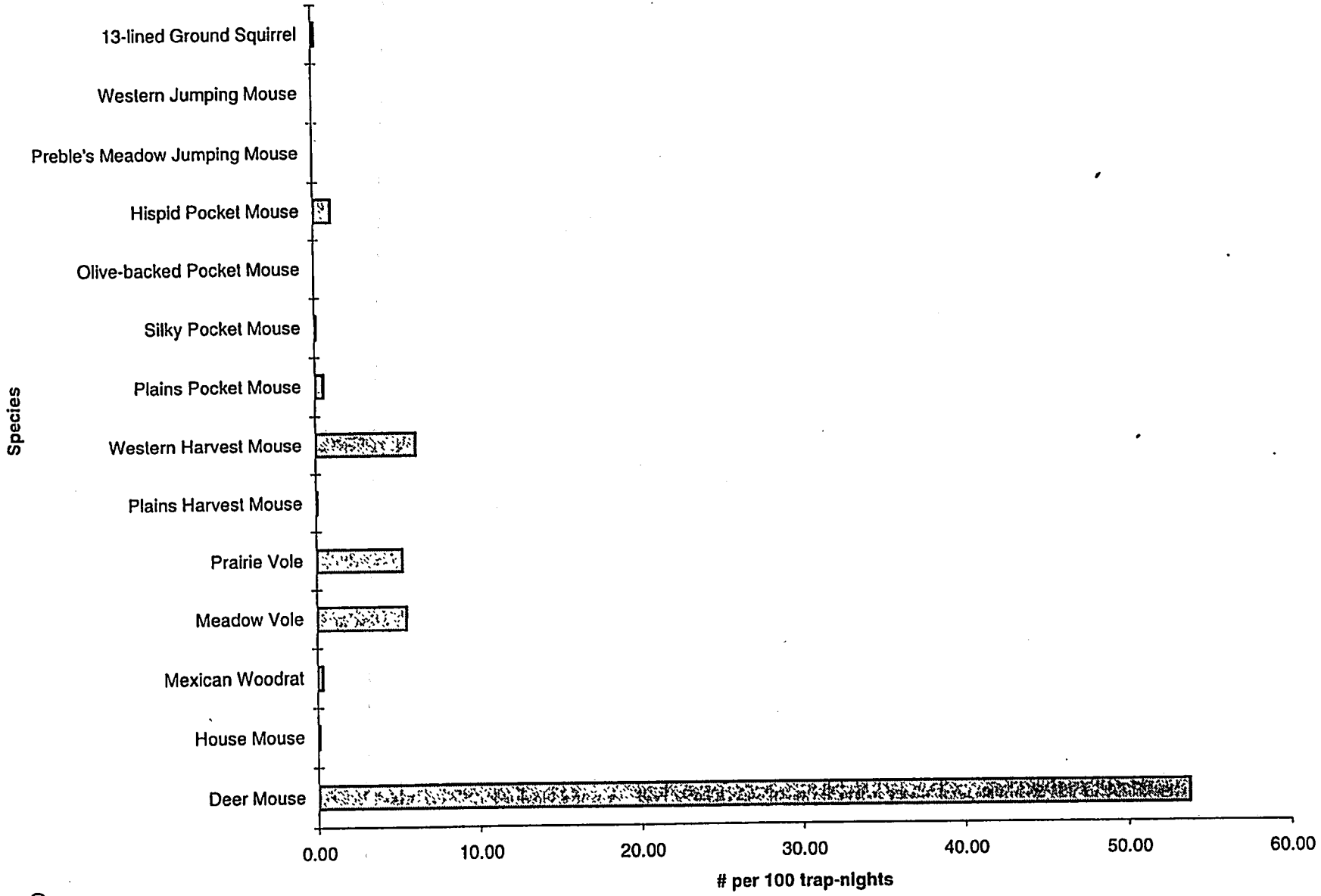


Figure C-4. Fall Capture Summary, All Communities, 1994.

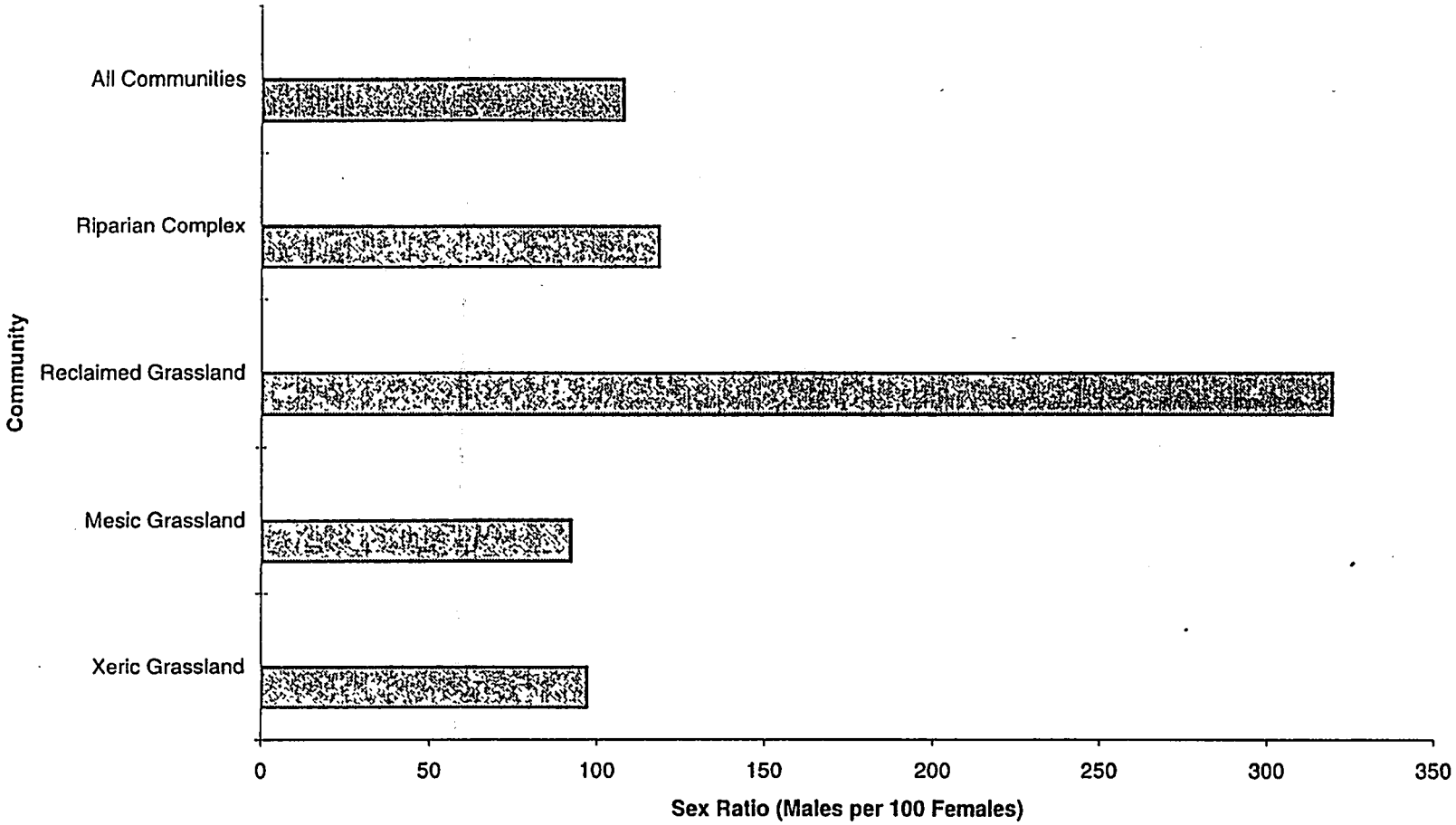


Figure C-5. Deer Mouse Sex Ratio, Fall 1994.

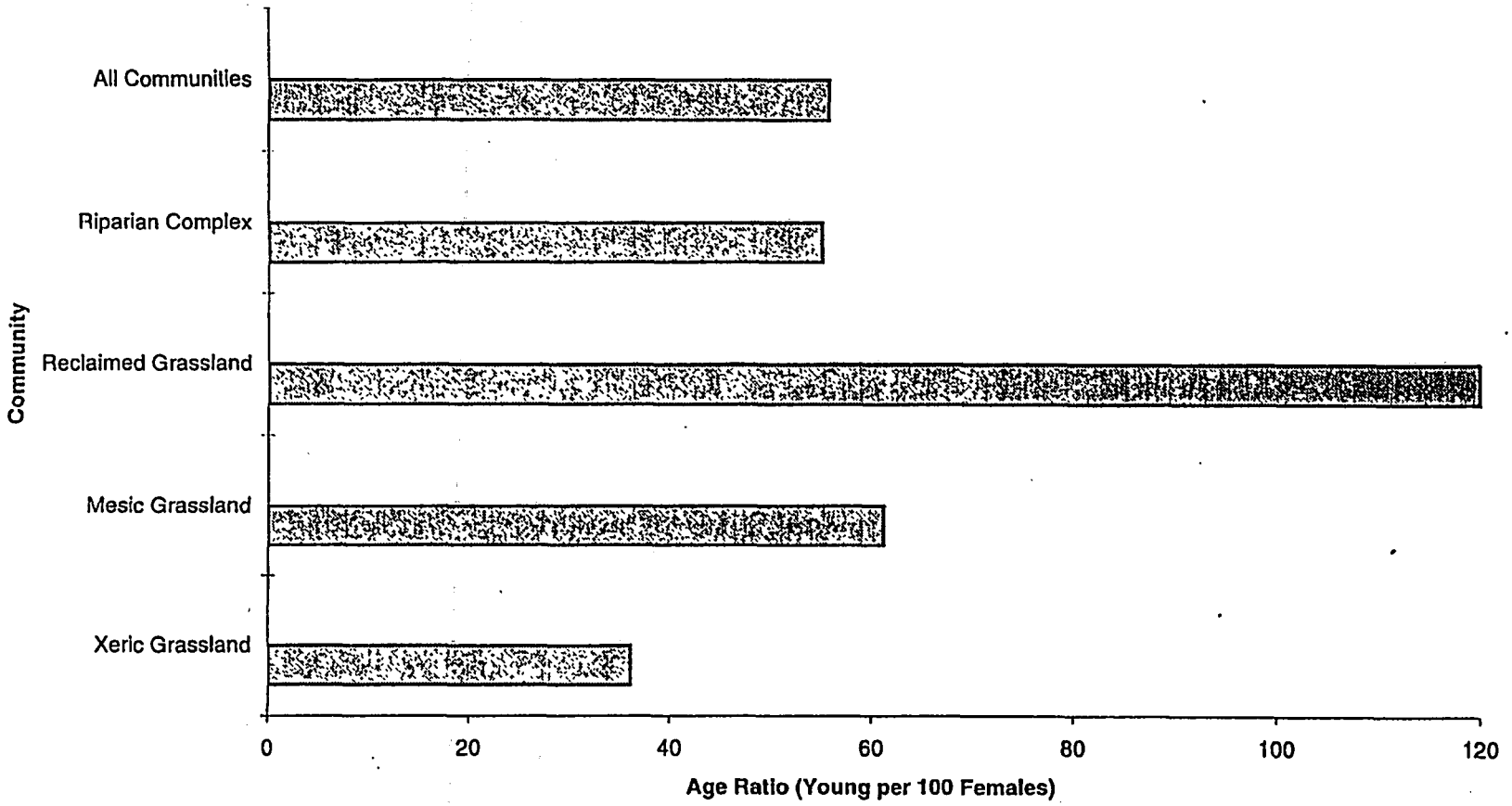


Figure C-6. Deer Mouse Age Ratio, Fall 1994.

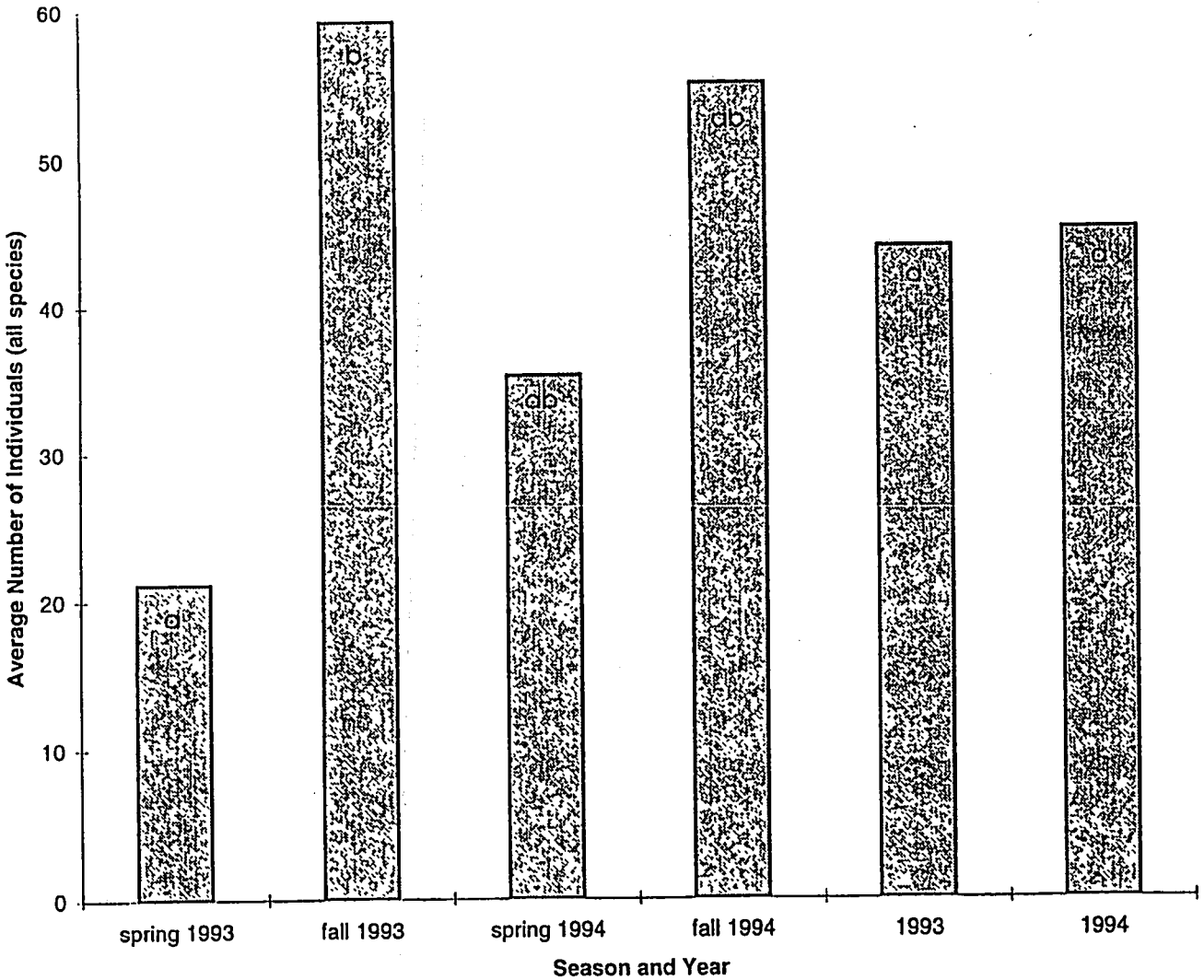


Figure C-7. Average Number of Individuals of All Species per Season and Year. Letters in common indicate no significant difference (α=0.05 and p=0.0

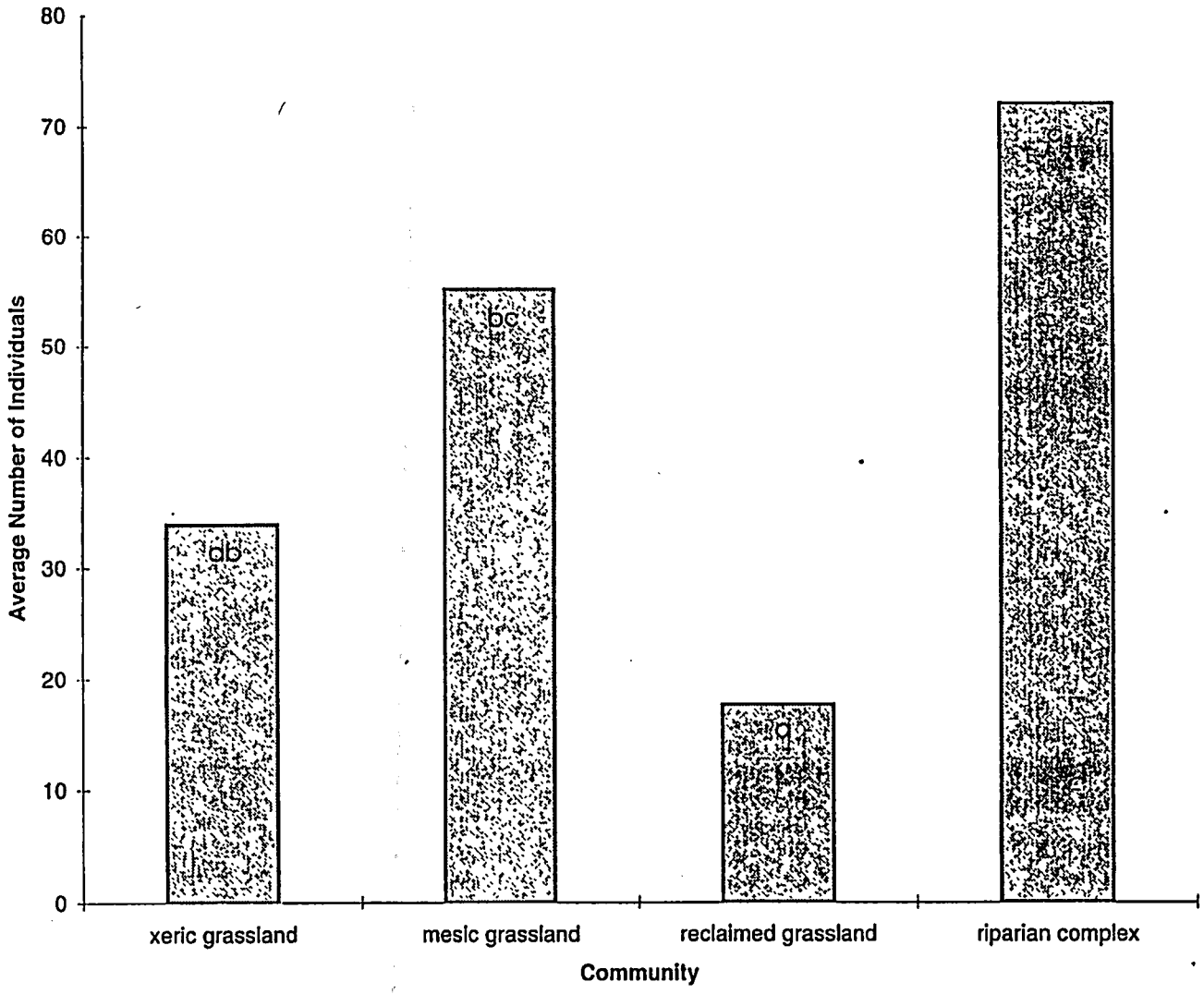
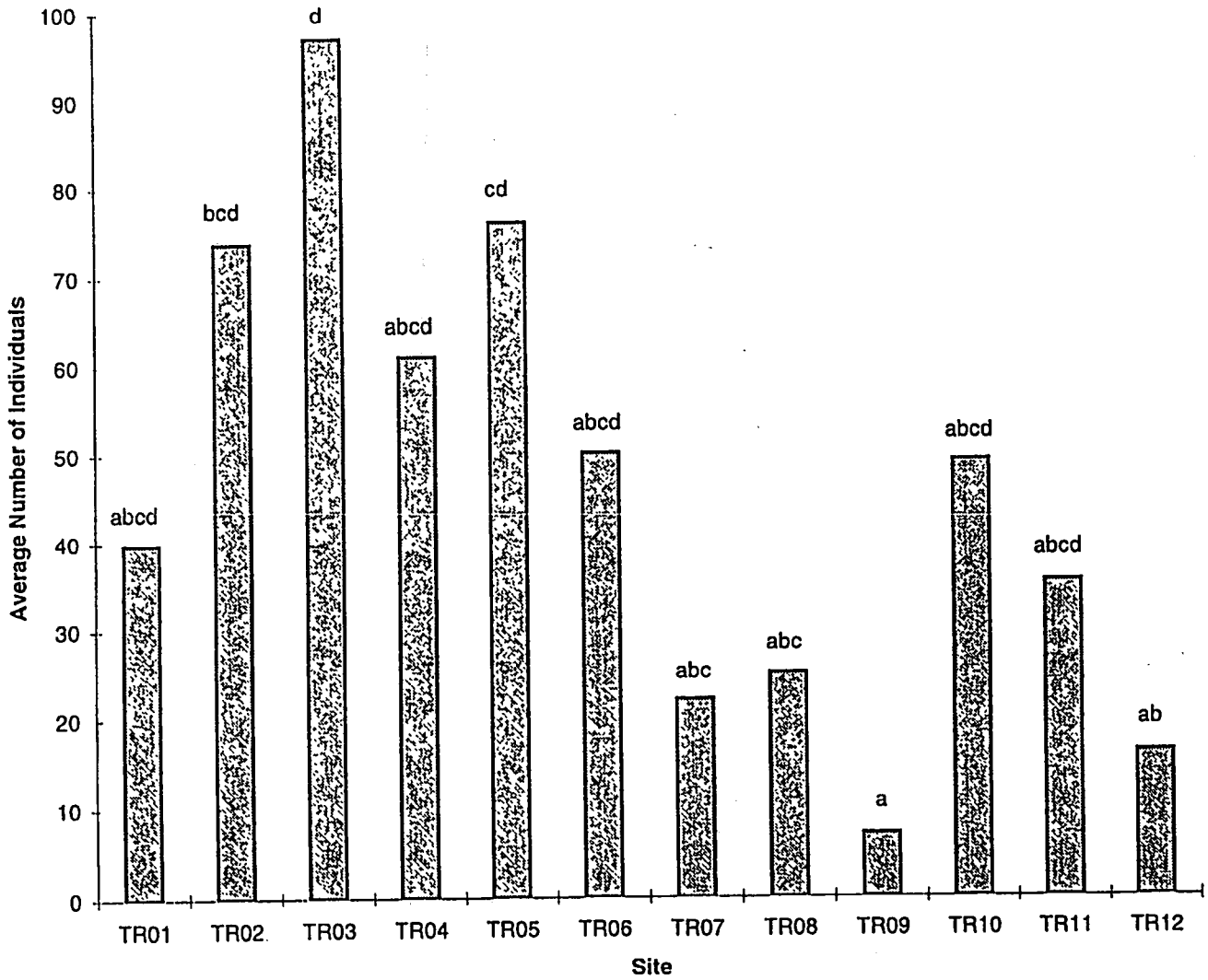


Figure C-8. Average Number of Individuals of All Species per Community (both years). Letters in common indicate no significant difference (α=0.05, p=0.0001).



Figur 9. Average Number of Individuals of All Species per Site. Lett in common indicate no significant difference (α=0.05).

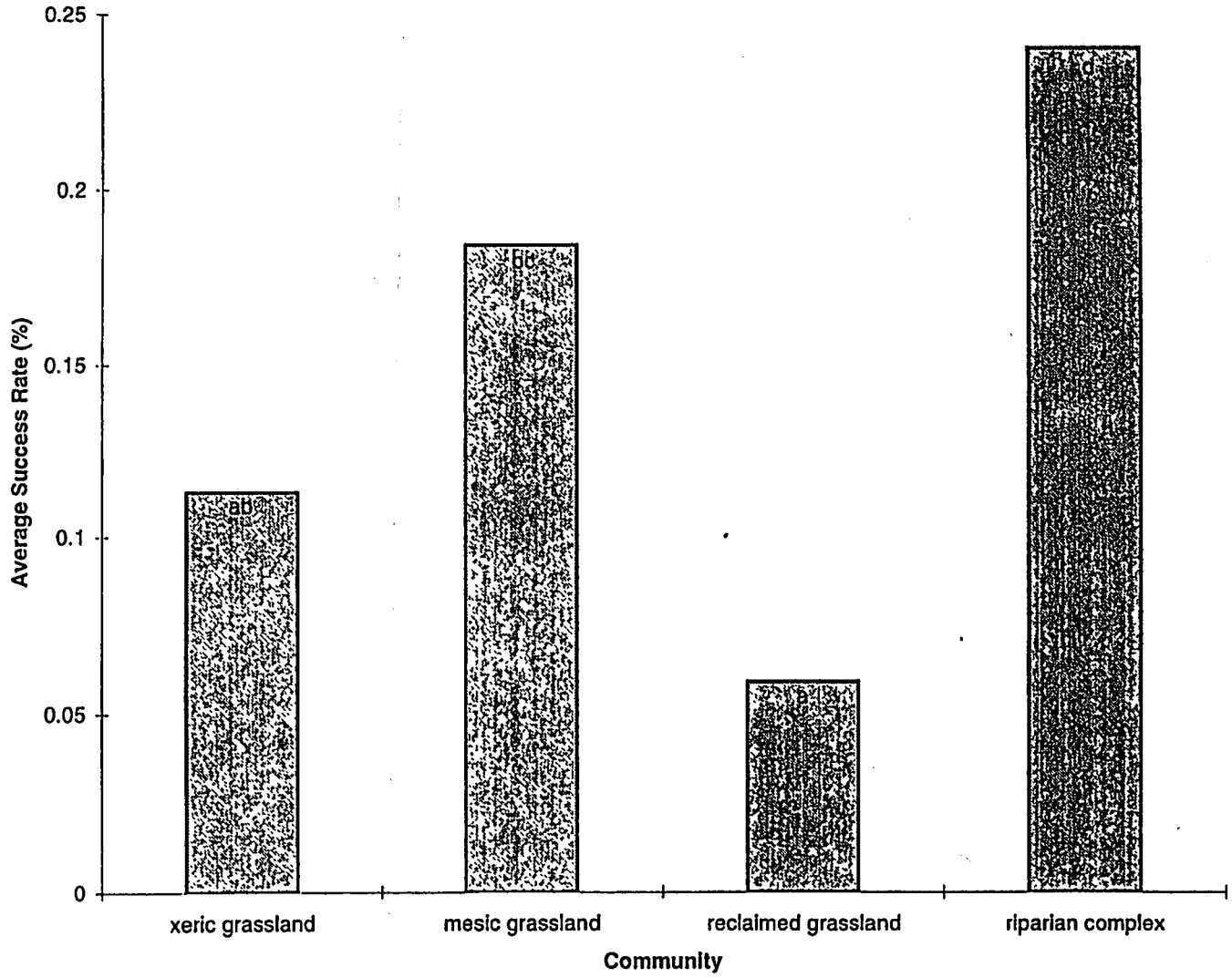


Figure C-10. Average Success Rate (% Traps with a Capture) per Community. Letters in common indicate no significant difference (α=0.05).

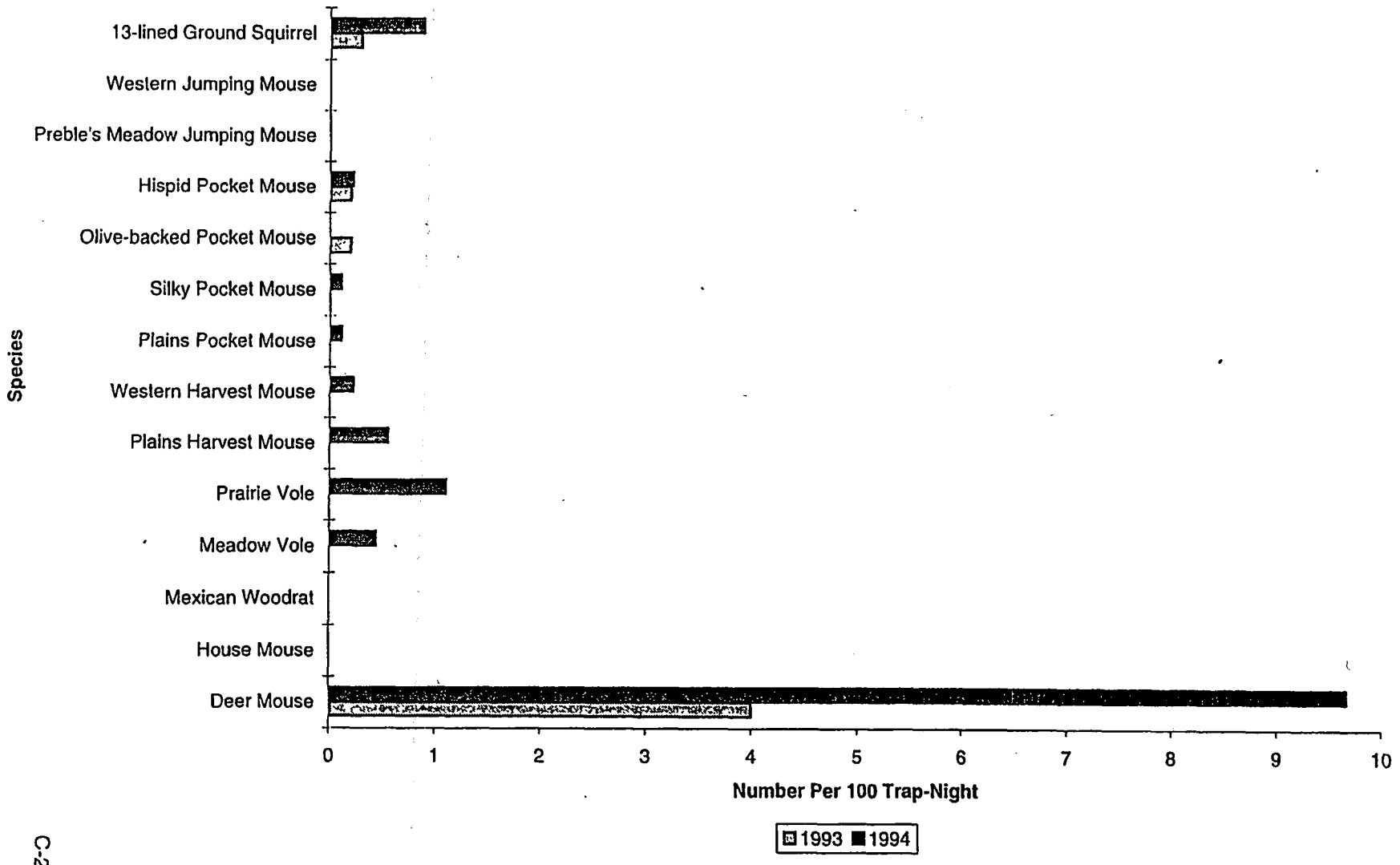


Figure C-11. Small Mammal Capture Compar' ٦, Xeric Mixed Grassland Community, Spring

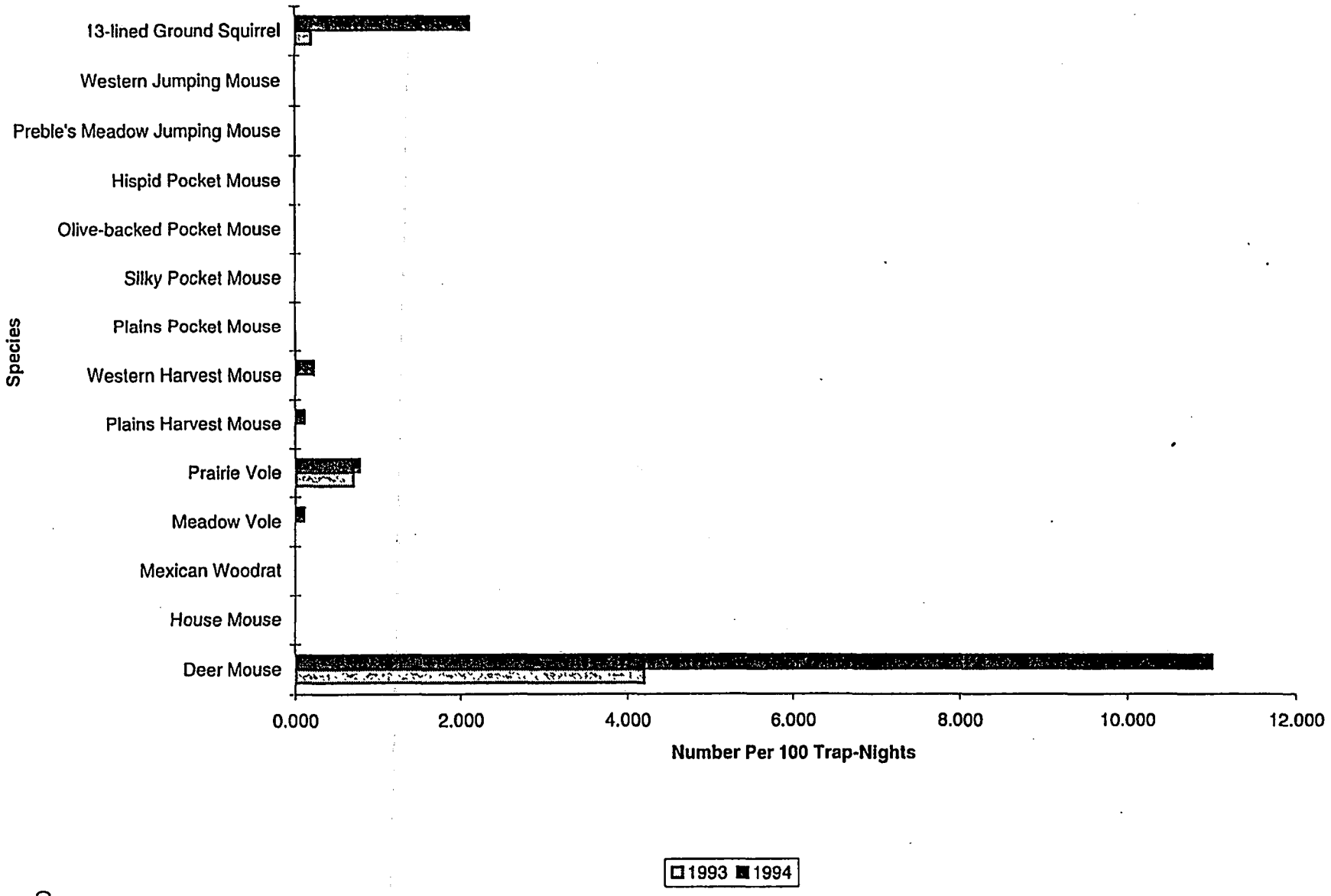


Figure C-12. Small Mammal Capture Comparison, Mesic Mixed Grassland Community, Spring

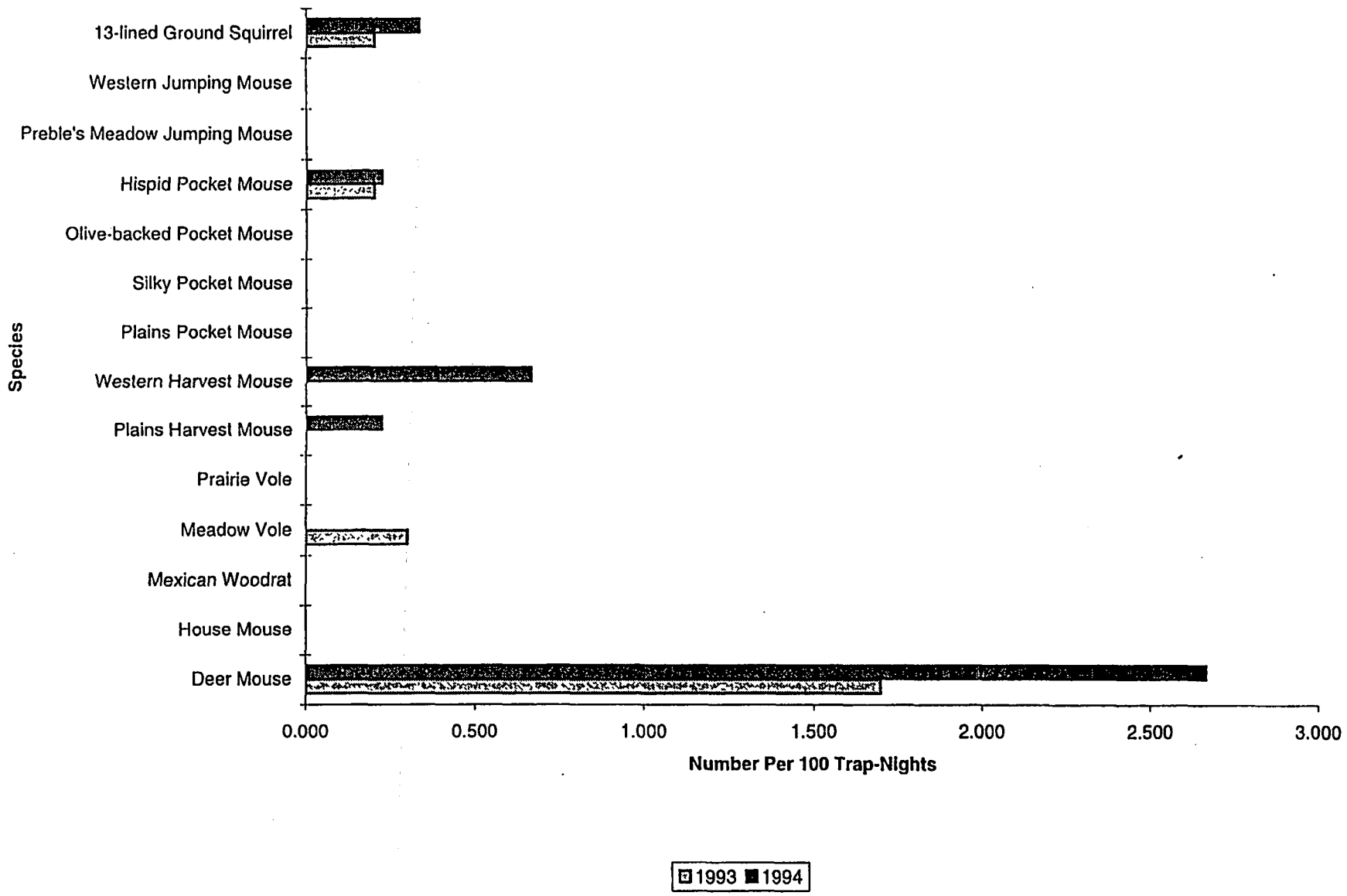


Figure C-13. Small Mammal Capture Compar[illegible]n, Reclaimed Grassland Community, Spring

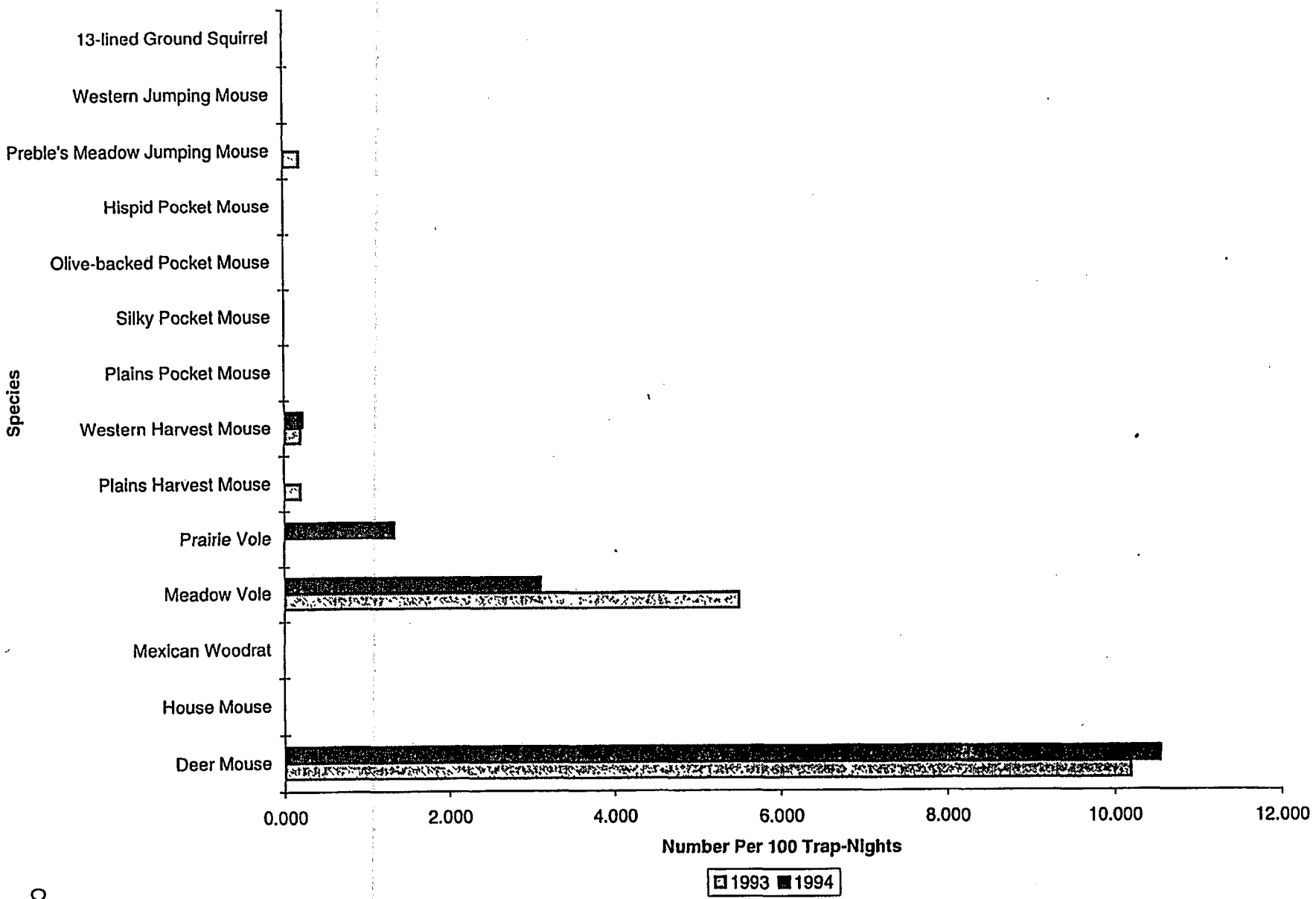


Figure C-14. Small Mammal Capture Comparison, Riparian Community Complex, Spring

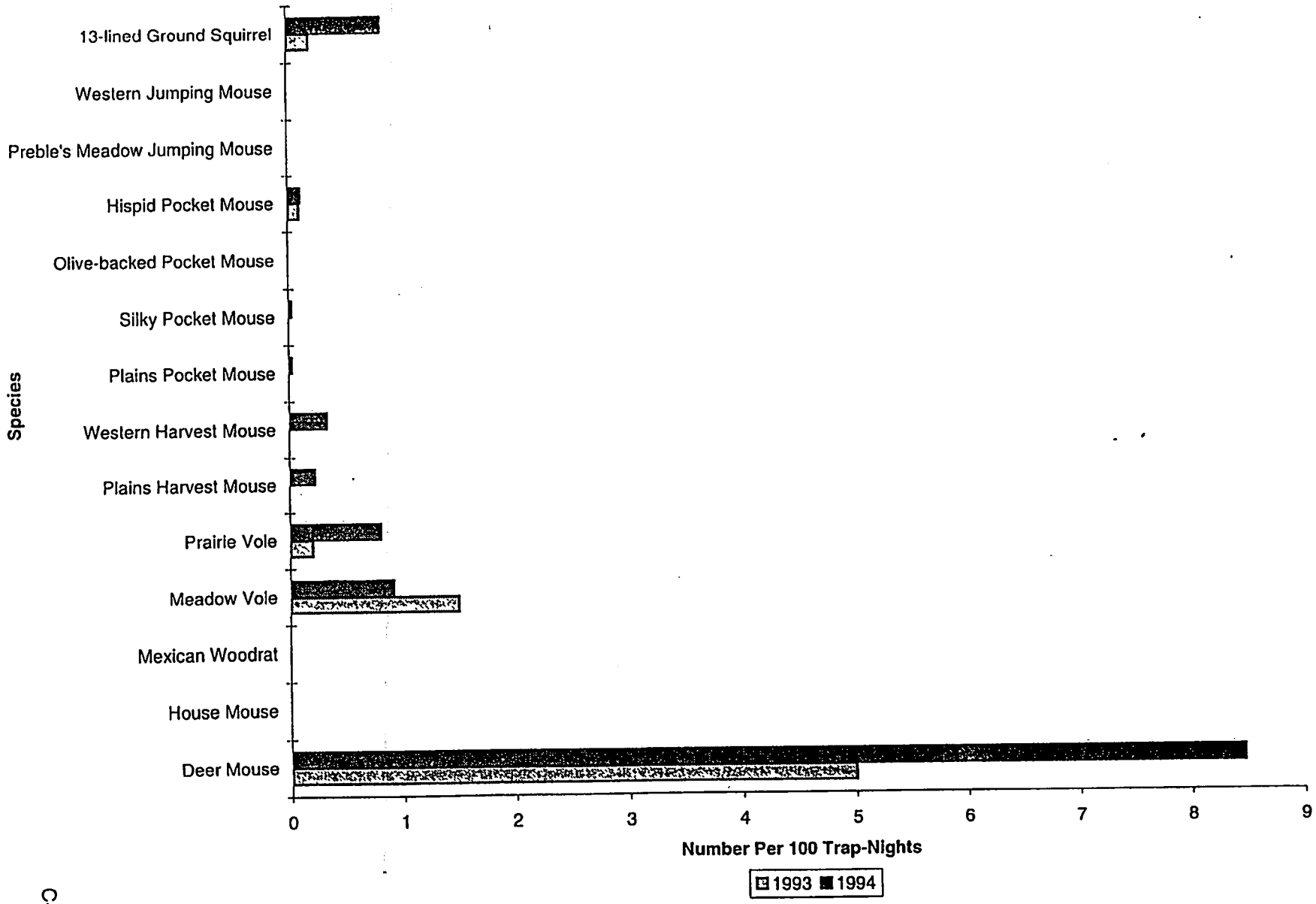


Figure C-15. Small Mammal Captur mparison, All Communities, Spring

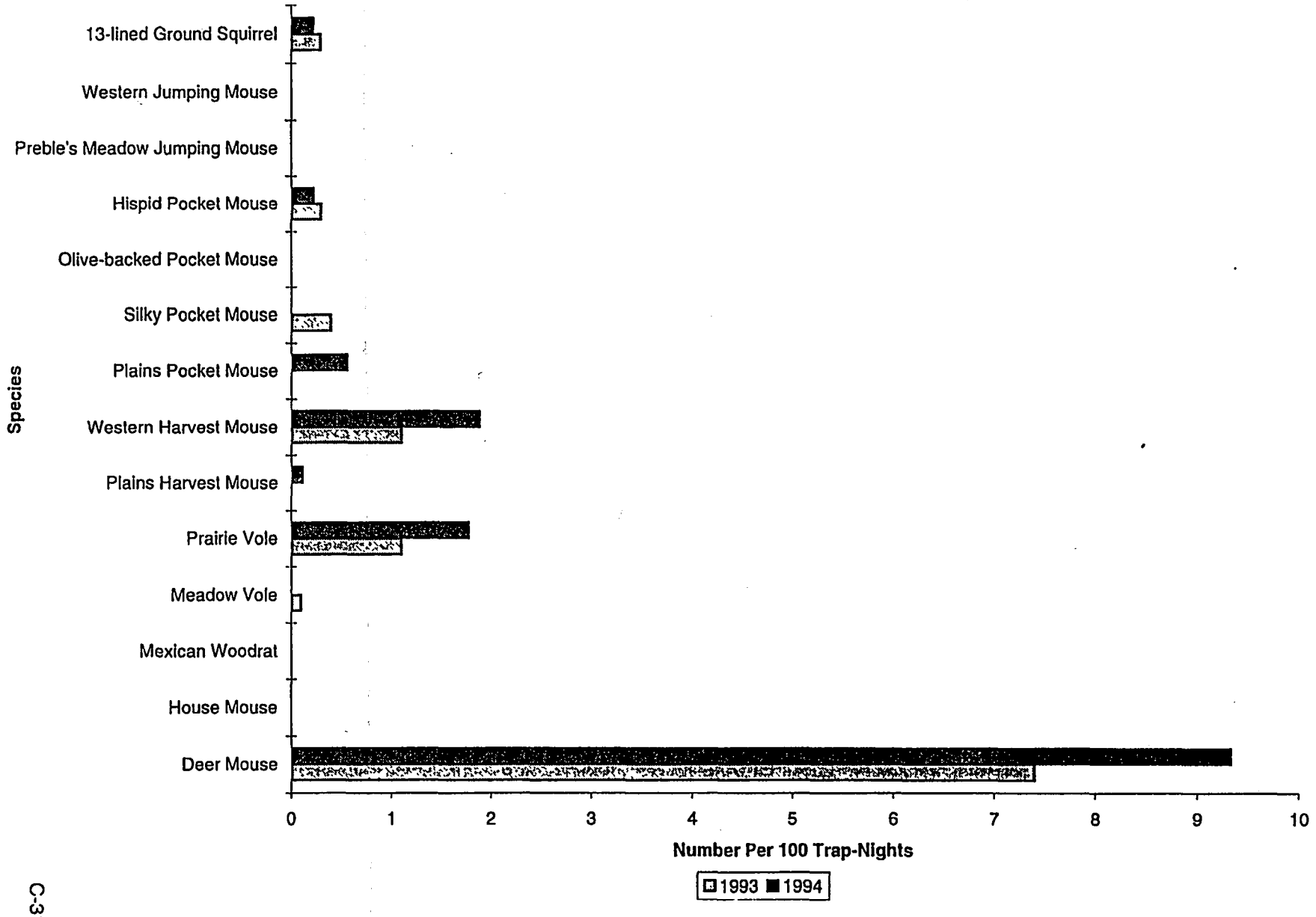


Figure C-16. Small Mammal Capture Comparison, Xeric Mixed Grassland Community, Fall

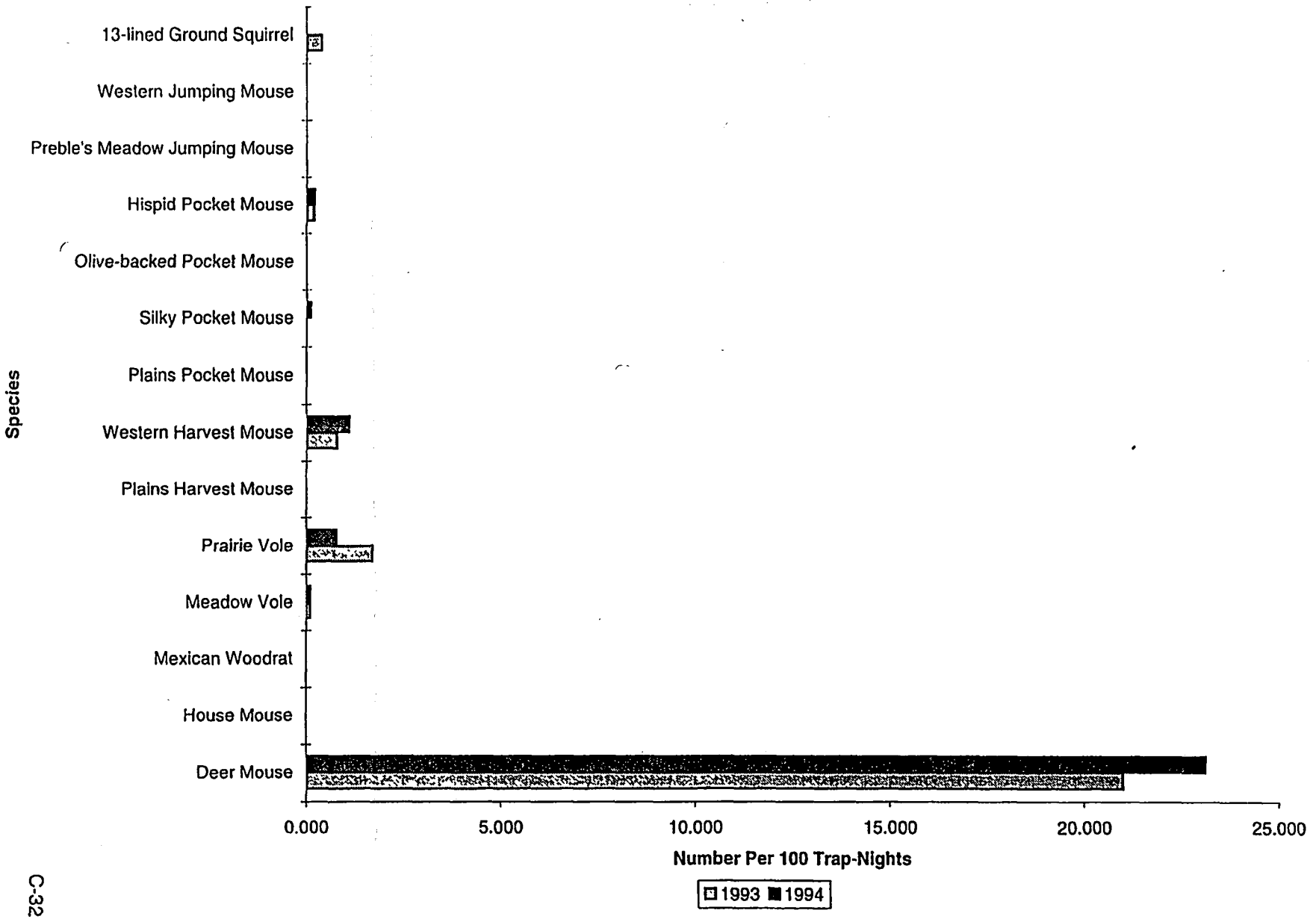


Figure C-17. Small Mammal Capture Comp ›n, Mesic Mixed Grassland Community, Fall

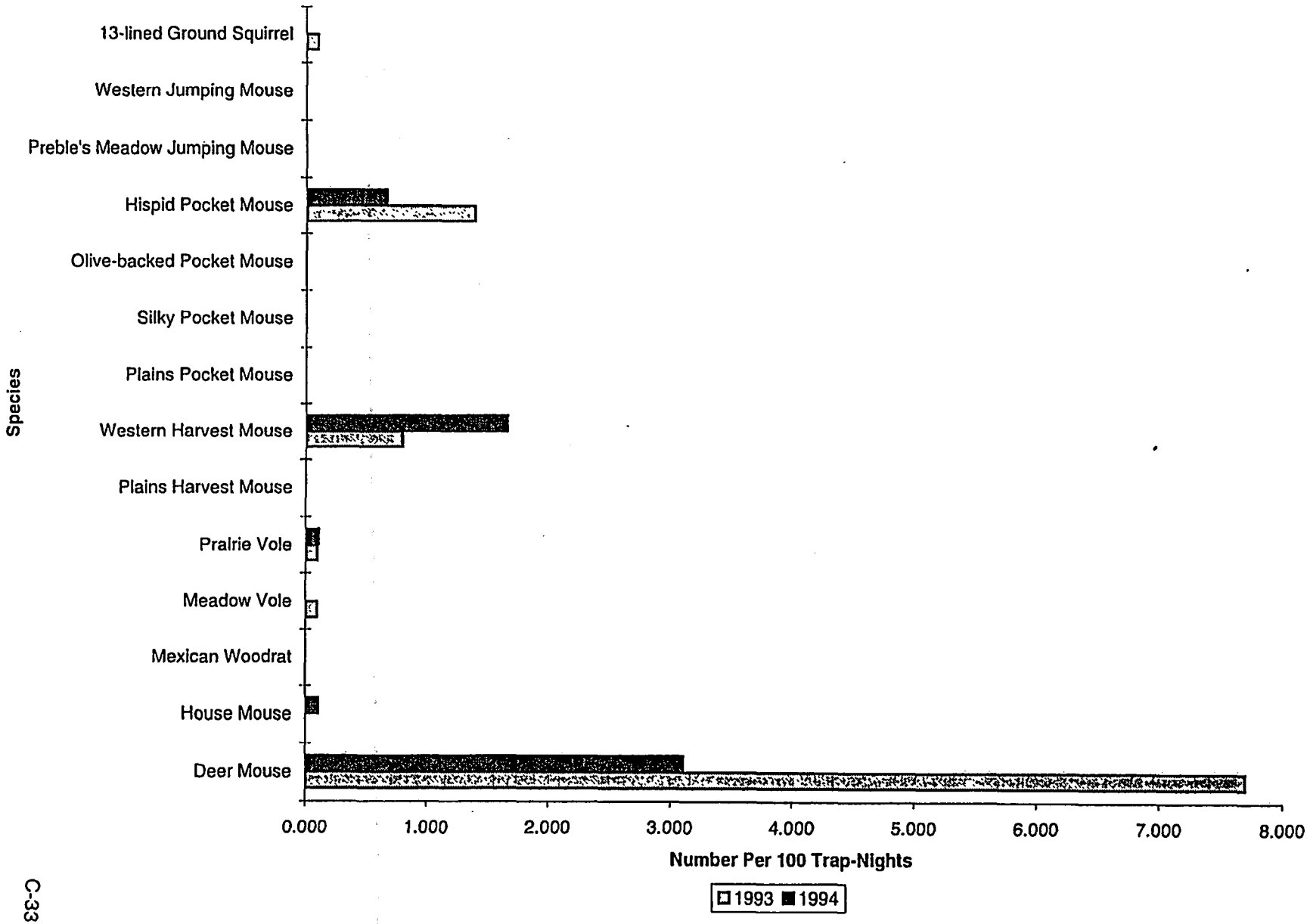


Figure C-18. Small Mammal Capture Comparison, Reclaimed Grassland Community, Fall

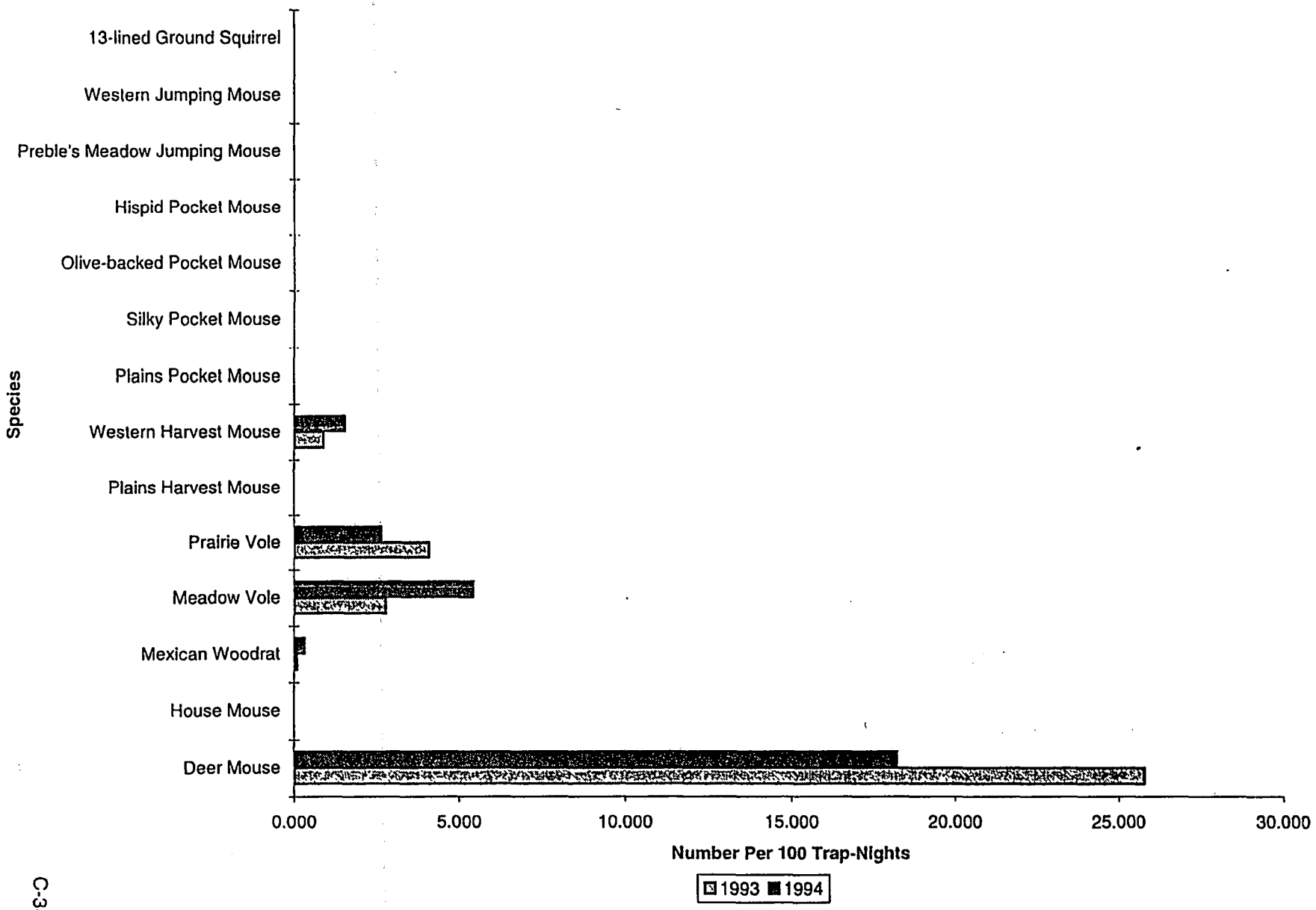


Figure C-19. Small Mammal Capture Cor ·ison, Riparian Community Complex, Fall

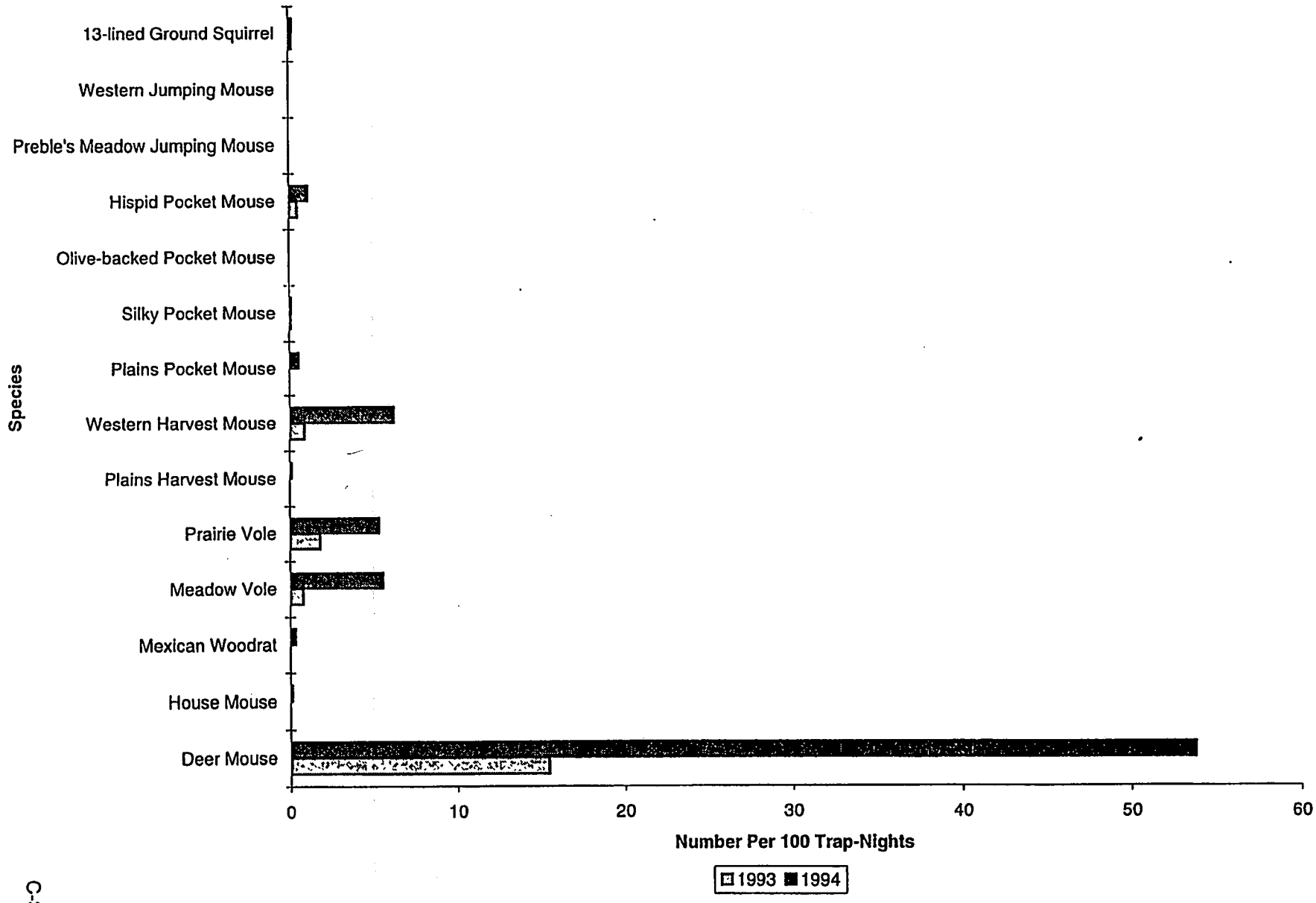


Figure C-20. Small Mammal Capture Comparison, All Communities, Fall

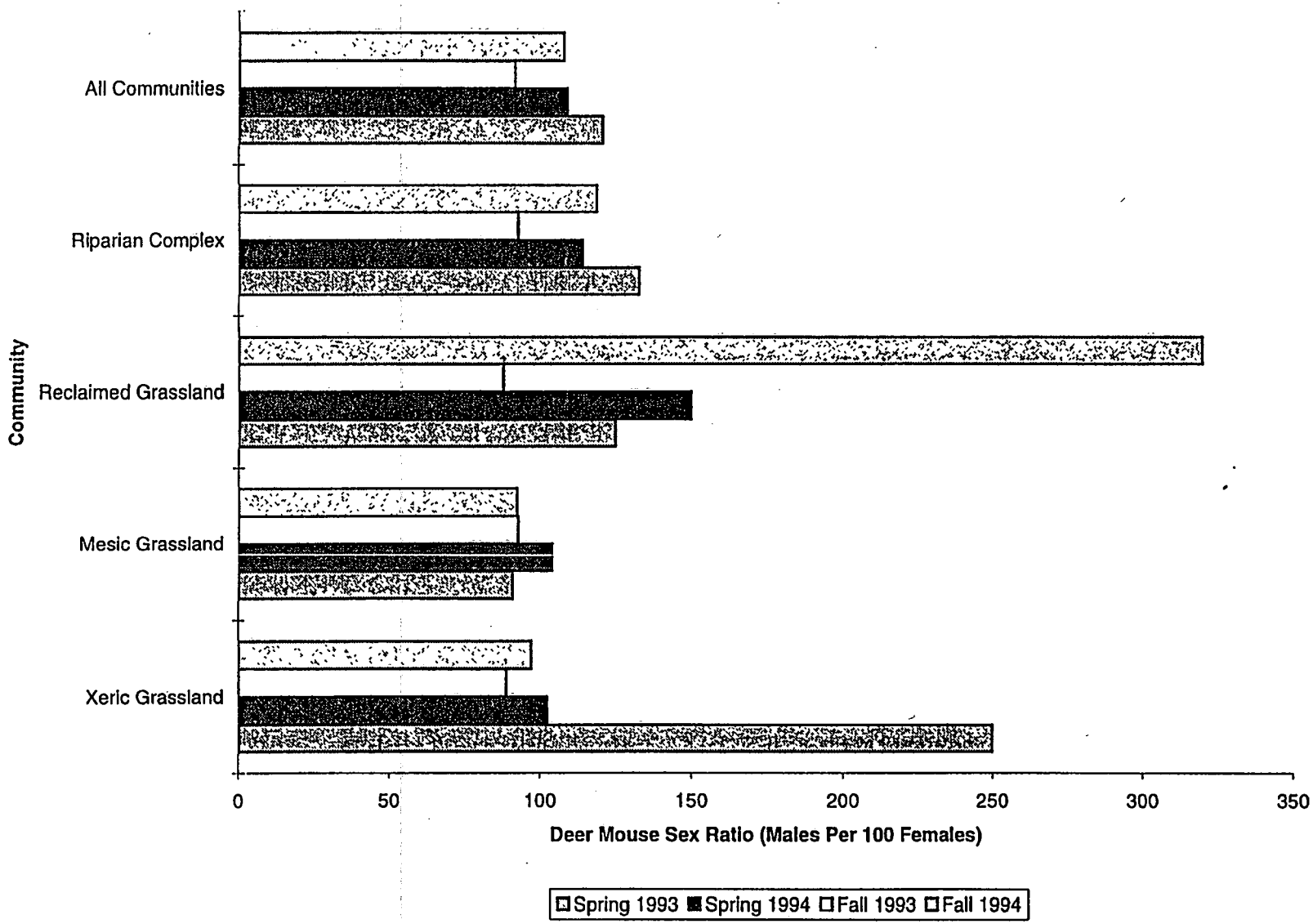
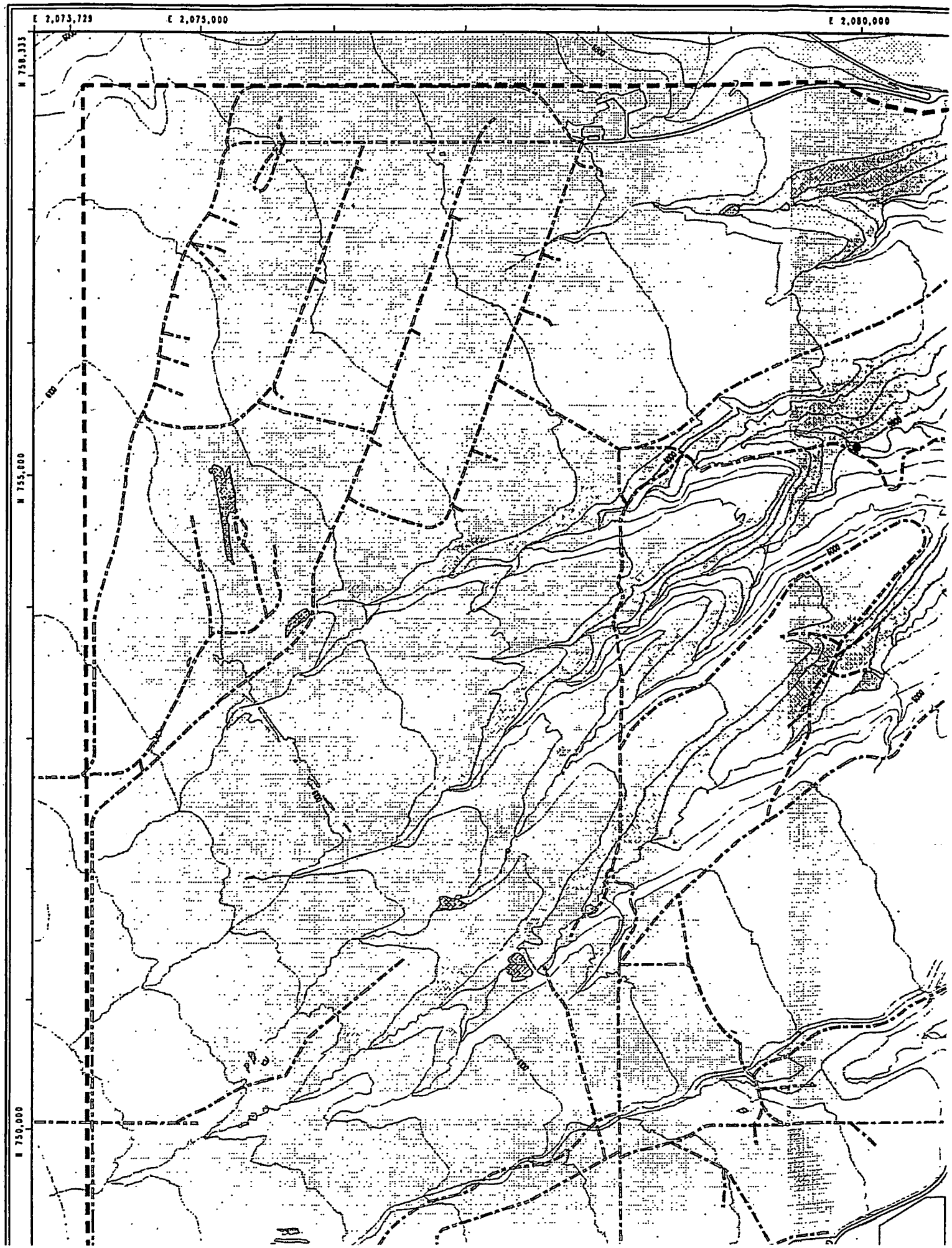


Figure C-21. Deer Mouse Sex Ratio Cc arison, Spring and Fall 1993 and 1994.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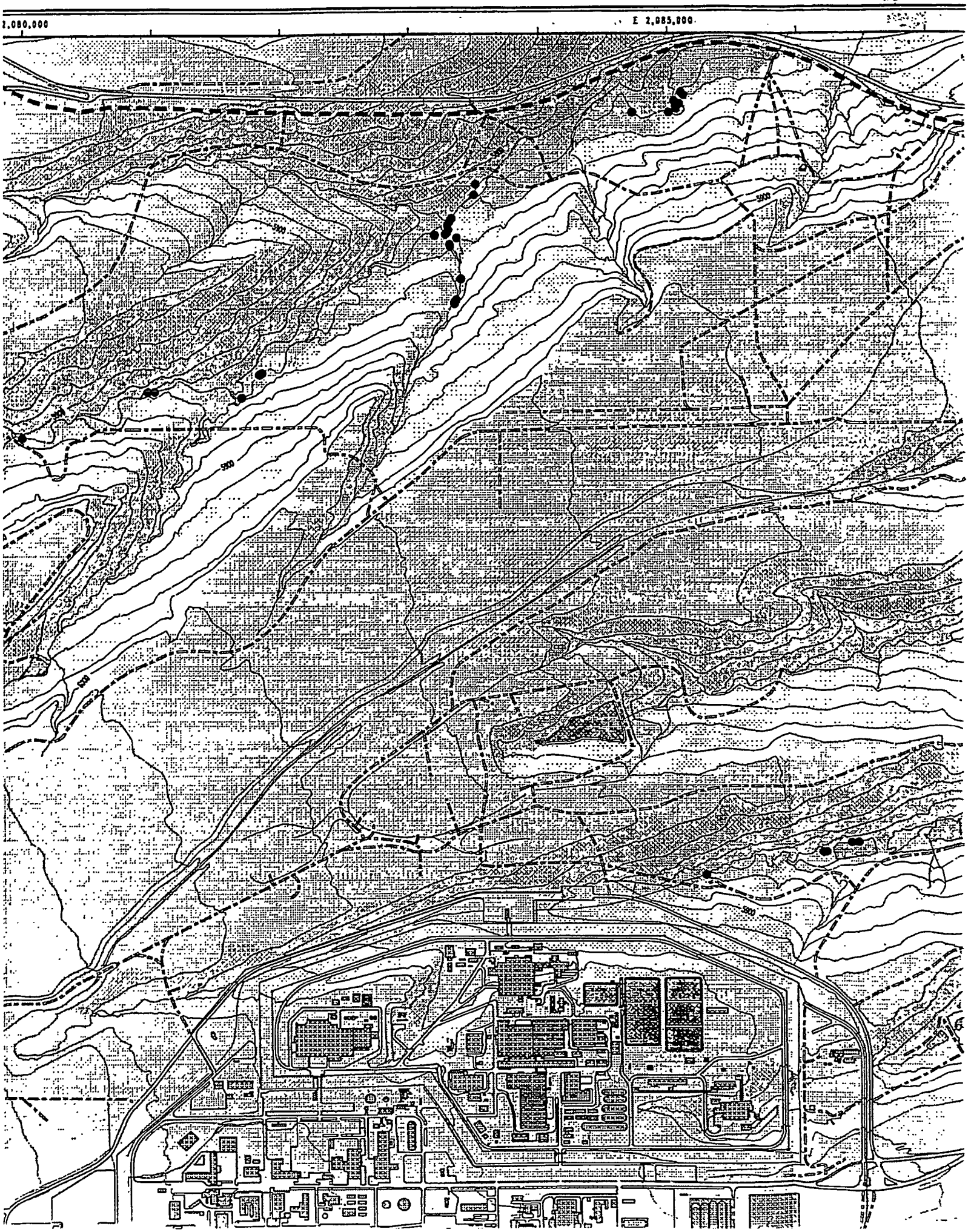
600
800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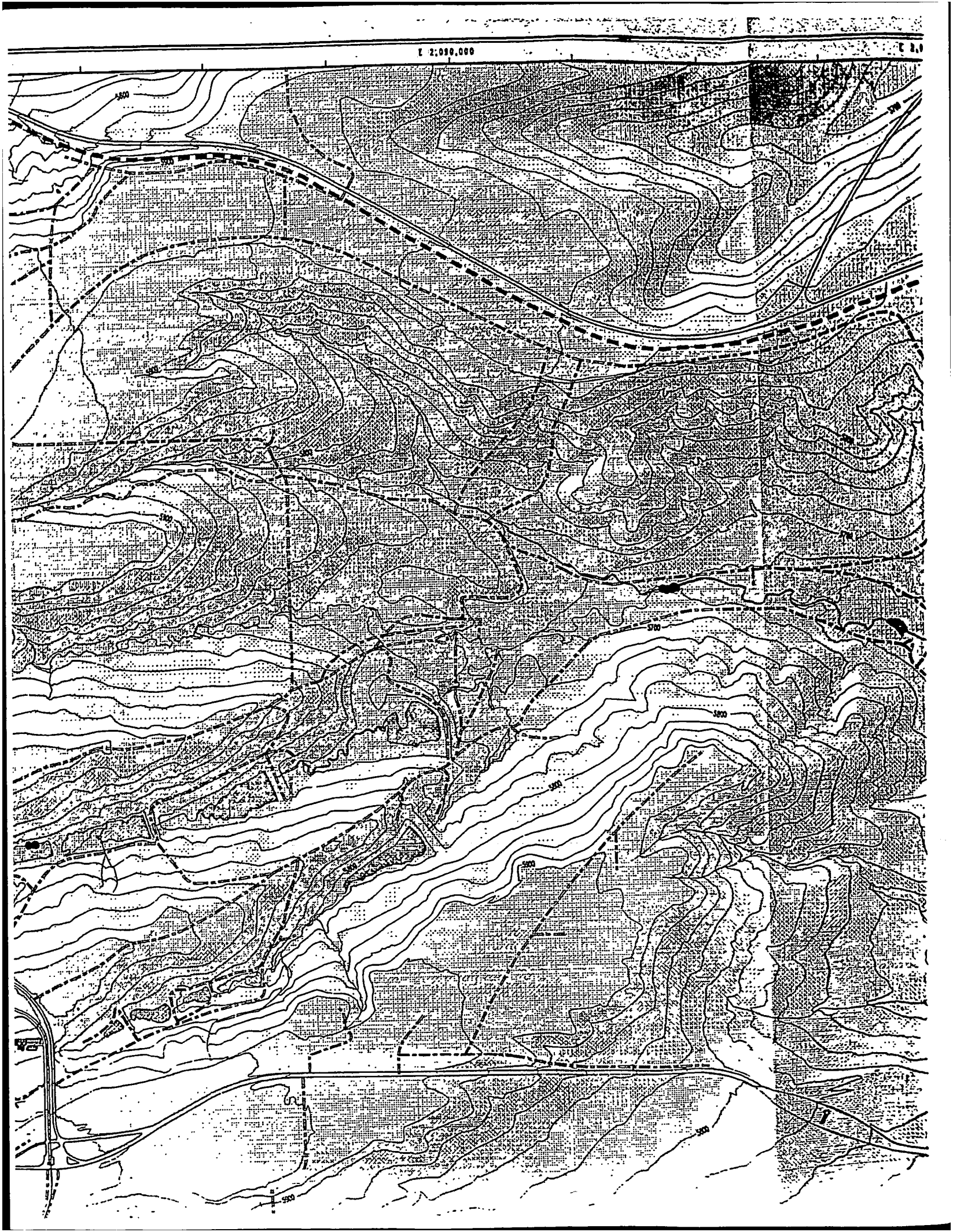
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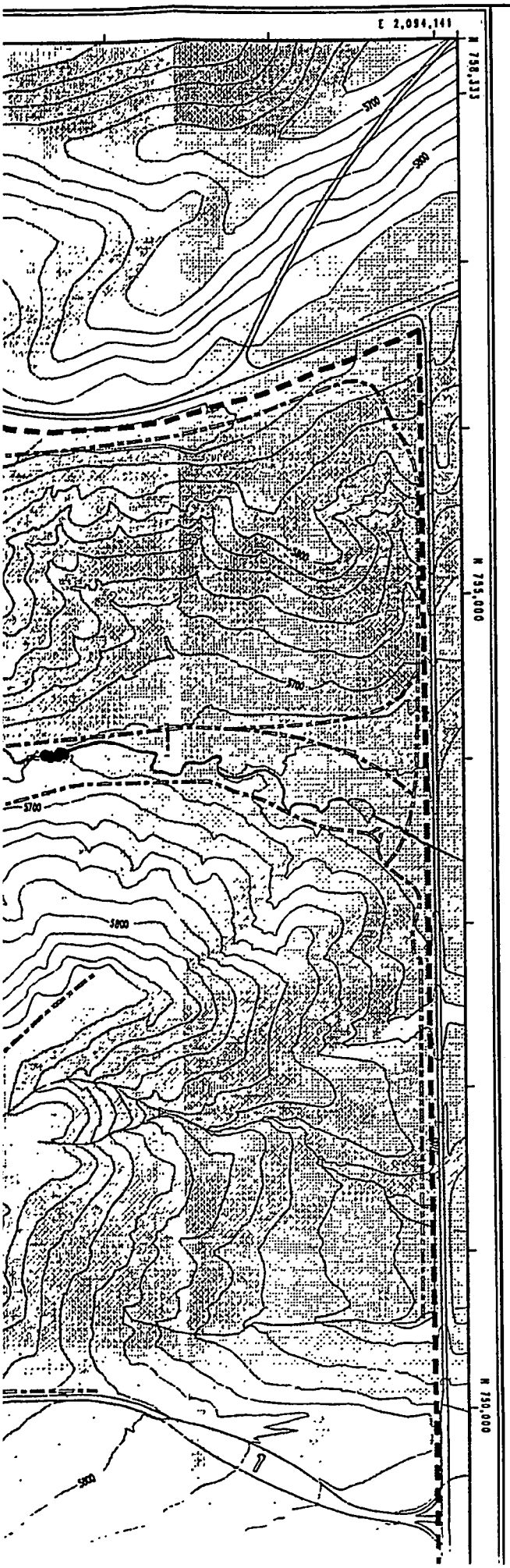


Capture Locations of Preble's Meadow Jumping Mouse

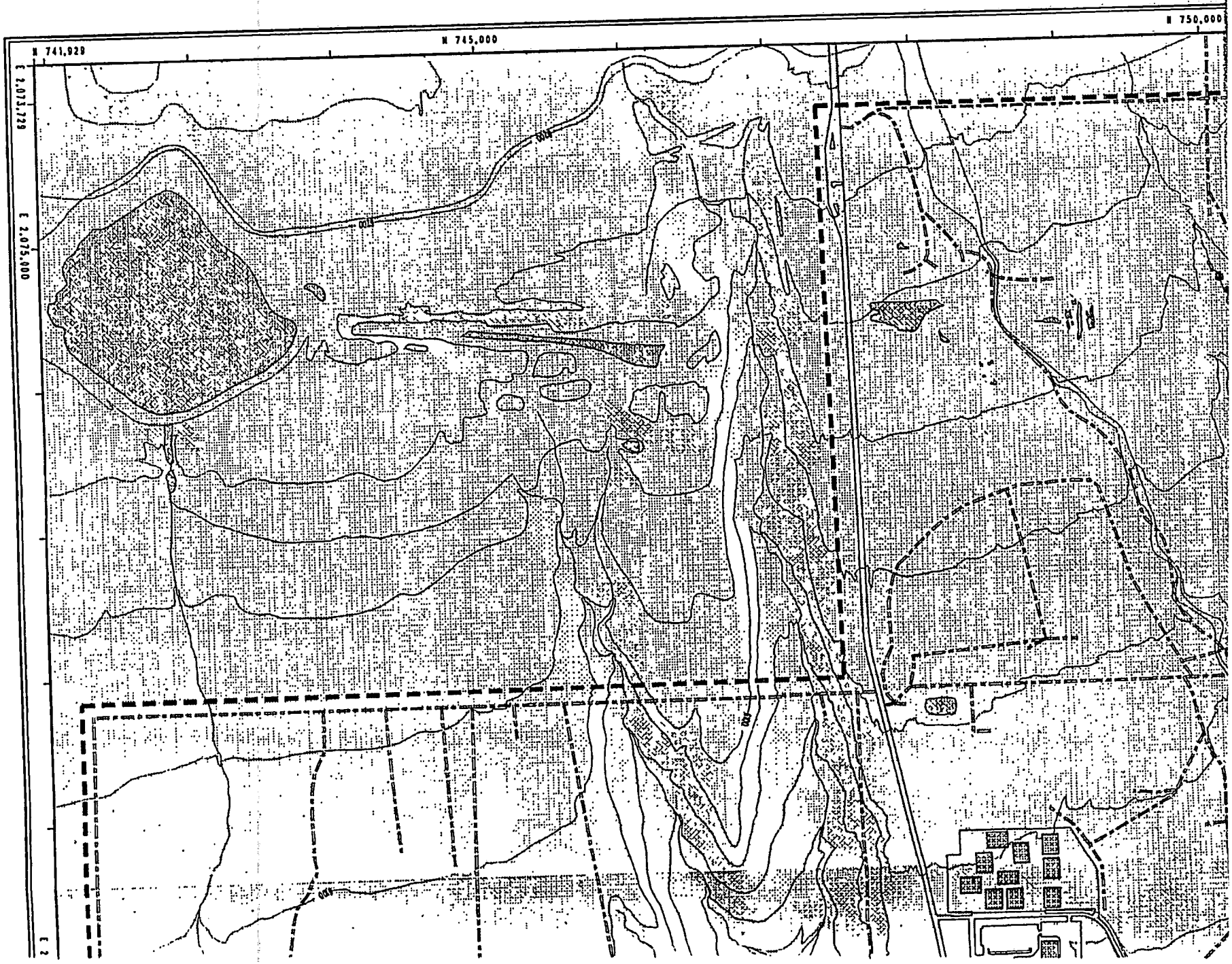
Figure C-23

Location of PMJM Capture

Standard Map Features

- Buildings or other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Contours (20′ Intervals)
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, roads, and fences provided by
Facilities Engr.,
EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by
USGS - (date unknown)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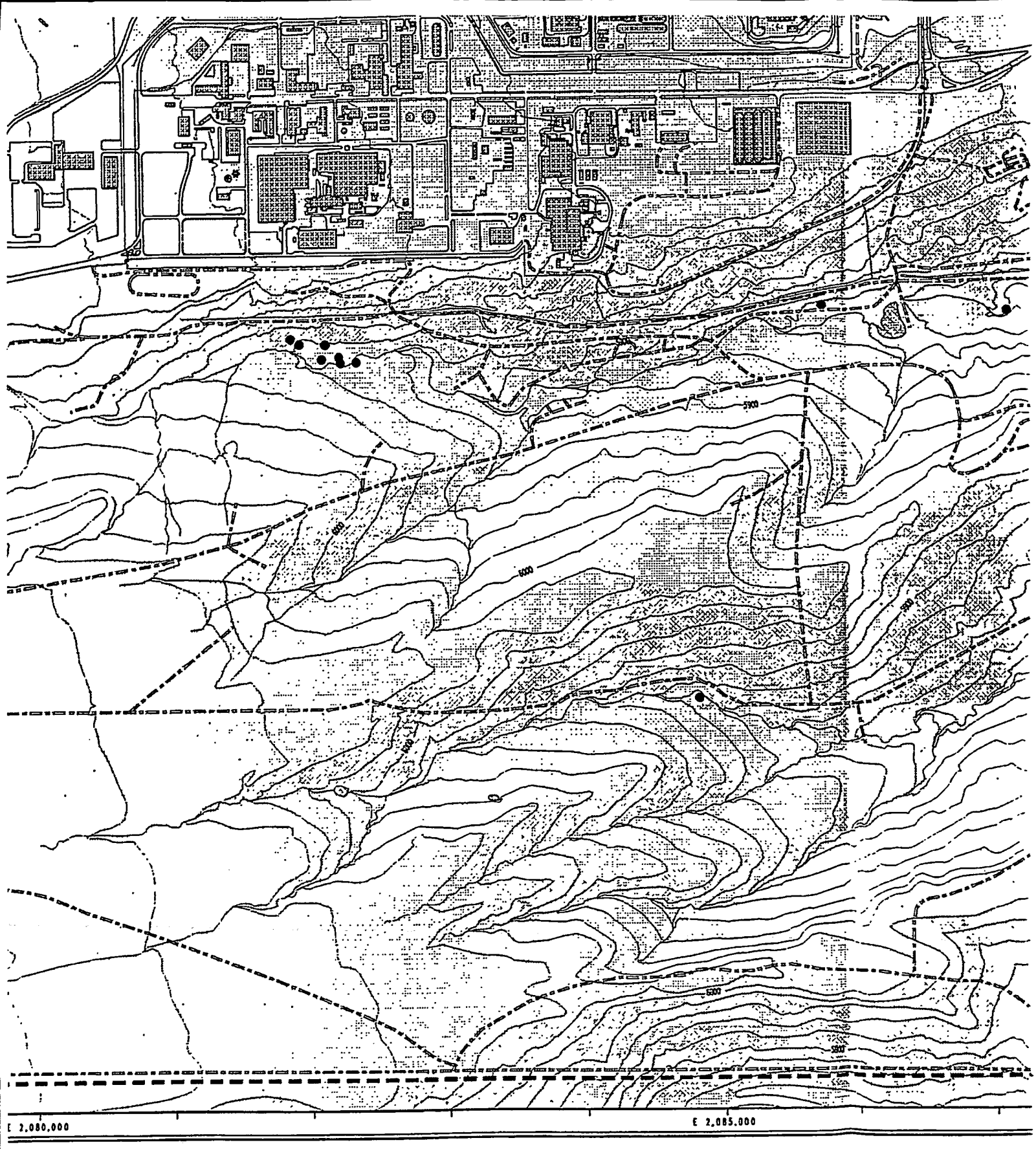
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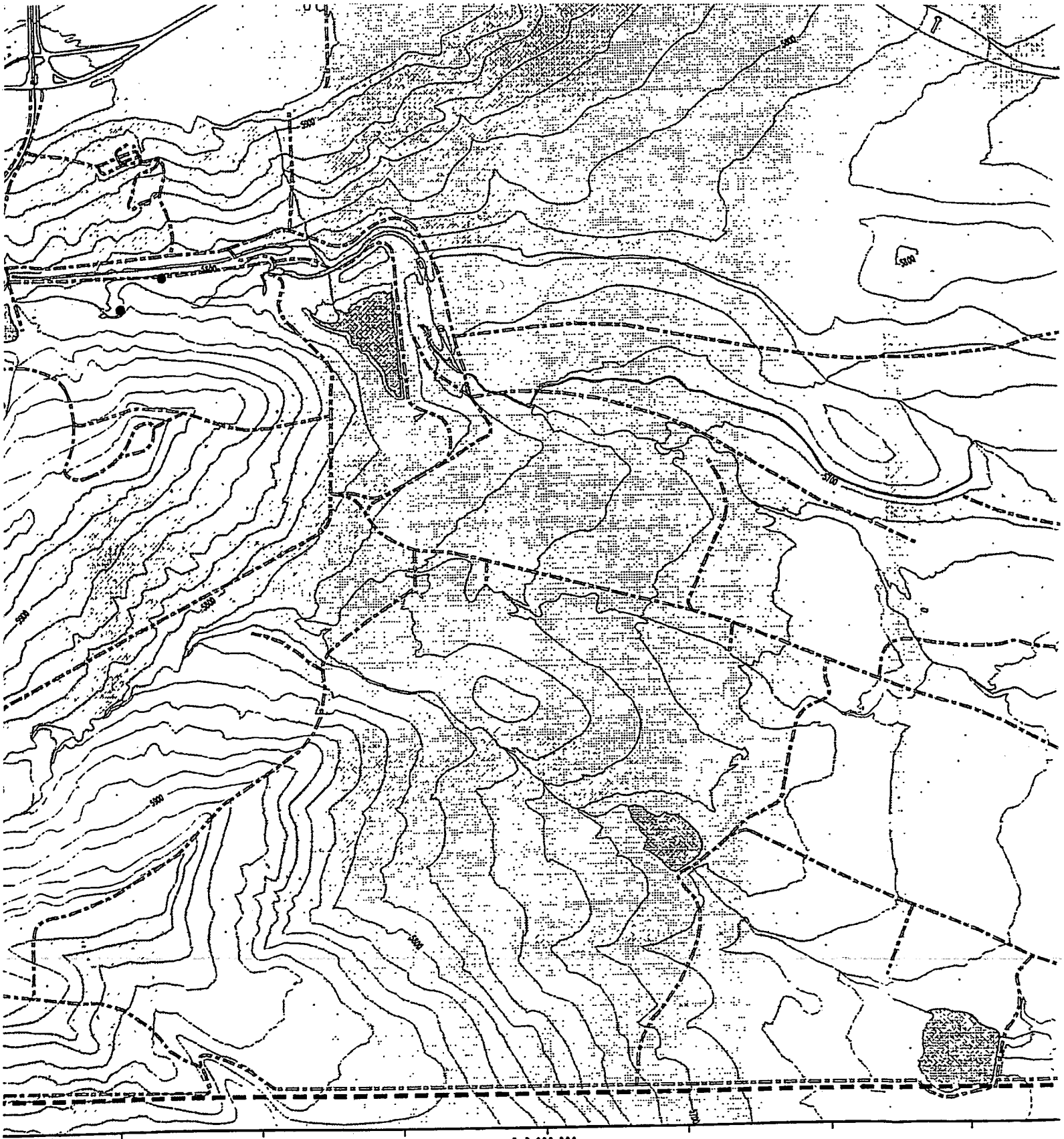
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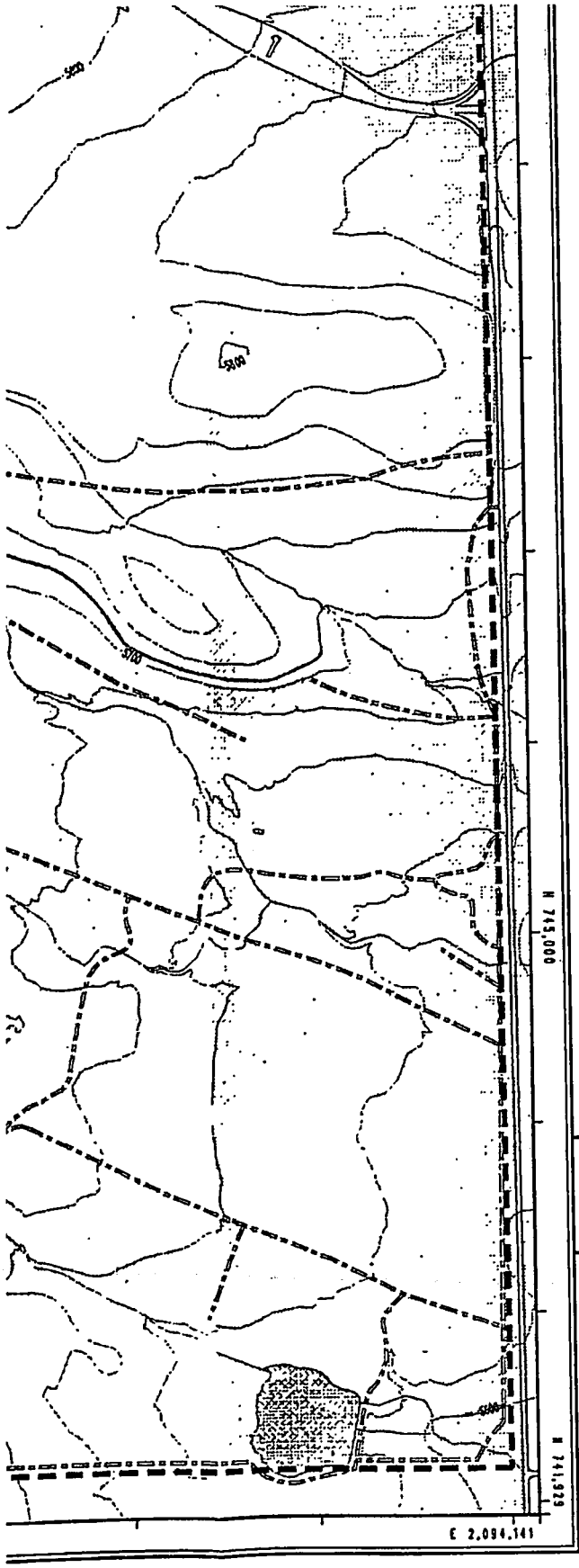

Scale = 1 : 10800
1 inch represents 900 feet

500 0 1000 2000ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:

EG&G ROCKY FLATS

Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, Colorado 80402-0464

MAP ID: oushd

May 25, 1995

/home/r518454/projects/eco-wshed-mngmt/preble-dsize.aml

Table C-1. Small Mammal Capture Summary, Xeric Mixed Grassland Community, Spring 1994.

Species	Code	TR01		TR06		TR12		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	51	17.00	26	8.67	10	3.33	87	9.67
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1		0	4	1.33		0	4	0.44
Prairie Vole	MIOC1	1	0.33	8	2.67	1	0.33	10	1.11
Plains Harvest Mouse	REMO1		0	3	1.00	2	0.67	5	0.56
Western Harvest Mouse	REME1		0	2	0.67		0	2	0.22
Plains Pocket Mouse	PEFL2		0	1	0.33		0	1	0.11
Silky Pocket Mouse	PEFL1		0	1	0.33		0	1	0.11
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1	1	0.33		0	1	0.33	2	0.22
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1	5	1.67	2	0.67	1	0.33	8	0.89
TOTAL		58	19.33	47	15.667	15	5.00	120	13.33

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-2. Small Mammal Capture Summary, Mesic Mixed Grassland Community, Spring 1994.

Species	Code	TR02		TR04		TR11		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	31	10.33	48	16.00	20	6.67	99	11.00
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1	1	0.33		0		0	1	0.11
Prairie Vole	MIOC1	1	0.33	5	1.67	1	0.33	7	0.78
Plains Harvest Mouse	REMO1		0	1	0.33		0	1	0.11
Western Harvest Mouse	REME1		0		0	2	0.67	2	0.22
Plains Pocket Mouse	PEFL2		0		0		0	0	0
Silky Pocket Mouse	PEFL1		0		0		0	0	0
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1		0		0		0	0	0
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1	12	4.00	4	1.33	3	1.00	19	2.11
TOTAL		45	15.00	58	19.33	26	8.67	129	14.33

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-3. Small Mammal Capture Summary, Reclaimed Grassland Community, Spring 1994.

Species	Code	TR07		TR08		TR09		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	11	3.67	13	4.33		0	24	2.67
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1		0		0		0	0	0
Prairie Vole	MIOC1		0		0		0	0	0
Plains Harvest Mouse	REMO1	2	0.67		0		0	2	0.22
Western Harvest Mouse	REME1	2	0.67		0	4	1.33	6	0.67
Plains Pocket Mouse	PEFL2		0		0		0	0	0
Silky Pocket Mouse	PEFL1		0		0		0	0	0
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1	1	0.33		0	1	0.33	2	0.22
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1		0		0	3	1.00	3	0.33
TOTAL		16	5.33	13	4.33	8	2.67	37	4.11

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-4. Small Mammal Capture Summary, Riparian Community Complex, Spring 1994.

Species	Code	TR03		TR05		TR10		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	26	8.67	32	10.67	37	12.33	95	10.56
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1	15	5	1	0.33	12	4.00	28	3.11
Prairie Vole	MIOC1	2	0.67	6	2.00	4	1.33	12	1.33
Plains Harvest Mouse	REMO1		0		0		0	0	0
Western Harvest Mouse	REME1	1	0.33		0	1	0.33	2	0.22
Plains Pocket Mouse	PEFL2		0		0		0	0	0
Silky Pocket Mouse	PEFL1		0		0		0	0	0
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1		0		0		0	0	0
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1		0		0		0	0	0
TOTAL		44	14.67	39	13.00	54	18.00	137	15.22

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-5. Small Mammal Capture Summary, All Communities, Spring 1994.

Species	Code	*Xeric Grassland*		*Mesic Grassland*		*Reclaimed Grassland*		*Riparian Complex*		*TOTAL*	
		#	#/100TN	#	#/100TN	#	#/100TN	#	#/100TN	#	#/100TN
Deer Mouse	PEMA1	87	9.67	99	11.00	24	2.67	95	10.56	305	8.47
House Mouse	MUMU1	0	0	0	0	0	0	0	0	0	0
Mexican Woodrat	NEME1	0	0	0	0	0	0	0	0	0	0
Meadow Vole	MIPE1	4	0.44	1	0.11	0	0	28	3.11	33	0.92
Prairie Vole	MIOC1	10	1.11	7	0.78	0	0	12	1.33	29	0.81
Plains Harvest Mouse	REMO1	5	0.56	1	0.11	2	0.22	0	0	8	0.22
Western Harvest Mouse	REME1	2	0.22	2	0.22	6	0.67	2	0.222	12	0.33
Plains Pocket Mouse	PEFL2	1	0.11	0	0	0	0	0	0	1	0.03
Silky Pocket Mouse	PEFL1	1	0.11	0	0	0	0	0	0	1	0.03
Olive-backed Pocket Mouse	PEFA1	0	0	0	0	0	0	0	0	0	0
Hispid Pocket Mouse	CHHI1	2	0.22	0	0	2	0.22	0	0	4	0.11
Preble's Meadow Jumping Mouse	ZAHU1	0	0	0	0	0	0	0	0	0	0
Western Jumping Mouse	ZAPR1	0	0	0	0	0	0	0	0	0	0
13-lined Ground Squirrel	SPTR1	8	0.89	19	2.11	3	0.33	0	0	30	0.83
TOTAL		120	13.33	129	14.33	37	4.11	137	15.22	423	11.75

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 900 trap-nights per community

Table C-6. **Small Mammal Capture Summary at the Rocky Mountain Arsenal, Spring 1987.** Adapted from Shell 1989.

Species	*Weedy Forbs* #/100 TN	*Shrubs/Yucca*[1] #/100 TN	*Thickets*[2] #/100 TN	*Cattails/ Rushes* #/100 TN	*Streamside Meadows* #/100 TN	*Cottonwoods* #/100 TN	*TOTAL* #/100 TN
Deer Mouse	30.0	9.8	2.7	2.6	1.0	1.0	47.1
Western Harvest Mouse		2.2	2.2	3.1	1.5		9.0
Meadow Vole		0.4		11.7	1.0		13.1
Prairie Vole		1.6	2.2	5.7			9.5
Silky Pocket Mouse		0.2					0.2
Hispid Pocket Mouse		0.8					0.8
Ord's Kangaroo Rat		2.5					2.5
TOTAL	30.0	17.5	7.1	23.1	3.5	1.0	82.2

#/100TN = number of captures per 100 trap-nights, from Shell (1989).

1 Shrubs include sand sagebrush and rubber rabbitbrush.

2 Thickets include New Mexico locust and American plum.

Table C-7. Small Mammal Age and Sex Data, Xeric Mixed Grassland Community, Spring 1994.

Species	Code	TR01			TR06			TR12			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	25	23		10	14	2	6	3	1	41	40	3
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1					1	3				0	1	3
Prairie Vole	MIOC1		1		1	4	3		1		1	6	3
Plains Harvest Mouse	REMO1				2	1		1	1		3	2	0
Western Harvest Mouse	REME1				1						1	0	0
Plains Pocket Mouse	PEFL2					1					0	1	0
Silky Pocket Mouse	PEFL1					1					0	1	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1		1						1		0	2	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1	1	3			2			1		1	6	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-8. Small Mammal Age and Sex Data, Mesic Mixed Grassland Community, Spring 1994.

Species	Code	TR02			TR04			TR11			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	16	15		24	23		10	10		50	48	0
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1		1								0	1	0
Prairie Vole	MIOC1	1			2	3		1			4	3	0
Plains Harvest Mouse	REMO1					1					0	1	0
Western Harvest Mouse	REME1							1	1		1	1	0
Plains Pocket Mouse	PEFL2										0	0	0
Silky Pocket Mouse	PEFL1										0	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1										0	0	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1	5	7		3	1		2	1		10	9	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-9. Small Mammal Age and Sex Data, Reclaimed Grassland Community, Spring 1994.

Species	Code	TR07			TR08			TR09			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	5	3	3	7	5					12	8	3
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1										0	0	0
Prairie Vole	MIOC1										0	0	0
Plains Harvest Mouse	REMO1	1	1								1	1	0
Western Harvest Mouse	REME1	1	1					2	2		3	3	0
Plains Pocket Mouse	PEFL2										0	0	0
Silky Pocket Mouse	PEFL1										0	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1	1						1			2	0	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1							2	1		2	1	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-10. Small Mammal Age and Sex Data, Riparian Community Complex, Spring 1994.

Species	Code	TR03			TR05			TR10			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	10	13		17	13		21	16		48	42	0
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1	4	8	3			1	7	3	2	11	11	6
Prairie Vole	MIOC1		2		2	4		3	1		5	7	0
Plains Harvest Mouse	REMO1										0	0	0
Western Harvest Mouse	REME1		1						1		0	2	0
Plains Pocket Mouse	PEFL2										0	0	0
Silky Pocket Mouse	PEFL1										0	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1										0	0	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1										0	0	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-11. Small Mammal Age and Sex Data, All Communities, Spring 1994.

Species	Code	Xeric Grassland			Mesic Grassland			Reclaimed Grassland			Riparian Complex			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	41	40	3	50	48	0	12	8	3	48	42	0	151	138	6
House Mouse	MUMU1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mexican Woodrat	NEME1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meadow Vole	MIPE1	0	1	3	0	1	0	0	0	0	11	11	6	11	13	9
Prairie Vole	MIOC1	1	6	3	4	3	0	0	0	0	5	7	0	10	16	3
Plains Harvest Mouse	REMO1	3	2	0	0	1	0	1	1	0	0	0	0	4	4	0
Western Harvest Mouse	REME1	1	0	0	1	1	0	3	3	0	0	2	0	5	6	0
Plains Pocket Mouse	PEFL2	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Silky Pocket Mouse	PEFL1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Olive-backed Pocket Mouse	PEFA1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hispid Pocket Mouse	CHHI1	0	2	0	0	0	0	2	0	0	0	0	0	2	2	0
Preble's Meadow Jumping Mouse	ZAHU1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Jumping Mouse	ZAPR1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-lined Ground Squirrel	SPTR1	1	6	0	10	9	0	2	1	0	0	0	0	13	16	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 900 trap-nights per community.

Table C-12. Small Mammal Capture Summary, Xeric Mixed Grassland Community, Fall 1994.

Species	Code	TR01		TR06		TR12		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	45	15.00	21	7.00	18	6.00	84	9.33
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1		0		0		0	0	0
Prairie Vole	MIOC1		0	16	5.33		0	16	1.78
Plains Harvest Mouse	REMO1		0	1	0.33		0	1	0.11
Western Harvest Mouse	REME1		0	13	4.33	4	1.33	17	1.89
Plains Pocket Mouse	PEFL2		0	5	1.67		0	5	0.56
Silky Pocket Mouse	PEFL1		0		0		0	0	0
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1	1	0.33	1	0.33		0	2	0.22
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1	1	0.33	1	0.33		0	2	0.22
TOTAL		47	15.67	58	19.33	22	7.33	127	14.11

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-13. Small Mammal Capture Summary, Mesic Mixed Grassland Community, Fall 1994.

Species	Code	TR02		TR04		TR11		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	73	24.33	101	33.67	34	11.33	208	23.11
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1	1	0.33		0		0	1	0.11
Prairie Vole	MIOC1	6	2.00		0	1	0.33	7	0.78
Plains Harvest Mouse	REMO1		0		0		0	0	0
Western Harvest Mouse	REME1		0	5	1.67	5	1.67	10	1.11
Plains Pocket Mouse	PEFL2		0		0		0	0	0
Silky Pocket Mouse	PEFL1		0	1	0.33		0	1	0.11
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1	1	0.33	1	0.33		0	2	0.22
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1		0		0		0	0	0
TOTAL		81	27.00	108	36.00	40	13.33	229	25.44

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-14. Small Mammal Capture Summary, Reclaimed Grassland Community, Fall 1994.

Species	Code	TR07		TR08		TR09		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	10	3.33	16	5.33	2	0.67	28	3.11
House Mouse	MUMU1		0	1	0.33		0	1	0.11
Mexican Woodrat	NEME1		0		0		0	0	0
Meadow Vole	MIPE1		0		0		0	0	0
Prairie Vole	MIOC1	1	0.33		0		0	1	0.11
Plains Harvest Mouse	REMO1		0		0		0	0	0
Western Harvest Mouse	REME1	14	4.67	1	0.33		0	15	1.67
Plains Pocket Mouse	PEFL2		0		0		0	0	0
Silky Pocket Mouse	PEFL1		0		0		0	0	0
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1	5	1.67	1	0.33		0	6	0.67
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1		0		0		0	0	0
TOTAL		30	10.00	19	6.33	2	0.67	51	5.67

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-15. Small Mammal Capture Summary, Riparian Community Complex, Fall 1994.

Species	Code	TR03		TR05		TR10		TOTAL	
		#	#/100 TN	#	#/100 TN	#	#/100 TN	#	#/100 TN
Deer Mouse	PEMA1	73	24.33	62	20.67	29	9.67	164	18.22
House Mouse	MUMU1		0		0		0	0	0
Mexican Woodrat	NEME1	2	0.67	1	0.33		0	3	0.33
Meadow Vole	MIPE1	26	8.67	9	3.00	14	4.67	49	5.44
Prairie Vole	MIOC1	2	0.67	16	5.33	6	2.00	24	2.67
Plains Harvest Mouse	REMO1		0		0		0	0	0
Western Harvest Mouse	REME1		0	3	1.00	11	3.67	14	1.56
Plains Pocket Mouse	PEFL2		0		0		0	0	0
Silky Pocket Mouse	PEFL1		0		0		0	0	0
Olive-backed Pocket Mouse	PEFA1		0		0		0	0	0
Hispid Pocket Mouse	CHHI1		0		0		0	0	0
Preble's Meadow Jumping Mouse	ZAHU1		0		0		0	0	0
Western Jumping Mouse	ZAPR1		0		0		0	0	0
13-lined Ground Squirrel	SPTR1		0		0		0	0	0
TOTAL		103	34.33	91	30.33	60	20.00	254	28.22

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 300 trap-nights per site

Table C-16. Small Mammal Capture Summary, All Communities, Fall 1994.

Species	Code	*Xeric Grassland*		*Mesic Grassland*		*Reclaimed Grassland*		*Riparian Complex*		*TOTAL*	
		#	#/100TN	#	#/100TN	#	#/100TN	#	#/100TN	#	#/100TN
Deer Mouse	PEMA1	84	9.33	208	23.11	28	3.11	164	18.22	484	53.78
House Mouse	MUMU1	0	0	0	0	1	0.11	0	0	1	0.11
Mexican Woodrat	NEME1	0	0	0	0	0	0	3	0.33	3	0.33
Meadow Vole	MIPE1	0	0	1	0.11	0	0	49	5.44	50	5.56
Prairie Vole	MIOC1	16	1.78	7	0.78	1	0.11	24	2.67	48	5.33
Plains Harvest Mouse	REMO1	1	0.11	0	0	0	0	0	0	1	0.11
Western Harvest Mouse	REME1	17	1.89	10	1.11	15	1.67	14	1.56	56	6.22
Plains Pocket Mouse	PEFL2	5	0.56	0	0	0	0	0	0	5	0.56
Silky Pocket Mouse	PEFL1	0	0	1	0.11	0	0	0	0	1	0.11
Olive-backed Pocket Mouse	PEFA1	0	0	0	0	0	0	0	0	0	0
Hispid Pocket Mouse	CHHI1	2	0.22	2	0.22	6	0.67	0	0	10	1.11
Preble's Meadow Jumping Mouse	ZAHU1	0	0	0	0	0	0	0	0	0	0
Western Jumping Mouse	ZAPR1	0	0	0	0	0	0	0	0	0	0
13-lined Ground Squirrel	SPTR1	2	0.22	0	0	0	0	0	0	2	0.22
TOTAL		127	14.11	229	25.44	51	5.67	254	28.22	661	73.44

= total number of captures, excluding recaptures

#/100TN = number of captures per 100 trap-nights, excluding recaptures, based on 900 trap-nights per community

Table C-17. ***Small Mammal Capture Summary at the Rocky Mountain Arsenal, Fall 1986.*** Adapted from Shell 1989.

Species	*Tall Weedy Forbs* #/100 TN	*Short Weedy Forbs* #/100 TN	*Cheatgrass* #/100 TN	*Crested Wheatgrass* #/100 TN	*Native Grass* #/100 TN	*Shrubs/Yucca*[1] #/100 TN	*Cottonwoods* #/100 TN	*TOTAL* #/100 TN
Deer Mouse	31.9	15.6	8.3	2.5	0.3	13.9	1.1	73.6
Plains Harvest Mouse	2.2						1.1	3.3
Western Harvest Mouse						2.2		2.2
Northern Grasshopper Mouse					0.6	3.3		3.9
Meadow Vole							7.8	7.8
Prairie Vole	0.3		0.3	0.3	0.3			1.2
Ord's Kangaroo Rat						1.1		1.1
TOTAL	34.4	15.6	8.6	2.8	1.2	20.5	10.0	93.1

#/100TN = number of captures per 100 trap-nights, from Shell (1989).

1 Shrubs include sand sagebrush and rubber rabbitbrush.

Table C-18. Small Mammal Age and Sex Data, Xeric Mixed Grassland Community, Fall 1994.

Species	Code	TR01			TR06			TR12			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	19	18	8	7	12	2	9	6	3	35	36	13
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1										0	0	0
Prairie Vole	MIOC1				3	9	4				3	9	4
Plains Harvest Mouse	REMO1						1				0	0	1
Western Harvest Mouse	REME1				4	8	1	4			8	8	1
Plains Pocket Mouse	PEFL2					5					0	5	0
Silky Pocket Mouse	PEFL1										0	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1		1			1					0	2	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1	1				1					1	1	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-19. Small Mammal Age and Sex Data, Mesic Mixed Grassland Community, Fall 1994.

Species	Code	TR02			TR04			TR11			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	17	31	23	42	40	17	15	9	9	74	80	49
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1		1								0	1	0
Prairie Vole	MIOC1	3	3						1		3	4	0
Plains Harvest Mouse	REMO1										0	0	0
Western Harvest Mouse	REME1				2	2	1	3	2		5	4	1
Plains Pocket Mouse	PEFL2										0	0	0
Silky Pocket Mouse	PEFL1				1						1	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1		1		1						1	1	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1										0	0	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-20. Small Mammal Age and Sex Data, Reclaimed Grassland Community, Fall 1994.

Species	Code	TR07			TR08			TR09			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	8	2		6	3	6	2			16	5	6
House Mouse	MUMU1				1						1	0	0
Mexican Woodrat	NEME1										0	0	0
Meadow Vole	MIPE1										0	0	0
Prairie Vole	MIOC1			1							0	0	1
Plains Harvest Mouse	REMO1										0	0	0
Western Harvest Mouse	REME1	7	6	1			1				7	6	2
Plains Pocket Mouse	PEFL2										0	0	0
Silky Pocket Mouse	PEFL1										0	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1	2	3		1						3	3	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1										0	0	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-21. Small Mammal Age and Sex Data, Riparian Community Complex, Fall 1994.

Species	Code	TR03			TR05			TR10			TOTAL		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	33	25	11	25	21	15	11	12	6	69	58	32
House Mouse	MUMU1										0	0	0
Mexican Woodrat	NEME1		1	1		1					0	2	1
Meadow Vole	MIPE1	10	15		2	3	4		2	12	12	20	16
Prairie Vole	MIOC1	2			5	10	1	3	3		10	13	1
Plains Harvest Mouse	REMO1										0	0	0
Western Harvest Mouse	REME1				2		1	5	3	3	7	3	4
Plains Pocket Mouse	PEFL2										0	0	0
Silky Pocket Mouse	PEFL1										0	0	0
Olive-backed Pocket Mouse	PEFA1										0	0	0
Hispid Pocket Mouse	CHHI1										0	0	0
Preble's Meadow Jumping Mouse	ZAHU1										0	0	0
Western Jumping Mouse	ZAPR1										0	0	0
13-lined Ground Squirrel	SPTR1										0	0	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 300 trap-nights per site.

Table C-22. Small Mammal Age and Sex Data, All Communities, Fall 1994.

Species	Code	*Xeric Grassland*			*Mesic Grassland*			*Reclaimed Grassland*			*Riparian Complex*			*TOTAL*		
		ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV	ADM	ADF	JUV
Deer Mouse	PEMA1	35	36	13	74	80	49	16	5	6	69	58	32	194	179	100
House Mouse	MUMU1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Mexican Woodrat	NEME1	0	0	0	0	0	0	0	0	0	0	2	1	0	2	1
Meadow Vole	MIPE1	0	0	0	0	1	0	0	0	0	12	20	16	12	21	16
Prairie Vole	MIOC1	3	9	4	3	4	0	0	0	1	10	13	1	16	26	6
Plains Harvest Mouse	REMO1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Western Harvest Mouse	REME1	8	8	1	5	4	1	7	6	2	7	3	4	27	21	8
Plains Pocket Mouse	PEFL2	0	5	0	0	0	0	0	0	0	0	0	0	0	5	0
Silky Pocket Mouse	PEFL1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Olive-backed Pocket Mouse	PEFA1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hispid Pocket Mouse	CHHI1	0	2	0	1	1	0	3	3	0	0	0	0	4	6	0
Preble's Meadow Jumping Mouse	ZAHU1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Jumping Mouse	ZAPR1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-lined Ground Squirrel	SPTR1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0

ADM = Adult Males
ADF = Adult Females
JUV = Juveniles and Sub-Adults
Values based on 900 trap-nights per community.

Table C-23. Average Number of Individuals of All Species and Average Trap Success per Season and Year.

	number of individuals (all species)			rate of successful traps (captures per trap-night)		
season and year	average	maximum	minimum	average	maximum	minimum
spring 1993	21.13[a]	59	2	0.071[a]	0.197	0.007
fall 1993	59.25[b]	144	16	0.198[b]	0.480	0.053
1993	44.00	144	2	0.147	0.480	0.007
spring 1994	35.25[ab]	58	8	0.118[ab]	0.193	0.027
fall 1994	55.08[ab]	108	2	0.184[ab]	0.360	0.007
1994	45.17	108	2	0.151	0.360	0.007

Letters in common signify no significant difference (α=0.05). Year totals do not differ significantly from each other at the α=0.05 level.

Table C-24. Average Number of Individuals of All Species and Average Trap Success Rate by Site and Community.

community		average number of individuals	average success rate (% traps with a capture)
xeric grassland			
	TR01	39.75	0.133
	TR06	50.00	0.167
	TR12	16.00	0.053
	All	33.91[ab]	0.113[ab]
mesic grassland			
	TR02	73.67	0.246
	TR04	61.00	0.203
	TR11	35.25	0.118
	All	55.09[bc]	0.184[bc]
reclaimed grassland			
	TR07	22.00	0.073
	TR08	25.00	0.083
	TR09	7.00	0.024
	All	17.64[a]	0.059[a]
riparian complex			
	TR03	97.00	0.323
	TR05	76.00	0.253
	TR10	49.00	0.164
	All	71.91[c]	0.24[c]

Means with one or more letter in common are not significantly different at $\alpha=0.05$.
Compare means down columns.

Table C-25. Small Mammal Capture Summary, All Communities, 1993 and 1994.

	Xeric				*Mesic*				*Reclaimed*				*Riparian*				*All Communities*			
	1993		1994		1993		1994		1993		1994		1993		1994		1993		1994	
Species	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Deer Mouse	4	7.4	9.7	9.3	4.2	21.0	11.0	23.1	1.7	7.7	2.7	3.1	10.2	25.8	10.6	18.2	5.0	15.5	8.5	53.8
House Mouse	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.1
Mexican Woodrat	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.3	0	0	0	0.3
Meadow Vole	0	0.1	0.4	0	0	0.1	0.1	0.1	0.3	0.1	0	0	5.5	2.8	3.1	5.4	1.5	0.5	0.9	5.6
Prairie Vole	0	1.1	1.1	1.8	0.7	1.7	0.8	0.8	0	0.1	0	0.1	0	4.1	1.3	2.7	0.2	1.5	0.8	5.3
Plains Harvest Mouse	0	0	0.6	0.1	0	0	0.1	0	0	0	0.2	0	0.2	0	0	0	0	0	0.2	0.1
Western Harvest Mouse	0	1.1	0.2	1.9	0	0.8	0.2	1.1	0	0.8	0.7	1.7	0.2	0.9	0.2	1.6	0	0.6	0.3	6.2
Plains Pocket Mouse	0	0	0.1	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6
Silky Pocket Mouse	0	0.4	0.1	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0.1	0	0.1
Olive-backed Pocket Mouse	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hispid Pocket Mouse	0.2	0.3	0.2	0.2	0	0.2	0	0.2	0.2	1.4	0.22	0.7	0	0	0	0	0.1	0.5	0.1	1.1
Preble's Meadow Jumping Mouse	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
Western Jumping Mouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-lined Ground Squirrel	0.3	0.3	0.9	0.2	0.2	0.4	2.1	0	0.2	0.1	0.3	0	0	0	0	0	0.200	0.2	0.8	0.2
TOTAL	4.7	10.7	0.0	14.1	5.1	24.2	14.3	25.4	2.3	10.2	4.11	5.7	16.2	33.7	15.2	28.2	7.0	18.9	11.8	73.4

Values based on number captured per 100 trap-nights, excluding recaptures.

Table C-26. Deer Mouse Age and Sex Ratios, Spring and Fall 1993 and 1994

Community	*Spring 1993*		*Fall 1993*		*Spring 1994*		*Fall 1994*	
	M/CF	Y/CF	M/CF	Y/CF	M/CF	Y/CF	M/CF	Y/CF
Xeric Grassland	250	33	89	56	103	8	97	36
Mesic Grassland	91	36	93	31	104	0	93	61
Reclaimed Grassland	125	25	88	88	150	38	320	120
Riparian Complex	133	17	93	36	114	0	119	55
All Communities	121	23	92	41	109	4	108	56

M/CF=Males per 100 Females
Y/CF=Young per 100 Females

Table C-27. Association Between Plant Species and Trap Success.

Scientific Name	X^2	P<	Number of Occurrences Associated with Successful Trapsites	Number of Occurrences Associated with Unsuccessful Trapsites
Spring 1994				
Artemisia ludoviciana	5.12	0.05	27	44
Draba reptans	5.22	0.05	19	7
Lactuca serriola	4.40	0.05	22	37
Salix exigua	4.42	0.05	15	5
Fall 1994				
Artemisia frigida	4.46	0.05	44	28
Convolvulus arvensis	6.44	0.05	8	22
Erigeron flagellaris	4.82	0.05	24	11
Gutierrezia sarothrae	4.40	0.05	45	29
Nepeta cataria	4.30	0.05	10	2
Plantago lanceolata	4.27	0.05	0	6
Senecio plattensis	5.22	0.05	16	5
Sporobolus cryptandrus	4.05	0.05	4	13
Taraxacum officinale	5.07	0.05	13	27
Fall 1993				
Agrostis hyemalis	6.33	0.05	3	14
Monarda fistulosa	5.30	0.05	0	7
Sisymbrium altissimum	5.22	0.05	16	5

Table C-28. Correlation of Physical Characteristics

Pair-wise Comparison	Pearson's r	P<
Spring 1994 (n = 241)		
DCE and ANG	0.248	0.01
DCE and ASP	0.141	0.05
ANG and ASP	0.250	0.01
Fall 1994 (n = 233)		
DCE and ANG	0.272	0.01
DCE and ASP	0.162	0.05
ANG and ASP	0.469	0.01

Table C-29. Distance of the Trap Station to the Nearest Canopy Edge for 1994 *Zapus hudsonius preblei* Captures.

distance to canopy edge (m)	number	frequency	%
0	35	35	63.64
1	7	42	76.36
2	3	45	81.82
3	2	47	85.45
5	2	49	89.09
10	2	51	92.73
30	1	52	94.55
40	1	53	96.36
45	1	54	98.18
150	1	55	100.00

Table C-30. Distance of the Trap Station to the Nearest Embankment for *Zapus hudsonius preblei* Captures.

distance to embankment (m)	number	frequency	%
0	19	19	34.55
1	13	32	58.18
2	5	37	67.27
3	6	43	78.18
4	1	44	80.00
5	2	46	83.64
9	1	47	85.45
10	3	50	90.91
16	1	51	92.73
20	1	52	94.55
30	1	53	96.36
40	2	55	100.00

Table C-31. Distance of the Trap Station to the Nearest Stream Channel for *Zapus hudsonius preblei* Captures.

distance to stream (m)	number	frequency	%
0	2	2	3.64
1	11	13	23.64
2	9	22	40.00
3	10	32	58.18
4	5	37	67.27
6	2	39	70.91
9	1	40	72.73
12	1	41	74.55
13	1	42	76.36
15	2	44	80.00
25	3	47	85.45
27	1	48	87.27
30	5	53	96.36
35	2	55	100.00

Table C-32. Soil Moisture, Burrowing Opportunities, Litter Cover, and Trap Position for *Zapus hudsonius preblei* Capture Locations.

moisture	number	%
xeric	0	0.00
mesic	21	38.18
humid	27	49.09
hydric	7	12.73

burrowing opportunities	number	%
low	0	0.00
medium	19	34.55
high	36	65.45

litter	number	%
low	2	3.64
medium	13	23.64
high	40	72.73

trap canopy position	number	%
in	3	5.45
out	17	30.91
edge	35	63.64

Table C-33. Primary Canopy Species for *Zapus hudsonius preblei* Capture Locations.

Canopy Species	common name	number	%
Salix exigua	coyote willow	31	56
Amorpha fruticosa	leadplant	19	35
Prunus virginiana	chokecherry	3	5
Symphoricarpos occidentalis	snowberry	1	2
Salix amygdaloides	peachleaf willow	1	2

Table C-34. Frequency of Occurrence of All Plant Species at *Zapus hudsonius preblei* Capture Locations.

Species	Common Name	Number	Occurrence
Cirsium arvense	Canadian thistle	58	96.67
Bromus japonicus	Japanese brome	46	76.67
Salix exigua	peachleaf willow	43	71.67
Agropyron smithii	western wheatgrass	40	66.67
Poa pratensis	Kentucky bluegrass	39	65.00
Juncus balticus	baltic rush	36	60.00
Barbarea orthoceras	northern winter cress	36	60.00
Amorpha fruticosa	leadplant	35	58.33
Hypericum perforatum	St. John's-wort	34	56.67
Symphoricarpos occidentalis	snowberry	32	53.33

Table C-35. Frequency and Cover of Community Types at *Zapus hudsonius preblei* Capture Locations.

	Primary Community		Secondary Community		Tertiary Community		Quaternary Community		Total	
Community Type	frequency	%	frequency	%	frequency	%	frequency	%	frequency	% cover
bottomland shrubland	41	68.33	9	15.00	2	3.33	0	0.00	52	0.615
mesic mixed grassland	8	13.33	26	43.33	4	6.67	4	6.67	42	0.133
upland shrubland, short	6	10.00	9	15.00	4	6.67	5	8.33	24	0.121
short marsh	4	6.67	3	5.00	3	5.00	4	6.67	14	0.078
tall marsh	0	0.00	4	6.67	3	5.00	1	1.67	8	0.006
deciduous woodland	0	0.00	1	1.67	4	6.67	0	0.00	5	0.006
rehabilitation mixed grassland	1	1.67	2	3.33	2	3.33	0	0.00	5	0.029
wet meadow/marsh	0	0.00	0	0.00	4	6.67	0	0.00	4	0.005
streams	0	0.00	2	3.33	1	1.67	0	0.00	3	0.003
upland shrubland, tall	0	0.00	1	1.67	1	1.67	1	1.67	3	0.004
xeric mixed grassland	0	0.00	0	0.00	1	1.67	0	0.00	1	0.001
disturbance habitats	0	0.00	0	0.00	0	0.00	0	0.00	0	0.000

APPENDIX D. AQUATIC ECOLOGY

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BACKGROUND

The aquatic ecosystems associated with the Site range from natural springs and seeps to diversion ditches and containment ponds designed to hold "domestic" sewage outfall and accidental contaminant releases. The hydrology of onsite streams and ponds is highly regulated by both onsite activities and the needs of neighboring municipalities and individual ranchers. Subsequently, both streamflow and pond elevation vary with both the season and short-term anthropogenic manipulation. Transport of contaminants via surface water to receptor ecosystems onsite; i.e:, Woman Creek, and possible transport offsite are major concerns of DOE-RFFO.

OBJECTIVES

The EcMP Aquatic Ecology Module had three main objectives for the 1994 season, corresponding to the three main projects of the module; 1) long-term ecological monitoring , 2) bioassessment of Walnut Creek, and 3) tissue sampling for the Woman and Walnut Creek Drainages and offsite reservoirs. This section is devoted primarily to the reporting and discussion of the aquatic ecological monitoring program. Results and discussion of the bioassessment are available in Wright Water Engineers, Inc. (1995). Results and discussion of the tissue sampling study are available in EG&G (1994).

Objectives specific to the monitoring program are a) to characterize the aquatic communities onsite, b) to determine sources of variation, both natural and anthropogenic, that affect seasonal, annual, and long-term fluctuations in the aquatic ecosystems, c) to compare the Rocky Flats aquatic ecosystems to offsite systems, and d) to determine if parameters associated with aquatic community structure can be correlated with the overall "health" (degree of disturbance or contamination) of individual systems.

Aquatic Ecological Monitoring Program

Due to budget constraints, sampling in 1994 was restricted to only onsite ponds. The objective of the program was to continue the long-term monitoring of the health and composition of Rocky Flats aquatic ecosystems. Four major biological components of aquatic systems were sampled; macrobenthic invertebrates (insect nymph and larvae), phytoplankton (algae), zooplankton (diatoms and other microscopic animals), and emergent insect (adult mayflies, mosquitoes, etc.) populations (Figure D-1). Abundance, taxonomic composition, and taxonomic richness were the main parameters measured from each. Some of the EcMP pond sampling results were used by the Environmental Restoration Program Division as reference data for the OU6 Remedial Investigation (RI).

Bioassessment of Walnut Creek

The main purpose of this study was to assess the overall ecologic health of Walnut Creek and to evaluate the potential causes of variations in the aquatic communities, in order to establish a relationship between the amount of ammonium (NH_4) in the water and the health of the biological community. A primary focus was on the potential effects on biota of ammonium effluent discharges from the Site wastewater treatment plant (WWTP) to the A- and B- series ponds and to the downstream reaches of Walnut Creek. EG&G's Surface Water Division and EcMP staff collaborated on this study to provide supporting documentation for a DOE proposal to the Colorado Water Quality Control Commission (WQCC) to re-classify portions of Segments 4 and 5 of Walnut Creek, such that all of Walnut Creek east of Indiana Street would become Segment 5 and to remove the current ammonium standard for this revised segment. This requires a demonstration that the targeted stream area has different characteristics than the rest of the stream segment. These characteristics include water flow, water quality, habitat, and biological conditions. Based on Section 3.1.6 (4) of the State's Basic Standards for surface water (1993), "segments shall generally

be delineated according to the points at which the use physical characteristics or water quality characteristics of a water course are determined to change significantly...." The assignment of standards is based on the nature of the pollutant, the need, effects on organisms, and other factors as described in Section 3.1.7(2) of the Basic Standards. Refer to Wright Water Engineers, Inc. (1995) for specific methods, results, and interpretation.

Tissue Sampling for Woman and Walnut Creek Drainage and Offsite Reservoirs

Results of sediment and tissue samples collected during the OU 6 RI (EG&G, 1994) indicated elevated polychlorinated biphenyl (PCB) concentrations from some of the A-and B-series ponds. The A- and B- series ponds are located in the drainages of North and South Walnut creeks (Table D-1 and Figure 2, Technical Summary). Prior to 1989, Walnut Creek discharged into Great Western Reservoir (OU 3, IHSS 200). A diversion canal was constructed in 1989 that routed the flow coming from Walnut Creek around Great Western Reservoir and back into Walnut Creek below the dam. The potential exists for sediments and/or specific biota in Great Western Reservoir and Standley Lake Reservoir to have been impacted by PCB contaminants from the Site prior to 1989.

Therefore, a sediment and tissue PCB's sampling project was included as part of the Environmental Evaluation (EE) portion of the OU 6 RI. EcMP staff conducted all fish tissue sampling for this project. Fish samples were taken from the Walnut Creek terminal pond at Indiana Street (OU 6) and Great Western Reservoir to determine if any PCB'S have migrated downstream of the terminal ponds and bioaccumulated in fish species.

The study was expanded at the request of DOE (DOE, 1994b) to include fish tissue samples from Mower Reservoir, Standley Lake Reservoir, the C-series ponds, and the D-series ponds (Figure 2, Technical Summary). Refer to EG&G (1994) for specific methods, results, and interpretation.

HYPOTHESES

Aquatic Ecological Monitoring Program

H_o: There is no significant difference between the macrobenthic invertebrate communities of onsite aquatic systems.
H_A: There is a significant difference between the macrobenthic invertebrate communities of onsite aquatic systems.

H_o: There is no significant difference between the phytoplankton communities of onsite aquatic systems.
H_A: There is a significant difference between the phytoplankton communities of onsite aquatic systems.

H_o: There is no significant difference between the zooplankton communities of onsite aquatic systems.
H_A: There is a significant difference between the zooplankton communities of onsite aquatic systems.

H_o: There is no significant difference between the emergent insect communities of onsite aquatic systems.
H_A: There is a significant difference between the emergent insect communities of onsite aquatic systems.

Bioassessment of Walnut Creek

H_o: There is no significant difference between the physical/chemical composition of onsite aquatic systems.

H_A: There is a significant difference between the physical/chemical composition of onsite aquatic systems.

H_o: The calculated Ephemeroptera, Plecoptera, Tricoptera over Chironomidae (EPT/C) index is directly correlated with the ecosystem health of a site.

H_A: The calculated EPT/C index is not directly correlated with the ecosystem health of a site.

METHODS

Various methods were used for collecting aquatic samples from ponds and streams. The techniques and tools used for obtaining aquatic samples depend on current velocity, substrate characteristics, and the objective of the sampling program.

Aquatic Ecological Monitoring Program

Field Methods

The sampling season was from April through September, 1994. A total of 346 biological samples were taken and used for the monitoring program (126 macrobenthic invertebrate samples, 68 phytoplankton samples, 69 zooplankton samples, and 83 emergent insect samples). Collection methods for aquatic samples are documented in the EcMP Program Plan (EG&G, 1993). In addition to following "Aquatic Invertebrate Sampling, Standard Operating Procedure" (SOP, 4-K49-ENV-ECOL.02 REVISION 2) and "Fish Sampling SOP" (4-L04-ENV-ECOL-04 REVISION 2), new sampling methods have been developed and implemented. A new water column zooplankton sampler, developed by subcontractor Ecosystem Testing Design Incorporated of Kansas (ETDI), was successfully used by aquatic technicians (Figure D-2). Both qualitative and quantitative results were obtained and time was saved by using this method. A different method, tested for the first time this year, was the new sediment core sampler (ETDI, manufacturer), for macrobenthic invertebrate sampling. Technicians were able to pull four core columns simultaneously, reducing effort and saving time (Figure D-3) over single core sampling. The core sampler was used from a boat only, due to the weight of the equipment.

Laboratory Methods

Quality assurance of taxonomic identification and enumeration procedures is accomplished by maintaining a voucher collection of aquatic organisms and the use of detailed Quality Assurance/Quality Control (QA/QC) procedures used by the contract laboratory (ETDI). Methods and data handling procedures employed by ETDI meet EPA protocols for level 3 data.

Analytical Methods

Macrobenthic Invertebrates

The Jaccard coefficient of similarity, J (Digby and Kempton, 1987), was calculated in a pair-wise manner (i.e., every possible combination of two sites paired) on the macrobenthic community composition for all sites sampled. The index was calculated at the level of family, the lowest taxonomic level to which individual organisms could be confidently and consistently identified. The Jaccard index is limited to comparing only the presence or absence of a taxa between two sites. The values range from 0 to 1, with 1 being a perfect match in taxonomic composition between two sites (Table D-2). The Jaccard coefficient is the most widely used index of similarity between two

objects and can be viewed in this instance as a percent value of taxa that two sites have in common (e.g., J = 0.44 for macrobenthic invertebrates in comparing ponds A-1 to A-2, then A-1 and A-2 share 44% of the same macrobenthic taxa).

Analyses of variance (ANOVA's) were calculated to determine differences between sites and differences between sampling methods using taxonomic richness (the number of distinguishably different taxa per sample) of macrobenthic invertebrates as the discriminating measure. Lindsay Pond (SW05) was removed from the data set because only one sample was taken at the pond. Each sampling method (drift net, dip net, core sampling, and surber sampling) was tested separately for differences among sites, with the exception of surber sampling, as there were no replicate samples using this method. Also, ANOVA was conducted on a composite macrobenthos richness value.

Phytoplankton

As with macrobenthic invertebrates, a Jaccard coefficient of similarity was calculated for each site sampled in a pair-wise fashion on phytoplankton community composition. Calculations were made at the genus level, as this was the lowest taxonomic level identified. Because similarity indices only deal with the presence or absence of a taxa, the phytoplankton community composition in terms of relative abundance was also examined for each pond sampled. Relative abundance was calculated at the taxonomic Division level to simplify visual comparison of sites.

ANOVA was used to determine differences between sites using taxonomic richness (number of genera per sample) of phytoplankton as the discriminating measure.

Zooplankton

A Jaccard coefficient of similarity was calculated for each site sampled in a pair-wise fashion on zooplankton community composition. Calculations were made at the genus level, as this was the lowest taxonomic level identified. ANOVA was used to determine differences between sites using taxonomic richness (number of genera per sample) of zooplankton as the discriminating measure.

Emergent Insects

A Jaccard coefficient of similarity was calculated for each site sampled in a pair-wise fashion on the emergent insect community composition. Calculations were made at the genus level, as this was the lowest taxonomic level identified. ANOVA was used to determine differences between sites using taxonomic richness (the number of distinguishably different taxa per sample) of emergent insects as the discriminating measure.

Bioassessment of Walnut Creek

Fields Methods

Three different sampling methods were chosen for the macrobenthic invertebrate sampling for the Bioassessment of Woman and Walnut Creeks. Dip net, surber sampler, and drift net methods were used according to the SOP, "Aquatic Invertebrate Sampling" (4-K49-ENV-ECOL.02 REVISION 2).

Flow and water quality characteristics of lower Walnut Creek below the Site ponds were compared to data from Woman Creek (the reference site). The bioassessment used data from a 1991 biological characterization study and new data collected by the Ecology Staff in July and September, 1994, which used procedures consistent with EPA's Rapid Bioassessment Protocols (EPA RBP III) for use in streams and rivers (EPA, 1989). These procedures assume that

macrobenthic invertebrates are sensitive biological indicators of the physical and chemical characteristics of a stream, and therefore the stream's overall biological health.

Quantitative samples of aquatic biota were collected in June, 1994, primarily to support the Ecological Risk Assessment for OU 6. These data were also used to characterize the Segment 5 pond ecosystems. At each pond, A-1 through A-4, B-1 through B-5, D-1, D-2, and Lindsay Pond, five samples each were taken from multicore samplers, emergent insect traps, integrated water column zooplankton samplers, and surface (0.25 m depth) phytoplankton samplers in order to quantify aquatic biota composition.

For water chemistry, two replicate samples were taken from eight sites, A-4, BD1, BD2, GW2, GW3, IW1, and W2 (Table D-1). See Figure 2, Technical Summary, for site locations.

Laboratory Methods

For biotic samples, the Ecology Staff maintain a voucher collection and detailed QA/QC procedures used by the contract laboratory (ETDI). Methods and data handling procedures employed by ETDI meet EPA protocols for level 3 data. For water chemistry samples, completed chemical analysis results and extensive QA/QC documentation for all of the 1994 samples were delivered by Global GeoChemistry (GGC) in hard copy and digital format. Laboratory methods and data handling procedures employed by GGC meet EPA protocols for level 3 data.

Analytical Methods

The sum of all individuals within the orders Ephemeroptera, Plecoptera, and Tricoptera was divided by the sum of individuals within the Chironomidae family to create the EPT/C index value for every sample (Table D-2). The EPT/C index was calculated for every sample taken as a representation of aquatic ecosystem health. The three orders in the numerator are considered to be sensitive to environmental pollutants, while Chironomids are generally pollution tolerant (EPA, 1989). Therefore, a low EPT/C index value indicates an unbalanced macrobenthic community and, presumably, a system in poor health. However, a zero value appears to represent insufficient data, rather than a highly polluted system. Therefore, only non-zero EPT/C index values were used in comparative calculations.

To explore the possibility that the EPT/C index is redundant to other measures of community health, correlations were performed on the index value and the corresponding taxonomic richness of collected samples. Pearson's Correlation Coefficient was used and results were initially significant ($P < 0.05$), but it was suspected that the high number of zero index values were skewing the results. The test was repeated with all samples containing a zero EPT/C index value removed and the correlation between the two parameters was no longer significant. Therefore, the EPT/C index is considered to be a measure of ecosystem health and it does not have a linear relationship to taxonomic richness. ANOVA's were calculated to determine differences between sites and differences between sampling methods using the EPT/C index.

Water chemistry samples were divided into "before" and "after" sewage release dates and analyzed with a paired Student's T-test for significant difference in major chemical parameters due to sewage releases. Parameters tested were NH_4, Cl, PO_4, Br, NO_3, SO_4, Na, K, Ca, Mg, Al, and Fe. A significant effect indicates that the difference between before and after release values of a variable are significantly different than zero.

Tissue Sampling for Walnut and Woman creek Drainages and Offsite Reservoirs

A gill net, seine net, and minnow traps were used for the sampling of fish tissue for the PCB sampling project. Methods cited in the SOP "Fish Sampling" (4-L04-ENV-ECOL-04 REVISION 2) were followed.
Detailed methods, results, and discussion of the tissue sampling study are available in EG&G (1994).

RESULTS

Aquatic Ecological Monitoring Program

Macrobenthic Invertebrates

Analyses used to make comparisons among sites included ANOVA tests, the EPT/C index and the Jaccard coefficient of similarity.

A one-way (one source of variance) ANOVA was used to test for significant difference in taxonomic richness between sites with a composite of all sampling methods (i.e., all taxa collected at a site, regardless of sampling method used. Table D-3). There is a highly significant difference in macrobenthic invertebrate richness between sites (p=0.00). Pond A-1 to pond A-4 show a trend of declining richness (Figure D-4). Pond A-1 had the highest mean macrobenthic invertebrate taxonomic richness of all the sites (18.4), which is significantly greater than the terminal pond in the series, A-4 (2.6). The sites that were most similar in their mean taxonomic richness values were BD1 (12.6) and W2 (12.8). Sites BD1 and W2 are streamsites in the Big Dry Creek drainage (Figure 2, Technical Summary). It is expected that sites BD1 and W2 would be most similar due to their close proximity (50 m) within the same drainage.

ANOVA's of taxonomic richness broken down by each sampling method indicate that there were significant differences between sampling methods. However, due to both variances and sample sizes being unequal, these were not reliable tests (Table D-3).

ANOVA'S were individually calculated for the core method, the drift net method and the hand picked dip net sampling method. Each result will be discussed separately by sampling method. The core method was used to sample pond and stream macrobenthos. There is a highly significant difference in macrobenthic invertebrate richness among sites (p=0.0000, Table D-3). The trend of declining richness from Pond A-1 to Pond A-4 is clearly repeated here (Figure D-5). Pond A-1 had the highest mean macrobenthic invertebrate taxonomic richness of all the sites (18.4), which is significantly greater than the terminal pond in the series, A-4 (2.6). The sites that were most similar by the core method in their mean taxonomic richness values were A-3 (6.2) and D-1 (6.0).

The dip net method showed no significant difference in taxonomic richness among sites sampled (Figure D-6). However, the sample size for this technique was small (n=17 for all sites sampled, approximately 3 observations per site), decreasing the reliability of the analysis. Dip net sampling will be repeated in the next season for comparison.

The results of the ANOVA for the drift net method (Table D-3) showed significant difference in taxonomic richness among sites (p=0.048), despite a small sample size (n=19 for all sites sampled, approximately 4 observations per site). However the Tukey Honest Significant Difference (HSD) analysis (a more conservative test) did not show a significant difference (Figure D-7). The mean taxonomic richness for all five sites sampled with drift nets are streams were: BD1 (16.0), BD2 (9.3), W1 (8.0), and W2 (14.3) and GW3 (24.3). Streamsite GW3 stands out as clearly higher in macrobenthic richness than the other streams (Figure D-7).

All macrobenthic invertebrate sampling methods were combined in a final analysis of taxonomic richness (Table D-3). Overall, sites differed in the number of macrobenthic families collected regardless of sampling method (p = 0.0001) and no sampling method stood out from the others in capturing distinctly more or less macrobenthic families (Figure D-8).

Pond A-1 has a mean macrobenthic invertebrate taxonomic richness of 18.4 (Table D-4), with 16 orders and 18 families represented in a total of six functional groups. The EPT/C index is low (0.078, Table D-5), with Chironomidae being well represented. The Jaccard coefficient indicated that Pond B-1 was most similar to B-2 (J=0.75, Table D-6). Eighty percent of all of the families in Pond A-1 are annelids (segmented worms). Pond B-1 is species rich with a mean taxonomic richness of 16.0 (Table D-4), with seven functional groups present. The mean EPT/C index is 1.876 with two representative taxonomic groups (Chironomidae, and Ephemeroptera). Forty percent of all of the families in Pond B-1 are annelids and 33% are mollusks. Pond D-1 contained 15 orders but had only one representative family from both Chironomidae and Ephemeroptera. The EPT/C index is zero and Pond D-1 has a lower taxonomic richness (6.66) than Pond B-1. There were six functional groups represented.

Pond D-2 is a reference pond for aquatic ecological studies. It has the highest mean value for the EPT/C index (2.172) which is directly correlated to the presence of all four target taxa (Ephemeroptera, Plecoptera, and Tricoptera orders and the Chironomidae family). There are 21 orders represented in nine functional groups. Although D-2 does not show the highest value for family richness (12.8, Table D-4), an analysis of the taxonomic composition of families reveals a comparatively well balanced ecosystem.

Phytoplankton

A one-way ANOVA was used to test for significant difference in phytoplankton taxonomic richness between sites (Table D-7, Figure D-9). There is a highly significant difference in richness between sites (p=0.0000). Seven Divisions of algae are represented in Rocky Flats aquatic ecosystems; Bacillariophyceae (diatoms), Chlorophyta (green algae), Chrysophyta (golden brown algae), Cryptophyta (cryptophytes), Cyanophyta (blue green algae), Euglenophyta (flagellates), and Pyrrhophyta (dinoflagelates). A total of 72 phytoplankton taxa have been identified and logged in the reference collection for the Site to date.

Community composition and relative abundance of algae varies widely between ponds, even those closely in series to one another. The Jaccard index shows that no two ponds are more than 65% alike in the composition of algal genera (A-3 and B-3, Table D-8). In an overall comparison against all other sites, both Pond B-4 and Pond C-2 are the most unlike any of the other ponds in their phytoplankton taxonomic composition.

Figures D-10 through D-16 represent the phytoplankton relative abundance for each site sampled. Overall, Cyanophytes were the most abundant algae on the Site, making up 47.1% of the algae sampled (sample standard deviation, s, = 27.3). Next abundant were the Chlorophytes, at 31.3% (s = 18.1). The rarest taxa were the Chrysophytes, 1% (s = 1.3), and the Pyrrhophytes, <1% of the algae sampled.

Ponds that were sampled for phytoplankton in both 1993 and 1994 are A4, B5, C2, D1, D2, and Lindsay Pond. Comparing the relative abundance from year to year, Lindsay and D2 ponds have remained the same, Cyanophytes have decreased in ponds A4, B5, and D1 (from 52.9% to 6.8%; 73.1% to 25.3%; and 81.2% to 45.9%, respectively). Chlorophytes increased in D1 (from 15% to 40.5%), Cryptophytes increased an order of magnitude in B5 (from 4.7% to 40.1%), and Euglenophytes increased nearly an order of magnitude in A4 (from 2.5% to 18%). The degree of variation in relative abundance of algae for the C2 Pond was too high in 1993 to allow a comparison with 1994 results.

Zooplankton

A one-way ANOVA was used to test for significant difference in zooplankton taxonomic richness between sites (Table D-9). There is a highly significant difference in richness between sites (p=0.0000). Pond B-2 was significantly greater in taxonomic richness than most other sites (Figure D-17). The greatest differences were between B-2 (19 taxa, s=3.32) and B-4 (6 taxa, s=1.00). The least amount of difference was between B-3 (10 taxa, s=2.79) and B-5 (11 taxa, s=4.37, Table D-4). Ponds B-3 through B-5, C-2, and D-1 show similarity in zooplankton taxonomic richness (Figure D-17). Pond B-2 is the most taxonomically rich.

The Jaccard coefficient of similarity indicates that ponds B-5 and A-3 are the most similar in their zooplankton community composition (J=0.636, Table D-10). Ponds B-4 and C-2 apparently have no zooplankton in common (J=0.00). Reference pond D-2 is most similar to Pond B-2 in zooplankton taxa (J=0.515).

Emergent Insects

A one-way ANOVA was used to test for significant difference in emergent insect taxonomic richness between sites (Table D-11). There is a highly significant difference in richness between sites (p=0.0000). Pond A-2 has the highest number of emergent insect taxa (18.8). The greatest amount of difference was between A-2 (18.8 taxa, s=3.90) and A-4 (3.0 taxa, s=2.12). Ponds A-1 and B-5 had identical numbers of insect taxa (8.4).

Woman Creek (SW03) and Pond C-2 share the most emergent insect taxa (J=0.478) and ponds A-1 and A-3 are the least similar (J=0.080, Table D-12). Reference pond D-2 is most similar to Pond A-2 in emergent insect communities (J=0.396) and the two ponds are not significantly different in taxonomic richness (Figure D-18). The taxonomic representation for Pond A-2 is 5 orders and 10 families. Pond D-2 also had 5 orders but there are 2 less families present.

Bioassessment of Walnut Creek

An EPT/C index value was calculated for all reference and impacted sites in Woman and Walnut Creek drainages, respectively; only non-zero values of the index were used. This reduced the number of sites compared. In addition, sites A-3, B-3, B-4 were removed from analysis because of a lack of non-zero replicates. As expected, ponds A-1, A-2, and B-2 all had low mean EPT/C index values (0.078, 0.003, and 0.220, respectively). Table D-13 displays the macrobenthic invertebrate community of each site to the family level. All sites contain individuals from the Chironomidae family, a ubiquitous taxon. Ponds A-1, A-2, and B-2 apparently contain no individuals from the Plecoptera or Tricoptera order, and few Ephemeroptera, thereby resulting in low EPT/C index values (Table D-5). However, a high number of sampled Chironomidae can produce a low EPT/C index value even if the numerator taxa are well represented, as is the case for Pond D-2. The highest mean EPT/C value (7.035) was for Walnut Creek (W2), approximately 50 meters from the confluence with Big Dry Creek. Chironomidae total 20 for this site but Ephemeroptera = 4, Plecoptera = 0 and Tricoptera = 3.

ANOVA comparisons of the EPT/C index were to be calculated to detect differences in the index value among sites and among macrobenthic sampling methods. However, the calculations could not be performed because the small sample sizes and unequal variances involved violated basic assumptions of the ANOVA technique.

The paired T-test resulted in significant differences for only three of the 13 analytes tested. Ammonium (NH_4) and potassium (K) increased significantly after sewage releases (p=0.01 and p=0.05, respectively). Nitrate (NO_3) decreased significantly after a release (p=0.05). Amounts by which these analytes increased or decreased were very small; NH_4 increased an average of

0.02mg/l (s=0.01mg/l), K increased an average of 1.44mg/l (s=1.64mg/l), and NO_3 decreased an average of 0.37mg/l (s=0.36mg/l). Other analytes had larger differences, for example, SO_4 decreased an average of 70.56mg/l, but the differences varied too greatly from site to site to achieve a significant difference (SO_4 s=153.84mg/l). A summary of ammonium concentrations is given in Figure D-20.

Graphical summaries of macrobenthos and emergent insect richness are given in Figure D-21 and zooplankton and phytoplankton in D-22.

INTERPRETATION

Aquatic Ecological Monitoring Program

Pond A-1 to Pond A-4 (Figure D-4) show a trend of declining macrobenthic invertebrate richness. This trend was not observed in any other pond series or with any other biotic community. The observable decline was detected by the core sampling method. The 1994 core method sampling schedule resulted in the largest number of replicates per site of any of the sampling methods (n=53). With the corresponding effect of higher precision (less variation), the core method was the only 1994 macrobenthic invertebrate field method that could detect the subtle decline (Figure D-5). The surber and the drift net method are both dependent on flowing water and would therefore be limited to sampling in streams. The hand-picked dip net method is designed to be a surface sweeper and would not accurately sample the mud and gravel bottoms. There could be any number of reasons for the decline of macrobenthic invertebrates in the A-series ponds. Pond A-1 is partly fed by a seep that could account for a healthier aquatic environment. During high water conditions, the ponds flow into one another (Figure 2, Technical Summary). A limiting factor to macrobenthic invertebrate taxonomic richness may be industrial practices that progressively degrade the ponds. One approach would be to compare facultative anaerobic macrobenthic invertebrates (organism normally growing anaerobically but able to tolerate aerobic conditions) to those with a continuously high oxygen demand in some of the deeper ponds such as A-4 and B-5. Sampling with the core may not be possible due the depth and may lead to the use of other methods such as an Ekman grabber. A plot of both thermoclines and oxygen isopleths may reveal new ecological relationships both spatially and temporally.

Using the Jaccard Similarity Index tables (Tables D-6, D-8, D-10, and D-12), overall biotic similarities between groups of sites can be examined (Figure D-19). Sites of interest are reference ponds (Ponds D-1, D-2, and SW05), and impacted ponds (the A- and B- series). Out of the four biotic populations sampled (macrobenthic invertebrates, emergent insects, zooplankton, and phytoplankton), the taxonomic composition of reference ponds were compared to each other, as were the composition of impacted ponds to each other, and the composition of reference ponds compared to impacted ponds. No group of ponds shared more than 45% of any of the biota sampled, indicating that Rocky Flats aquatic systems show considerable diversity in their biotic composition. For macrobenthic invertebrate, emergent insect, and phytoplankton community compositions, reference ponds shared more taxa with each other (29%, 29%, and 42%, respectively) and impacted ponds shared more taxa with each other (28%, 29%, and 45%, respectively) than reference and impacted ponds shared(25%, 24%, and 40%, respectively), but only by a few percent. This does not hold true for zooplankton community composition (reference ponds were 25% alike, impacted ponds were 40% alike, and impacted ponds had 30% of the same taxa as reference ponds).

The most diverse OU site for overall biotic community composition is Pond A-2 (mean of 57.4 biotic taxa sampled). The most diverse reference site is Pond D-2 (53 biotic taxa). The least diverse OU site is B-4 (25.2 taxa). The fact that an OU site is slightly more diverse than a reference site would seem to indicate that the effects of contamination in the OU ponds are not a major consideration. However, contaminant concentrations are known to be higher in OU ponds than in reference ponds

(Wright Water Engineers, 1995 and EG&G, 1994). This question will be addressed again during the 1995 field season. Some data are available for biota and contaminants that were sampled concurrently. Future analysis will determine if a relationship exists between these variables.

Cyanophytes decreased in A-4, B-5, and D-1 from 1993 to 1994, while Chlorophytes increased in D-1, Chrysophytes increased in B-5, and Euglenophytes increased in A-4. Chlorophytes replaced Cyanophytes in D-1. Seasonal algal fluctuations called blooms are dependent upon nutrient availability (nitrates, phosphates) and other limiting factors such as pH, temperature and available sunlight. An increase in the frequency of sampling at different times of the growth season is necessary to understand what limiting factors are primary in seasonal taxonomic richness.

Zooplankton feed on phytoplankton. The fathead minnow (*Pimephales promelas*) is a predator of the larger zooplankton species, such as Cladocera and some copopods. Ponds found to have a fathead minnow population include C-2, D-1, and D-2. Seining methods used in Pond D-1 for collecting fish for tissue analysis revealed a high population of fathead minnows near the north shore. There is an inverse relationship between the mean taxonomic richness (20.2) of phytoplankton to zooplankton (9.0) in Pond D-1, whereas, for Pond D-2, phytoplankton mean taxonomic richness (8.6) in less than the zooplankton richness (14, Figure D-2). Therefore, ponds with minnows have fewer taxa zooplankton due to predation, resulting in more phytoplankton diversity.

<u>Bioassessment of Walnut Creek</u>

A survey of the macrobenthic invertebrate taxa sampled from Pond D-2 showed that approximately 60% were pollution intolerant and only 30% were facultatively intolerant (EPA, 1973). A survey of the macrobenthic taxa sampled from Pond A-2 showed that equal numbers (33% each of the total taxa collected) were pollution intolerant and facultatively intolerant (EPA, 1973). A facultatively intolerant organism has inherent characteristics or demonstrates a facility for tolerance to pollutants under certain conditions e.g., water temperature, dissolved oxygen level or the presence of the pollutant at a particular point in the life cycle. An intolerant organism is sensitive to pollution and shows no facility to tolerate contamination under most circumstances.

EcMP's use of the EPT/C index is for the purpose of comparing this metric with other indicators and performing analyses of a composite of the Site's aquatic profile (Table D-4, Figures D-20 through D-23). A ranking can be derived from the ratio of the target site EPT/C index value to a reference site EPT/C value and then multiplying the ratio by 100 (EPA, 1989). To receive a top score of six the result must be >90%. To receive a minimum score of three the result must be between 70% - 90%. Any result <70% is scored 0. When using Pond D-2 as the reference site, Pond B-1 was the only pond to receive the minimum score of three with a ratio of 86.37% (Table D-14). Pond B-2 was only 10.13%, followed by A-1(3.6%), B-3 (0.46%), B-4 (0.32%), A-2 (0.14%) and A-3 (0.09%). To test the integrity of this method, the ratios were re-calculated by alternately using ponds A-2, B-1, and streamsite BD1 as the designated reference site (Table D-14). With Pond A-2 (the most diverse pond onsite) and Pond B-1 as the reference sites, all scoring results were either 0 or non-applicable. A-3 (with a 66.7% ratio) came the closest to a non-zero score when compared with A-2. BD2 as the reference site gave streamsite GW3 a score of 3, other streamsites scored 0. This calculated ratio method was used in Wright Water Engineers (1995) bioassessment study. Results from that paper and from the above ratio calculations indicate that this ratio method is most effective as a bioassessment value when used strictly on streamsites, and not ponds. The EPT/C index value by itself seems to be a good overall indicator of aquatic ecosystem health when used in conjunction with other analyses, such as ANOVA's, T-tests, Jaccard coefficient of similarity, and Pearson's correlation coefficient.

For remediation purposes, EcMP staff can provide DOE and regulatory agencies with information on the spatial and temporal variability of Rocky Flats aquatic systems and how these resources will

respond to present or future stressors, either natural or anthropogenic. Following remediation, monitoring efforts could focus on the aquatic community successional changes of the pond ecosystems.

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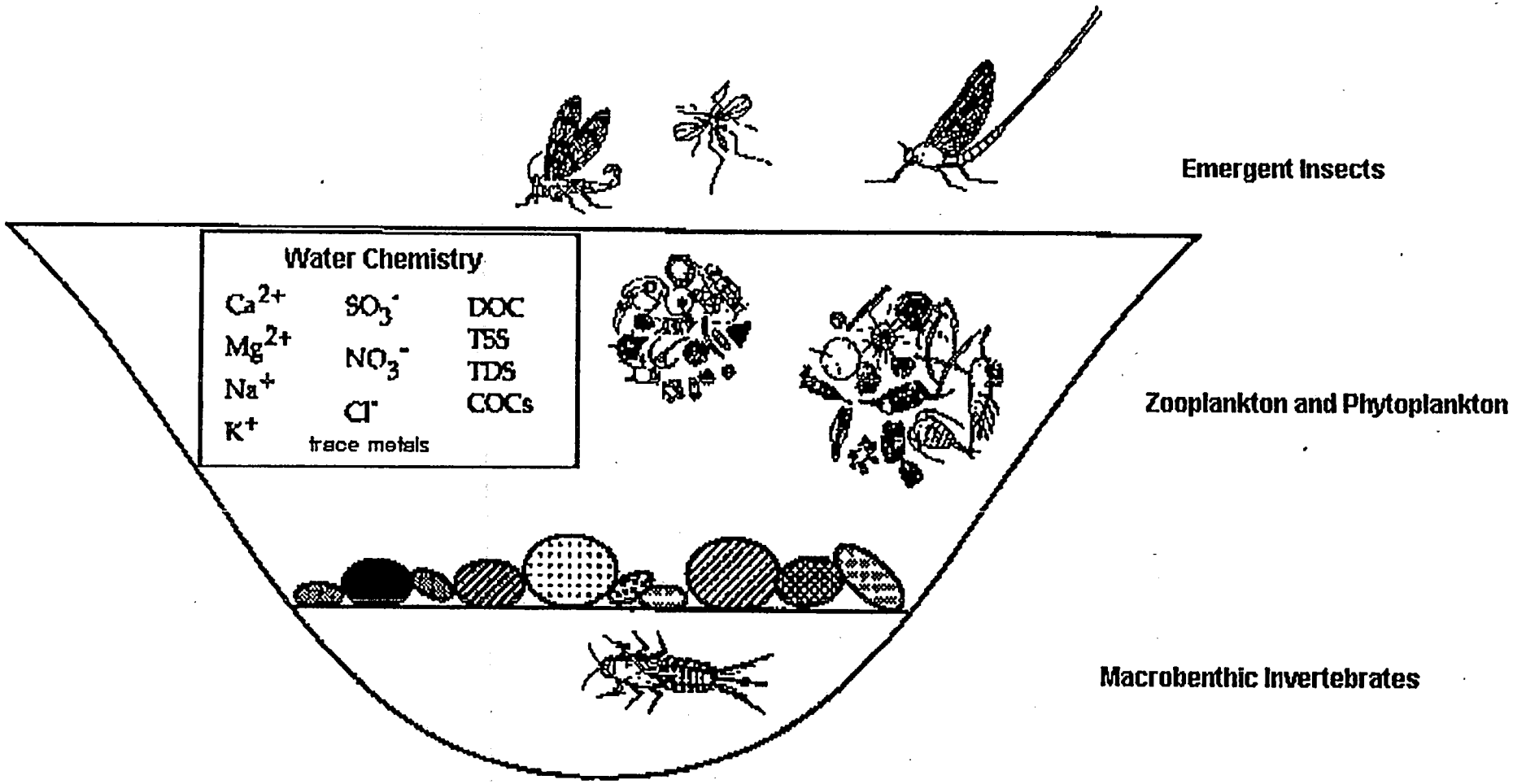


Figure D-1. The Four Biotic Components of EcMP Aquatic Sampling.

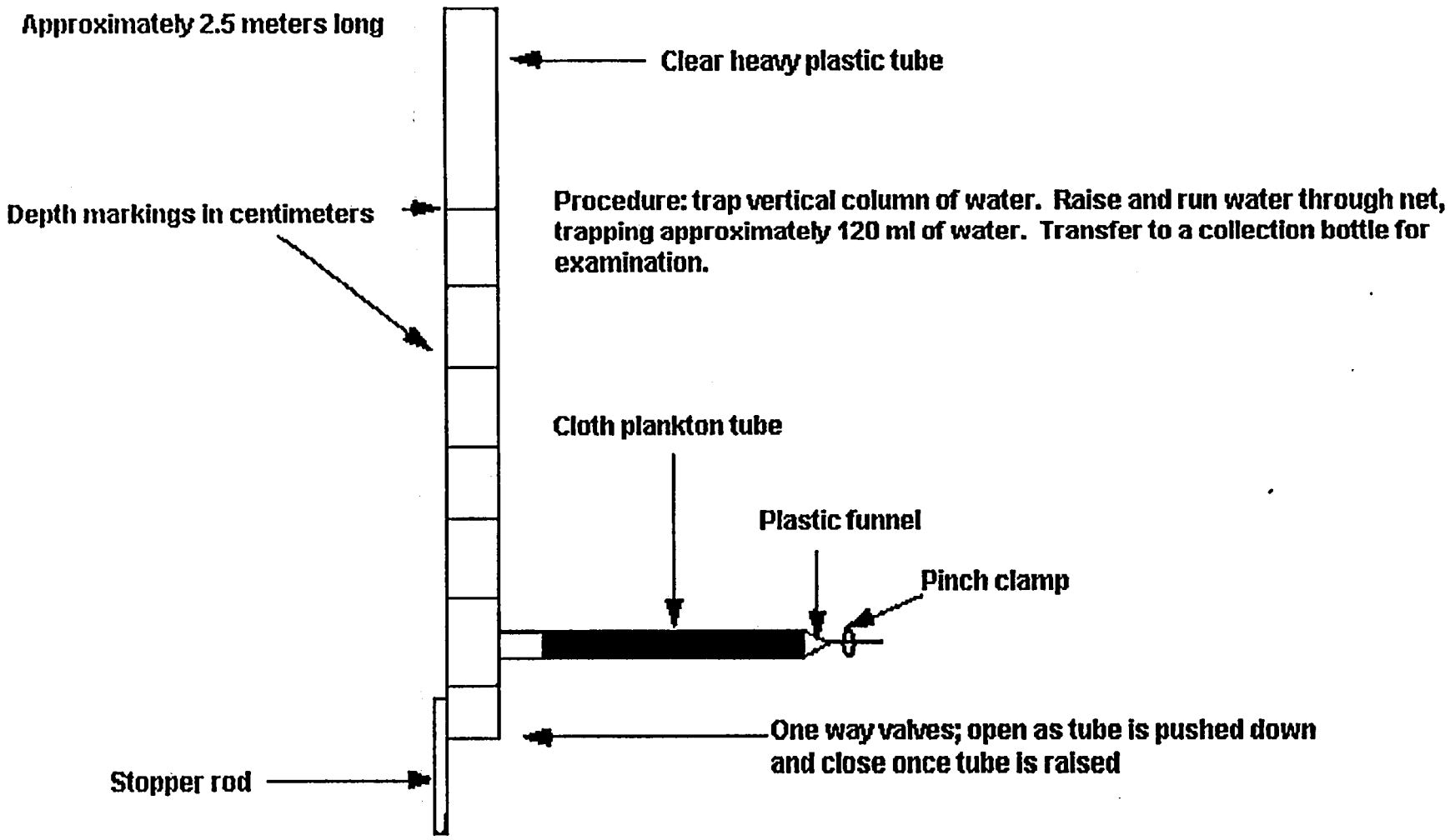
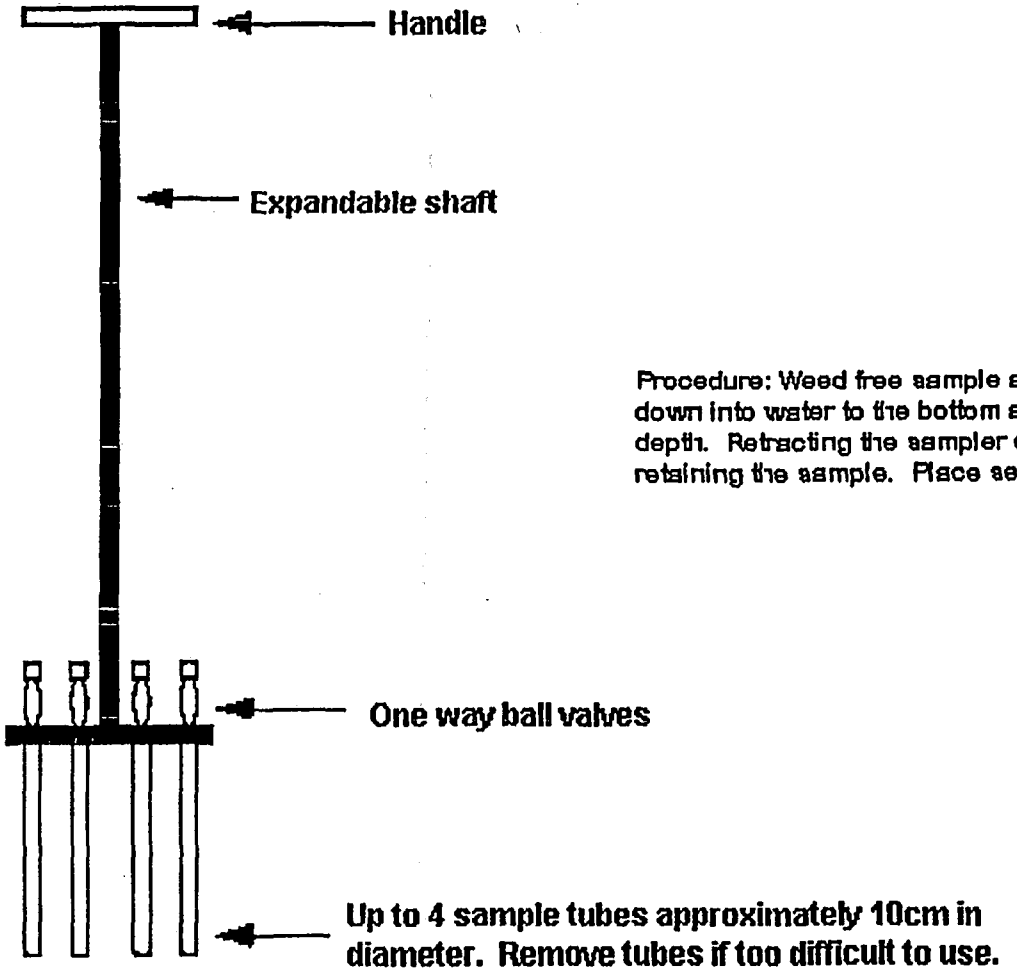


Figure D-2. Diagram of Zooplankton Sampler.



Procedure: Weed free sample area preferred. Push sampler straight down into water to the bottom and force into substrate to the desired depth. Retracting the sampler causes the valves to close, thereby retaining the sample. Place sediment samples into collection bottles.

Figure D-3. Diagram of Multicore (Core) Macrobenthic Invertebrate and Sediment Sampler.

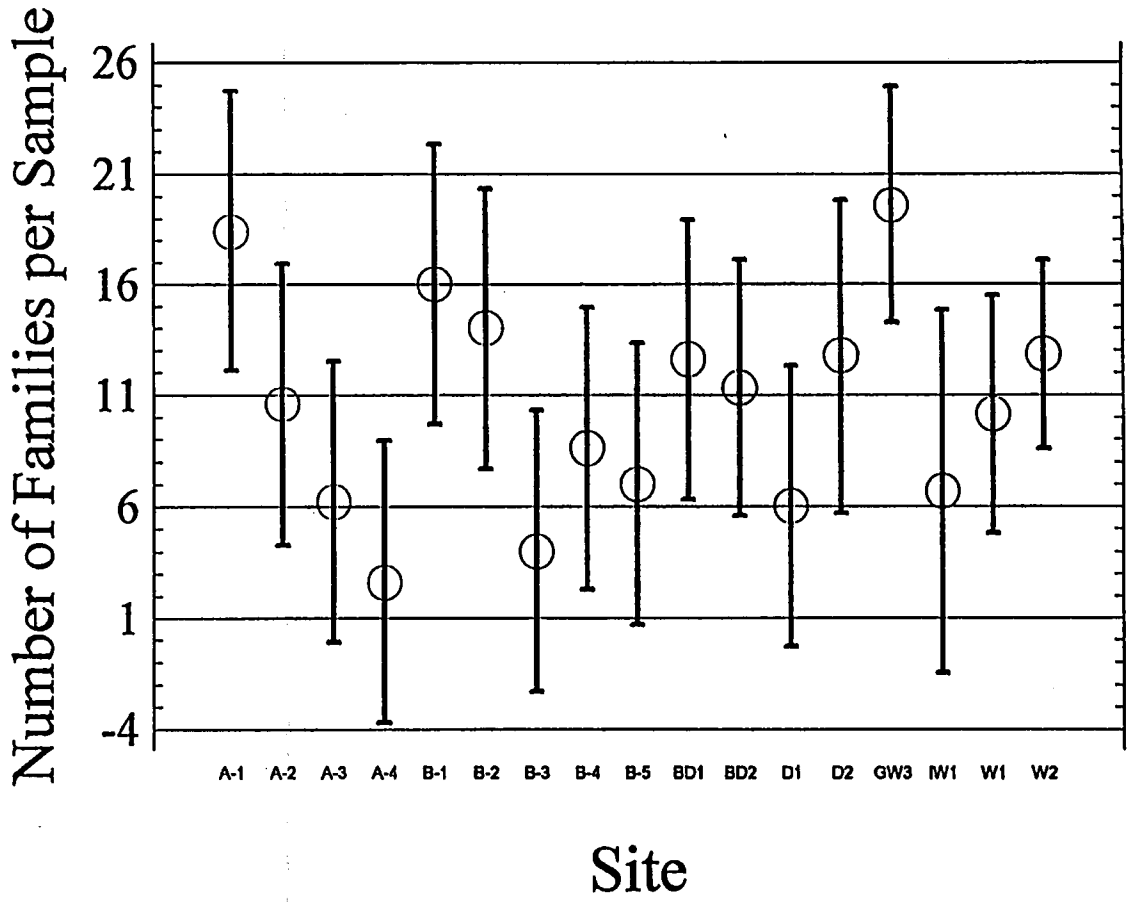


Figure D-4. Number of Macrobenthic Families Sampled, All Methods Combined Means and 95.0 Percent Tukey HSD Intervals.

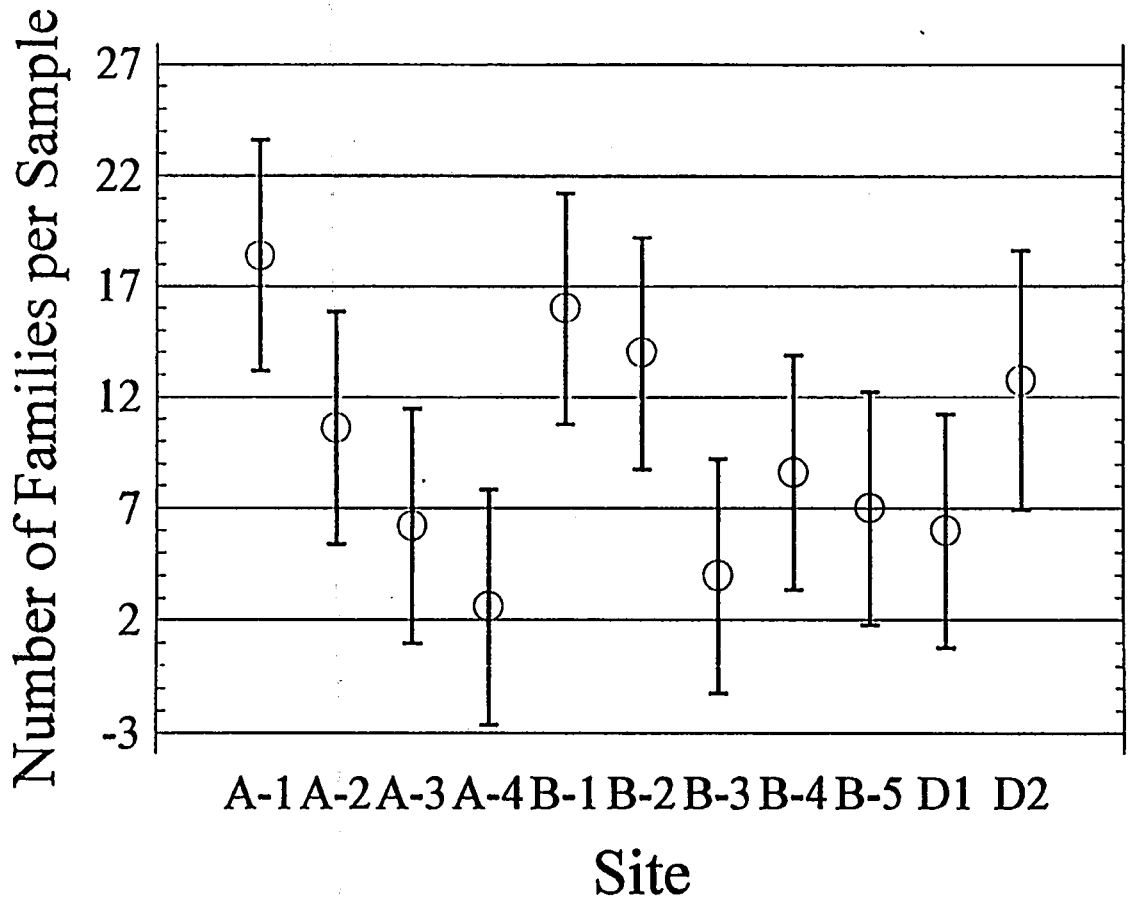


Figure D-5. Number of Macrobenthic Families Sampled With the Core Method Means and 95.0 Percent Tukey HSD Intervals.

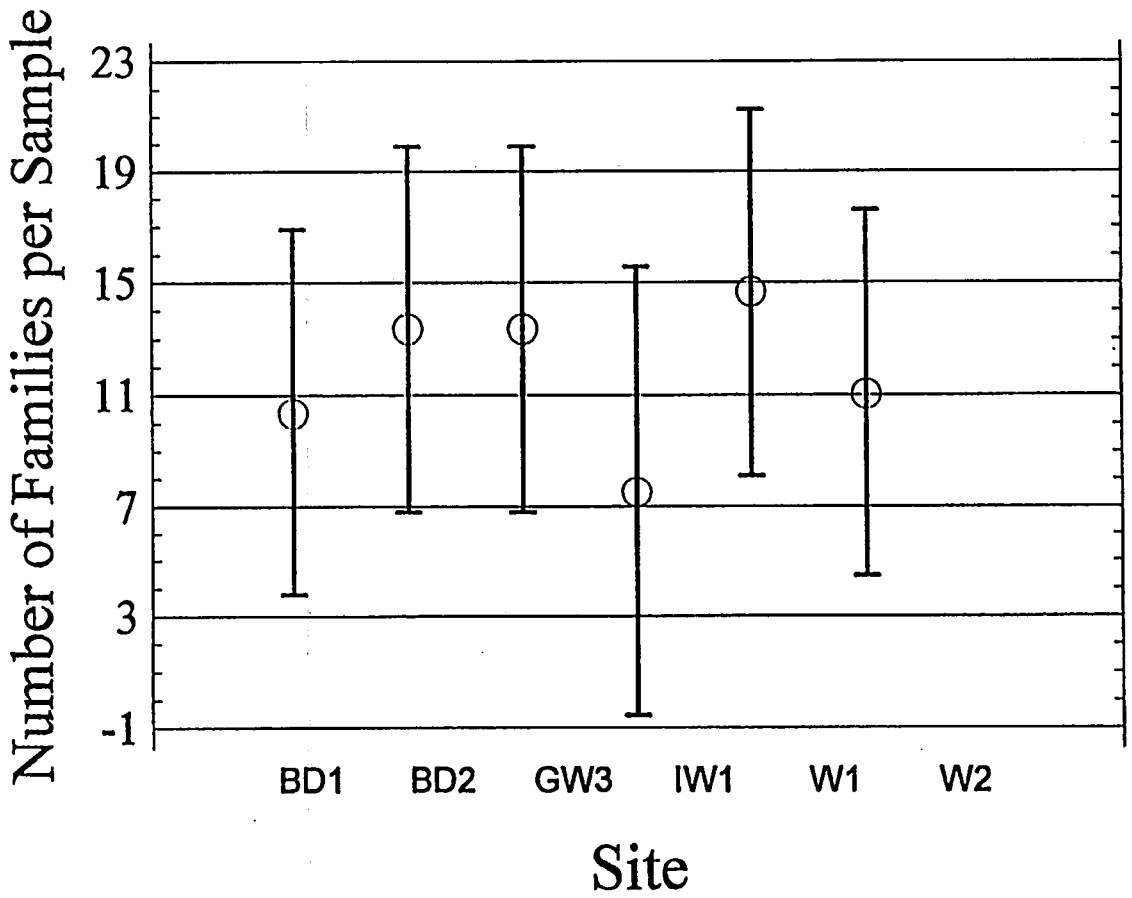


Figure D-6. Number of Macrobenthic Families Sampled With the Dip Net Method Means and 95.0 Percent Tukey HSD Intervals.

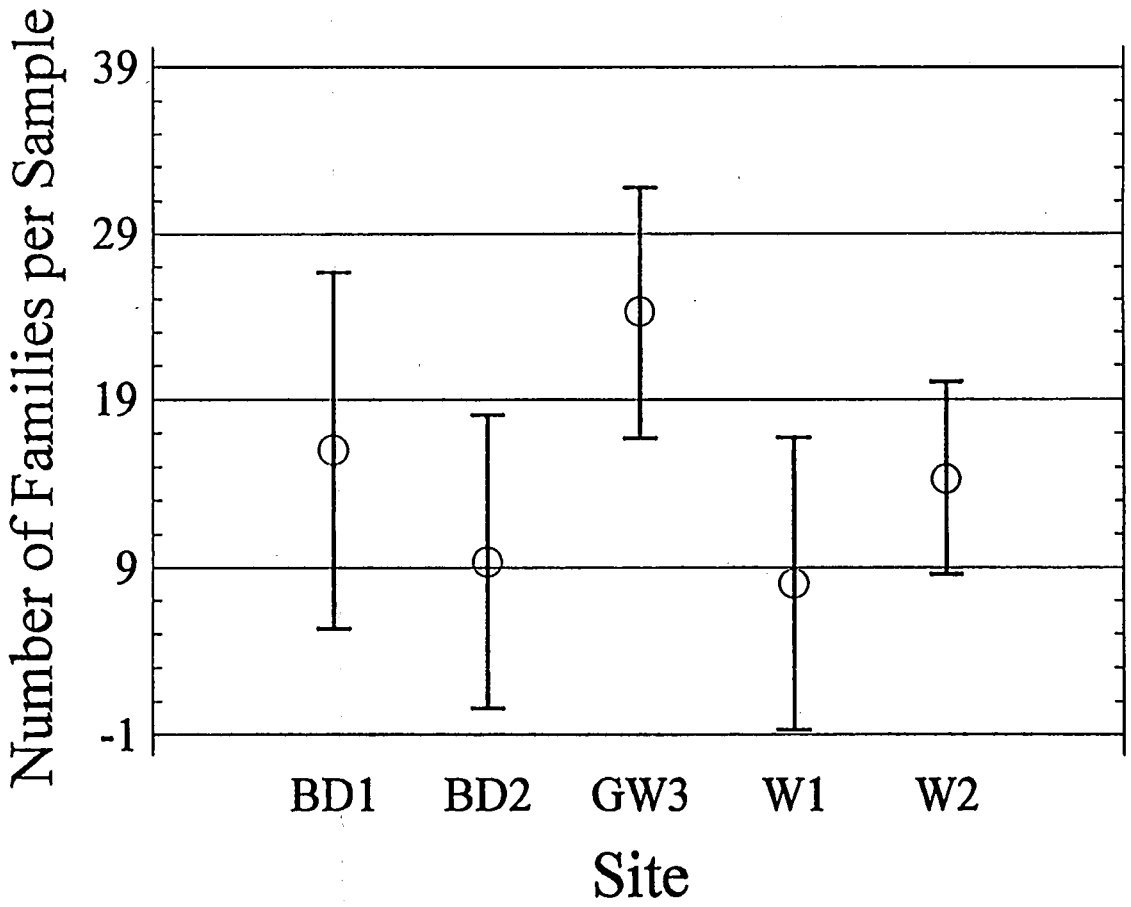


Figure D-7. Number of Macrobenthic Families Sampled With the Drift Net Method Means and 95.0 Percent Tukey HSD Intervals.

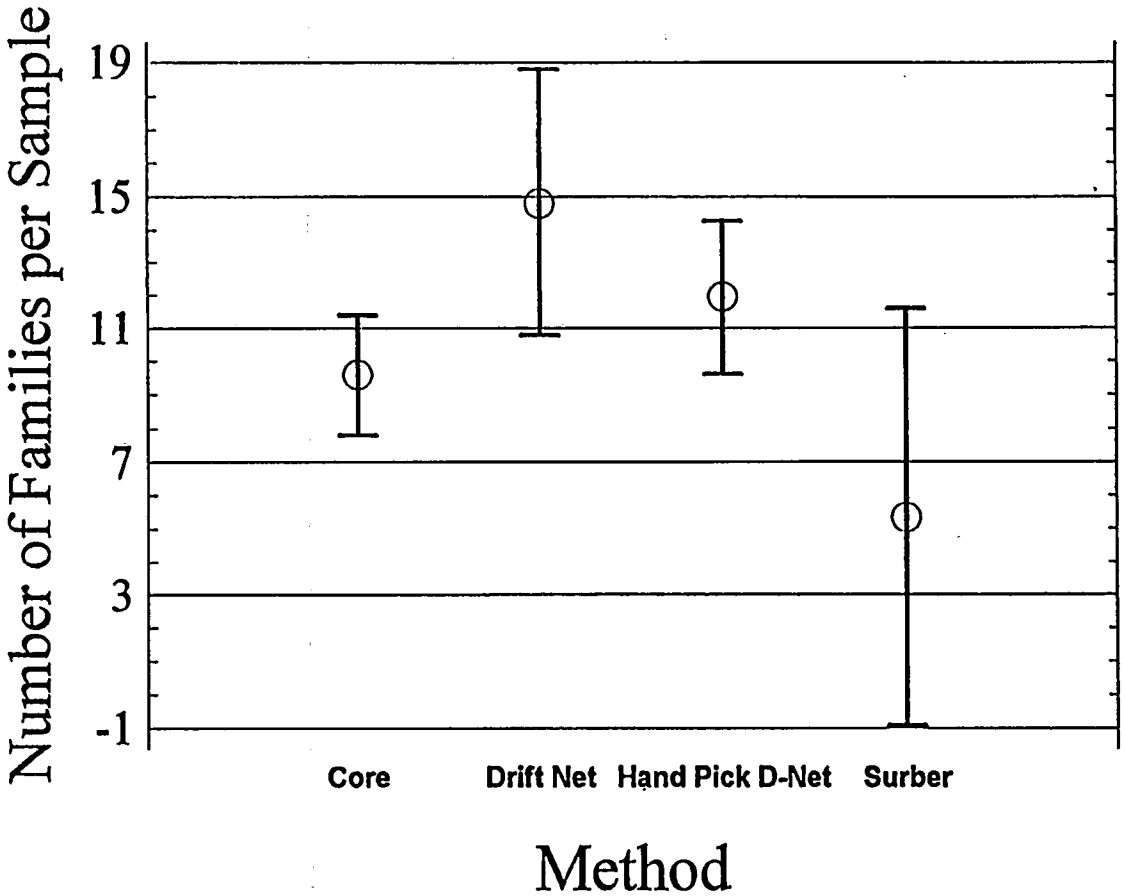


Figure D-8. Number of Families Versus Macrobenthic Sampling Method Means and 95.0 Percent Confidence Intervals (internal s).

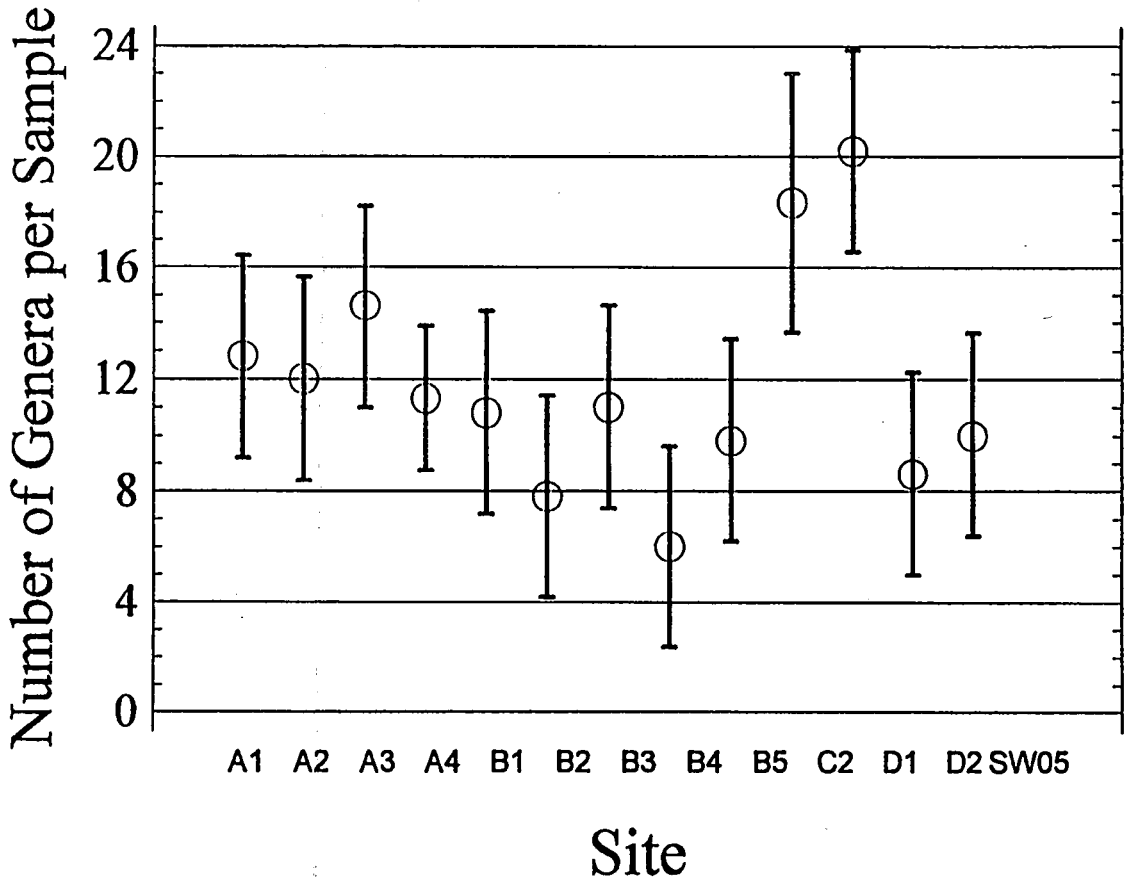


Figure D-9. Number of Phytoplankton Genera Sampled Means and 95.0 Percent Tukey HSD Intervals.

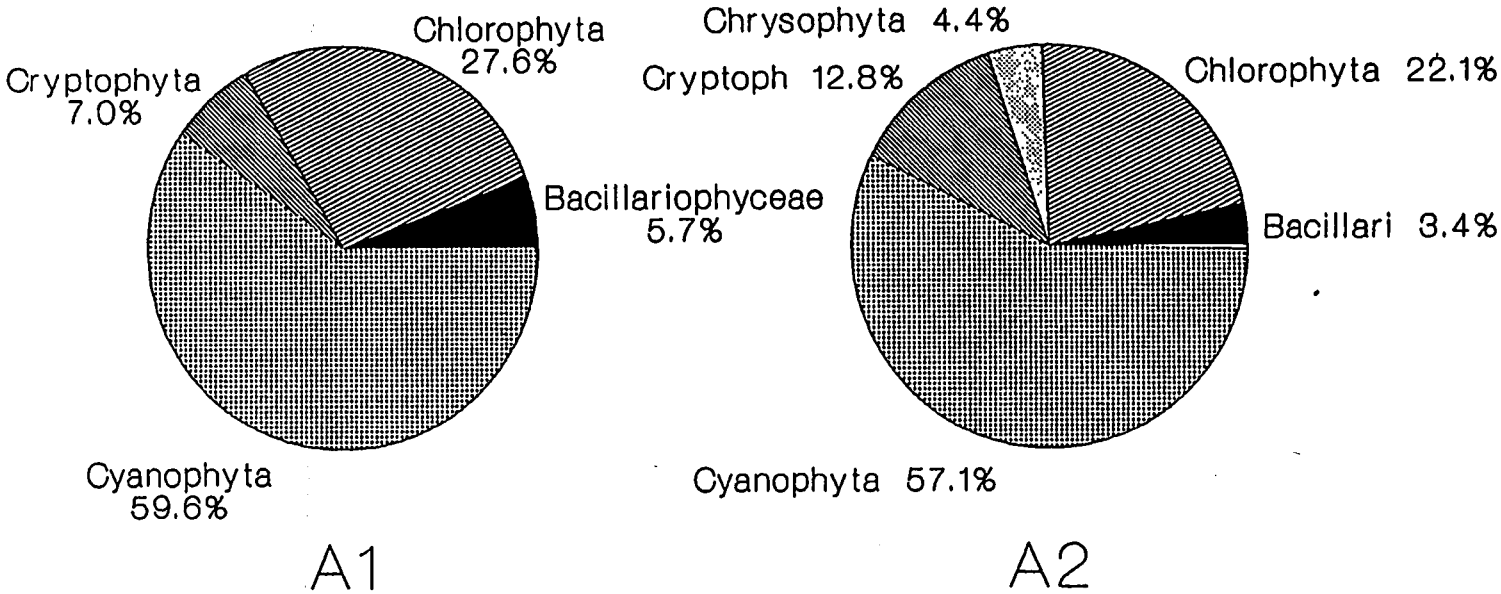
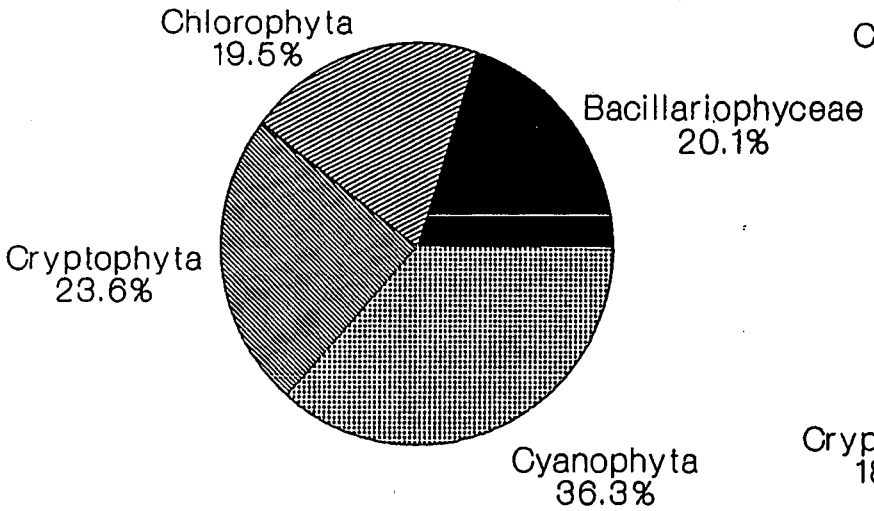
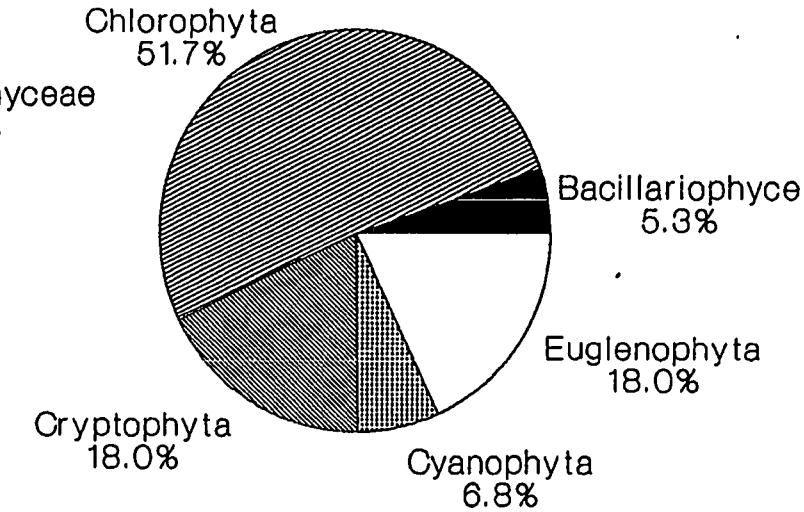


Figure D-10. A-Series Ponds
Phytoplankton Community Composition.



A3



A4

Figure D-11. A-Series Ponds
Phytoplankton Composition, continued.

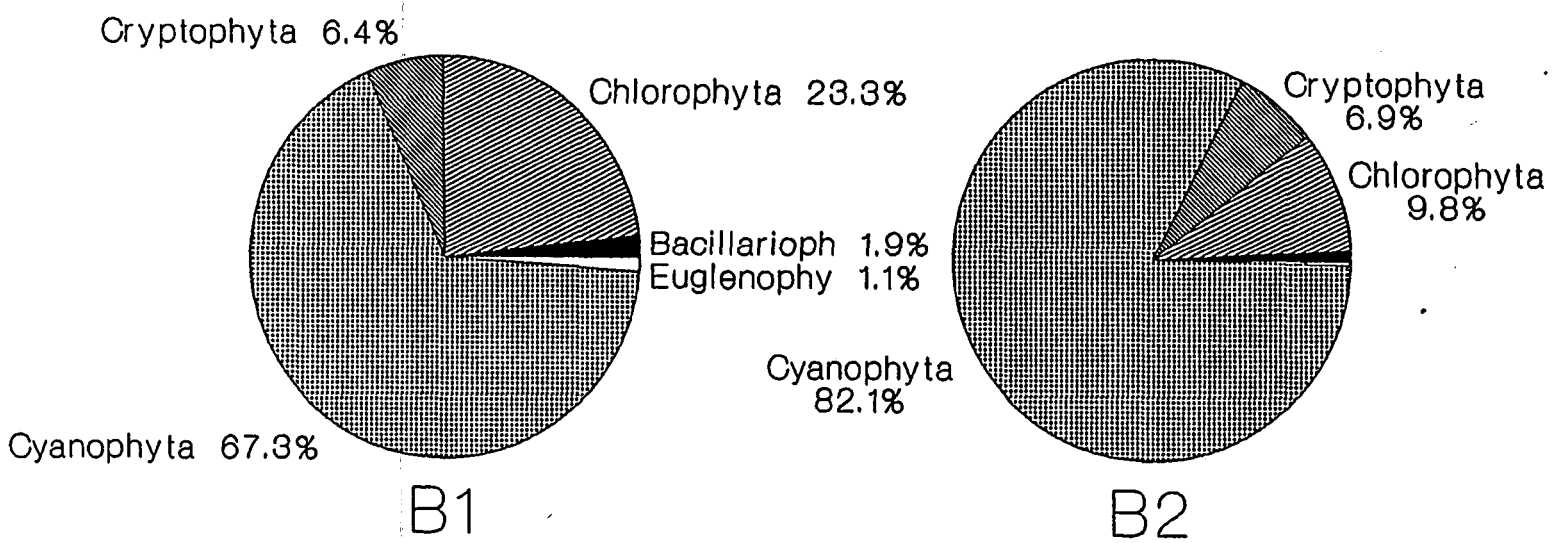
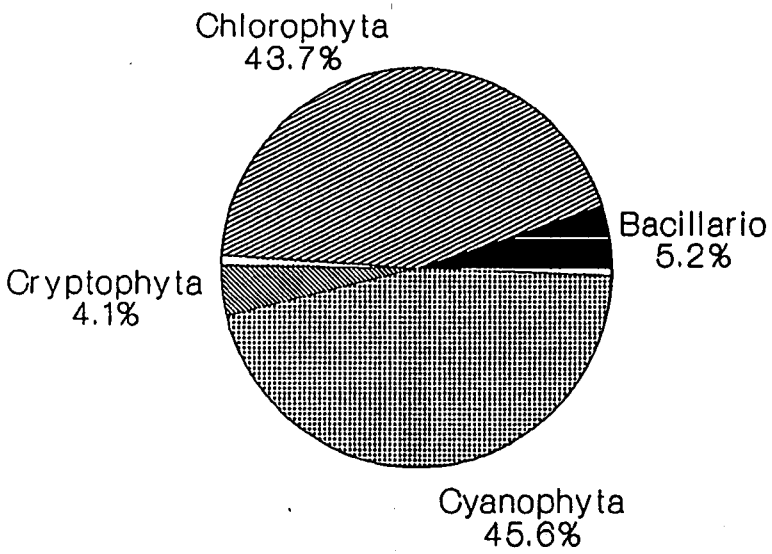
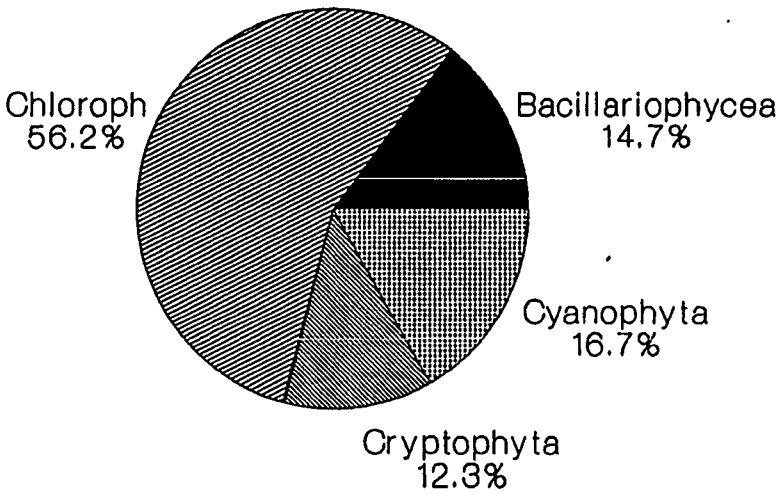


Figure D-12. B-Series Ponds
Phytoplankton Community Composition.



B3



B4

Figure D-13. B-Series Ponds
Phytoplankton Composition, continued.

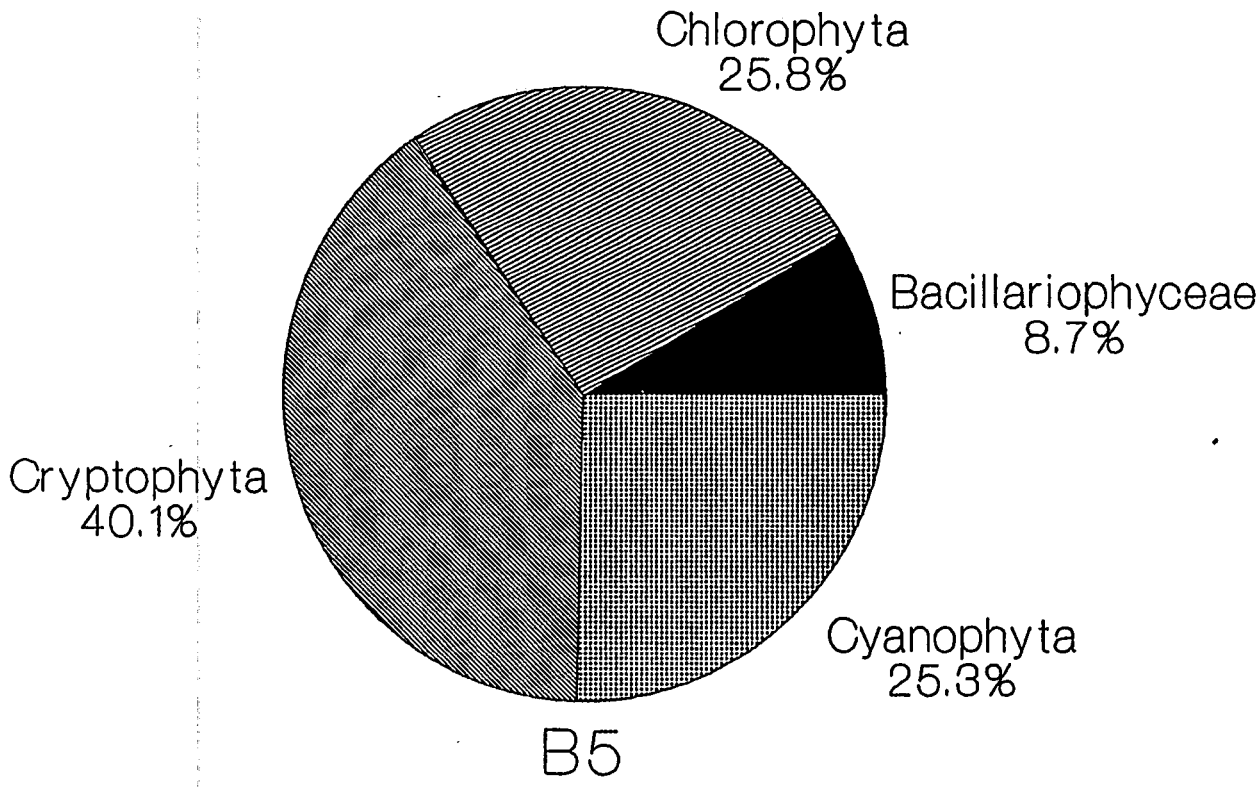


Figure D-14. B-Series Ponds
Phytoplankton Composition, continued.

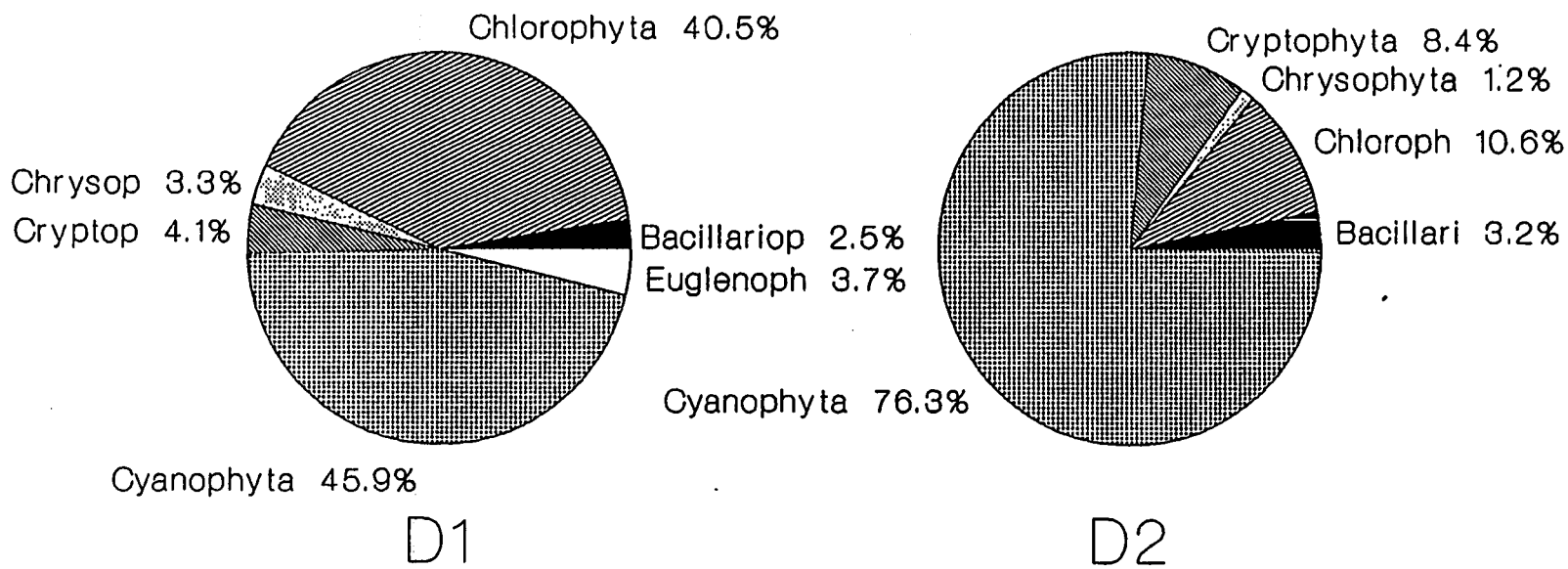


Figure D-15. D-Series Ponds
Phytoplankton Community Composition.

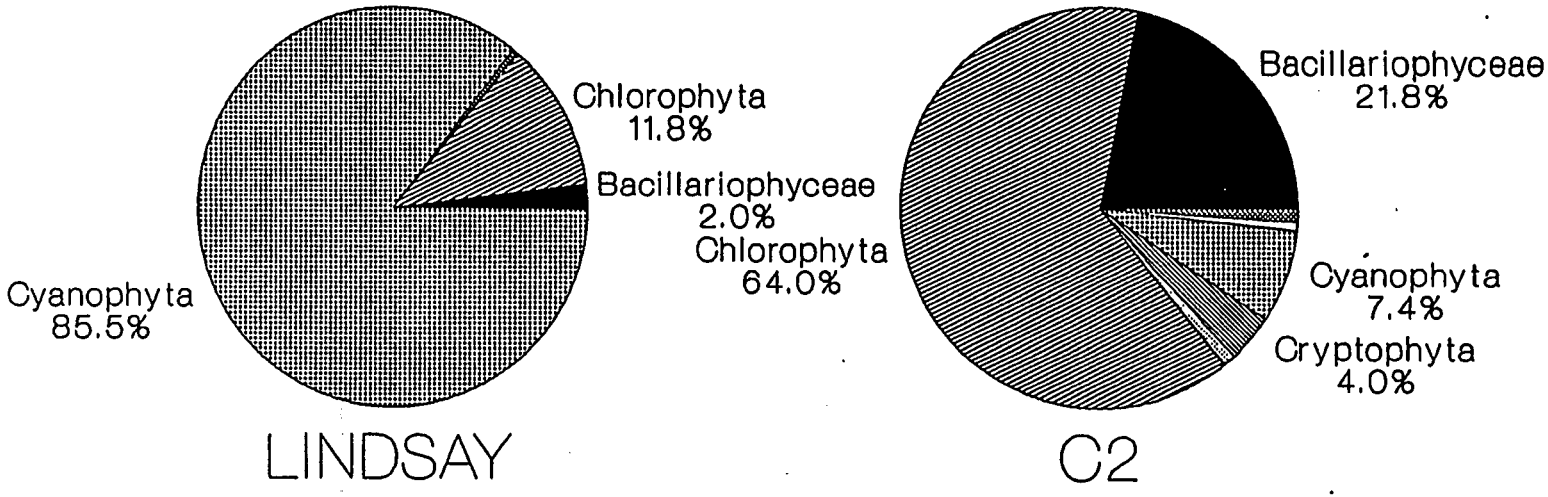


Figure D-16. Lindsay and C2 Ponds
Phytoplankton Community Composition.

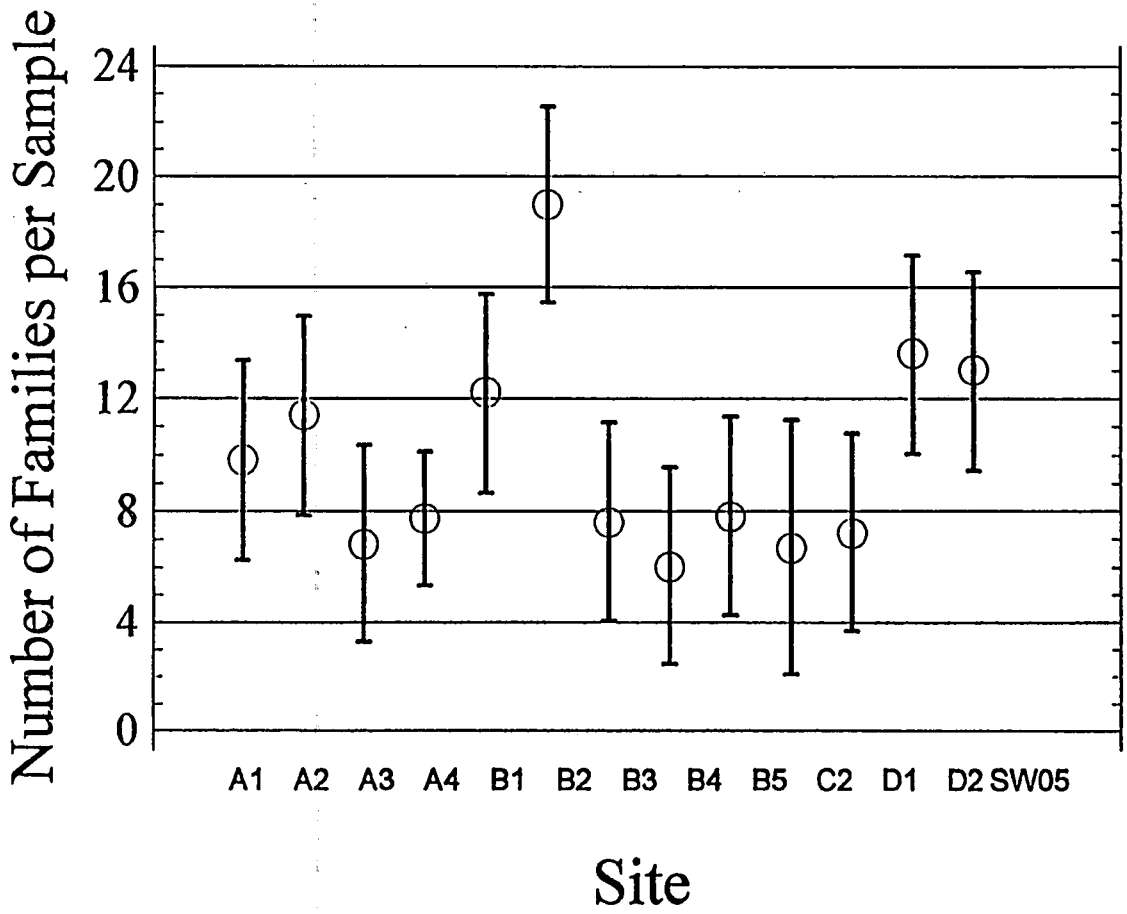


Figure D-17. Number of Zooplankton Families Sampled Means and 95.0 Percent Tukey HSD Intervals.

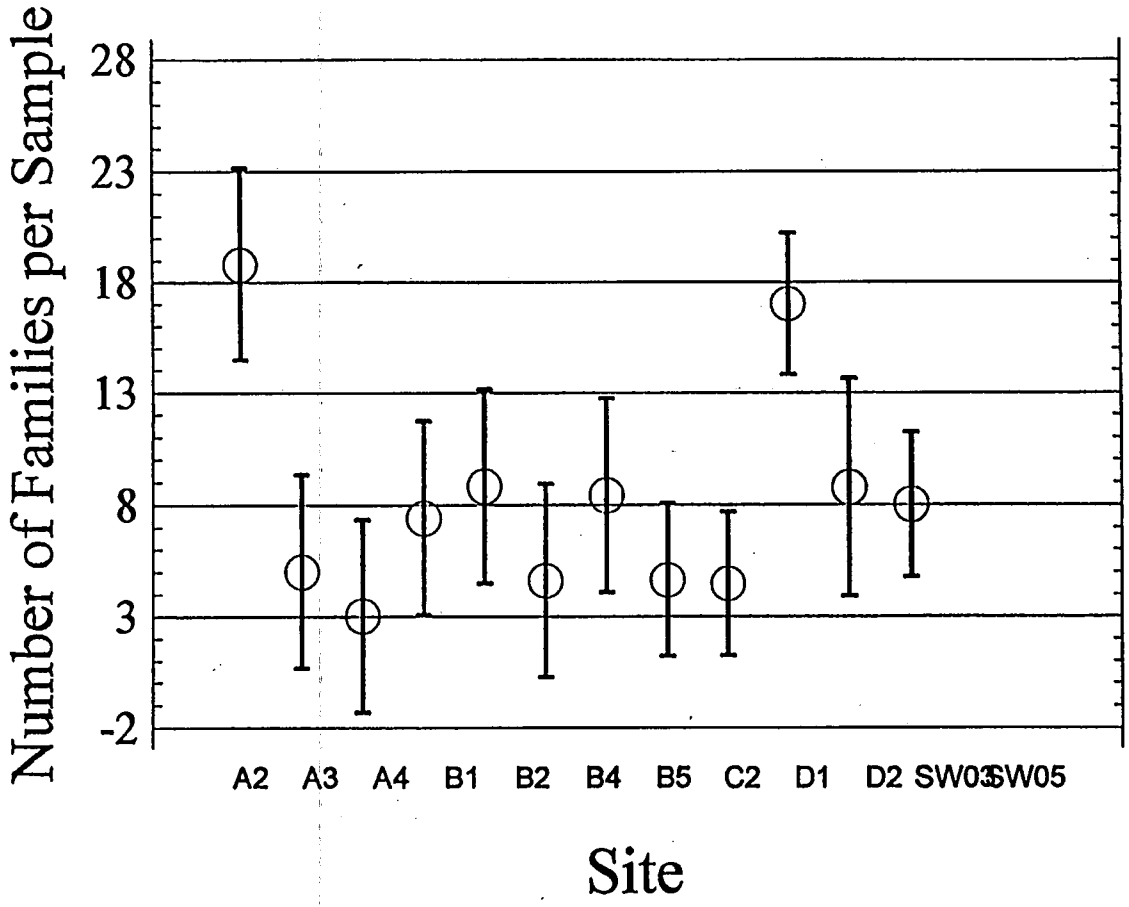


Figure D-18. Number of Emergent Insect Families Sampled Means and 95.0 Percent Tukey HSD Intervals.

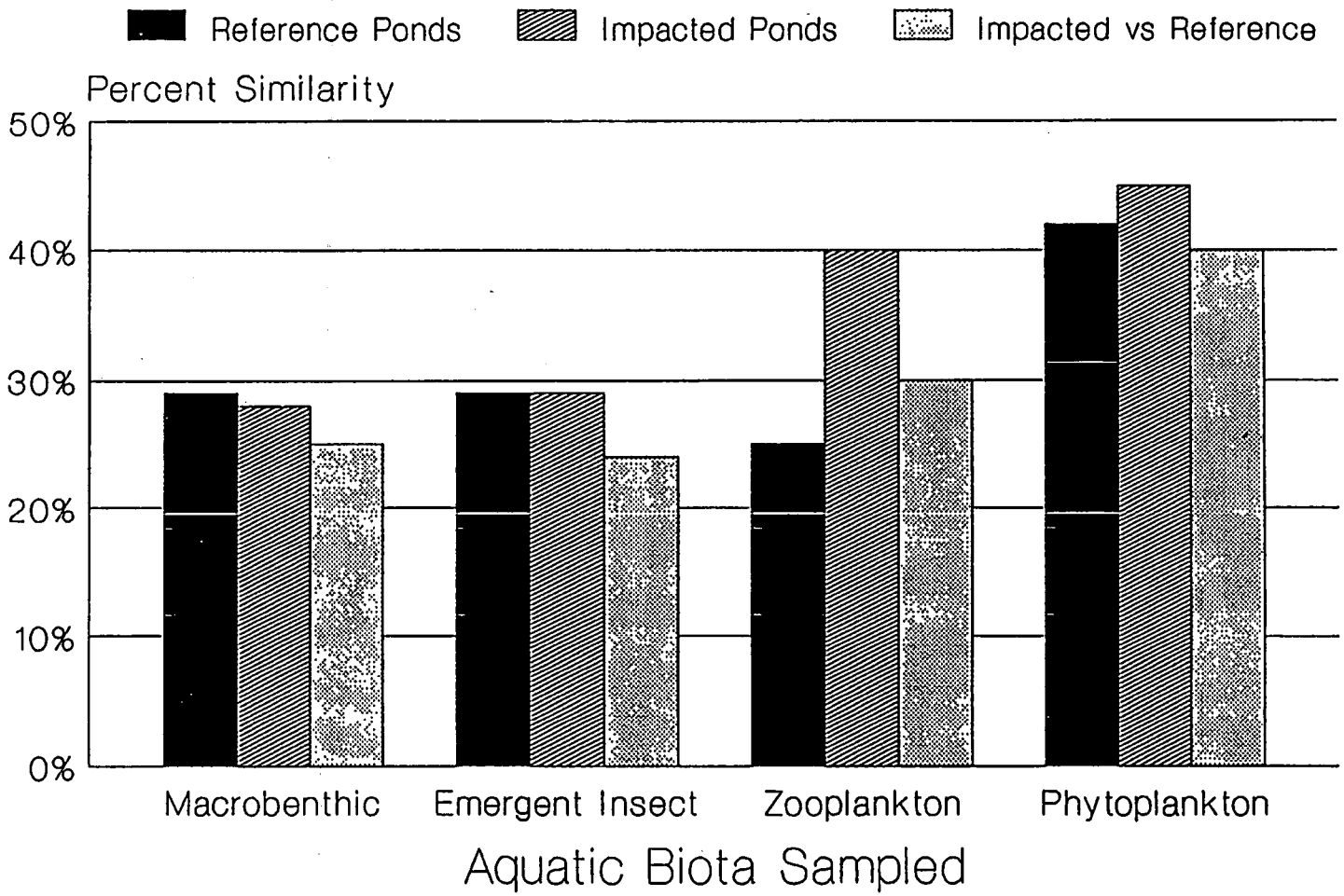


Figure D-19. Percentage of Biotic Taxa Shared Among Ponds Sampled.

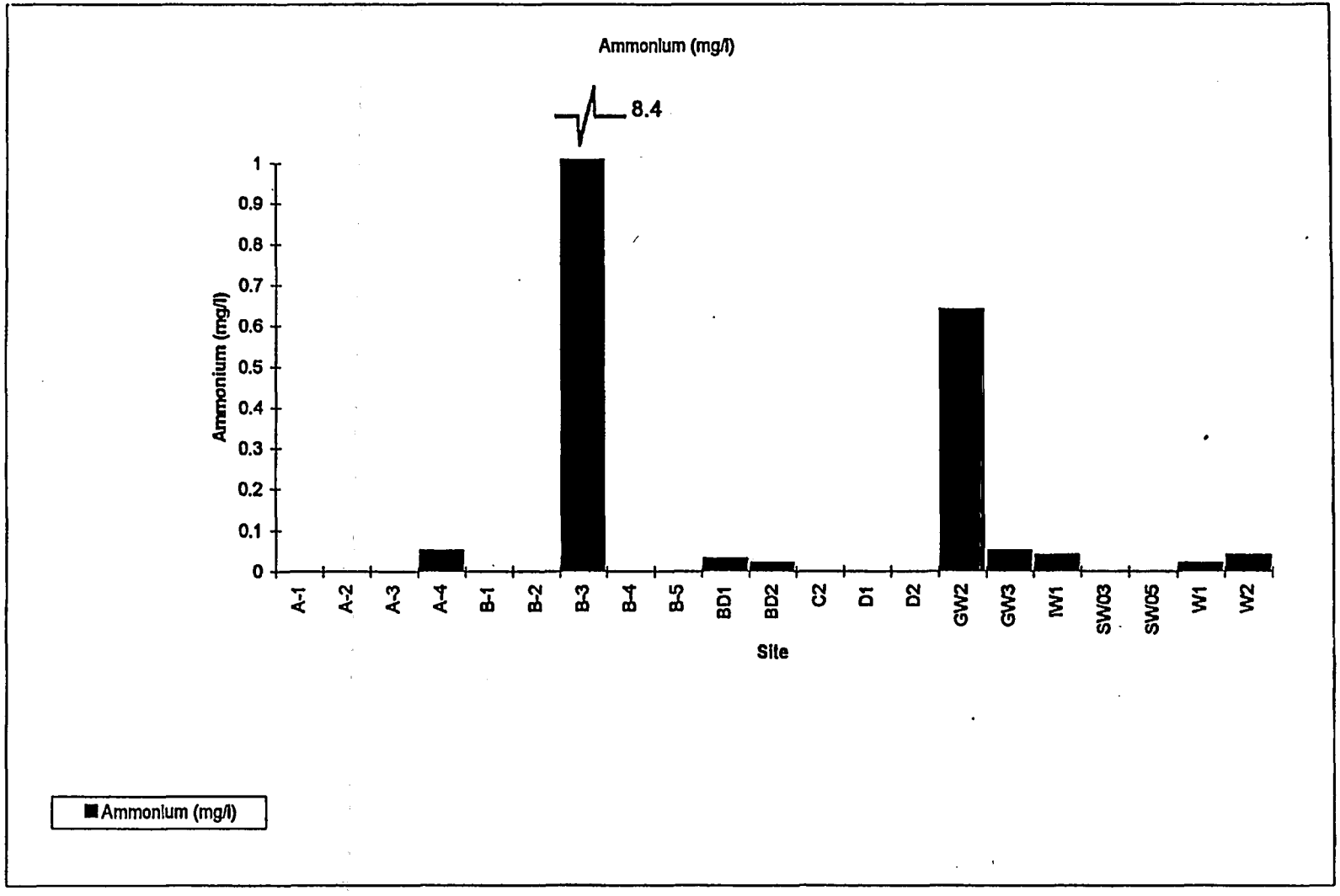
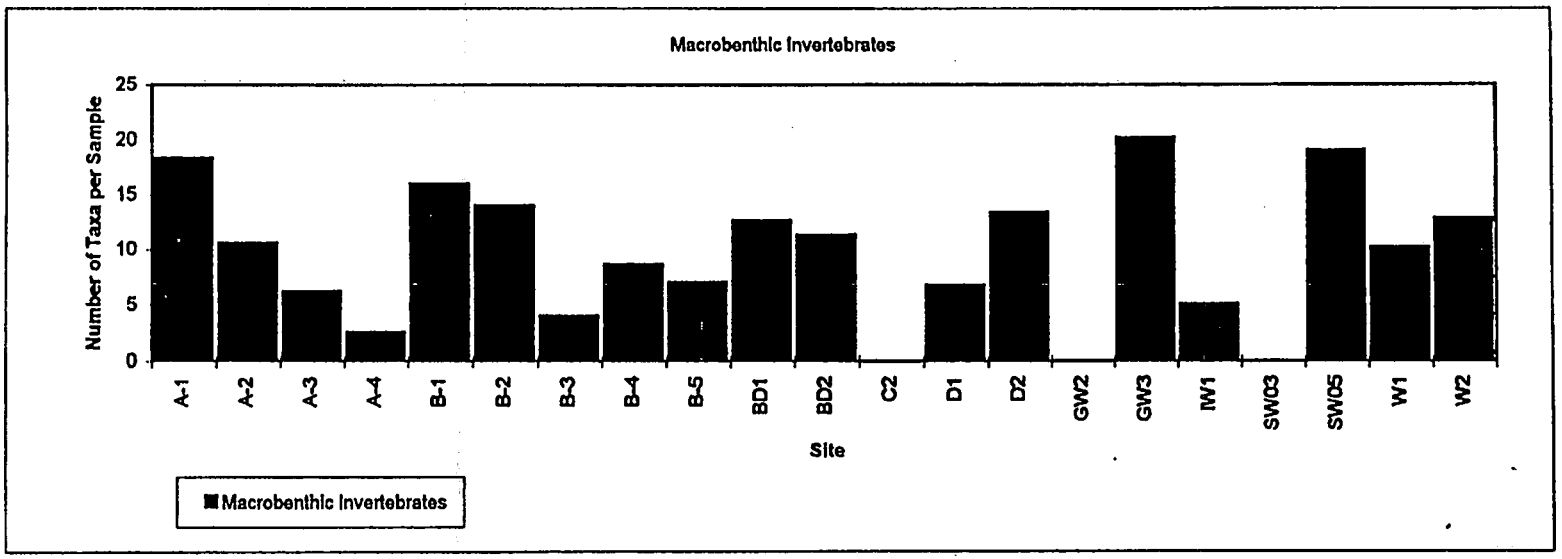


Figure D-20. Graphical Site Summary of Ammonium Concentrations.



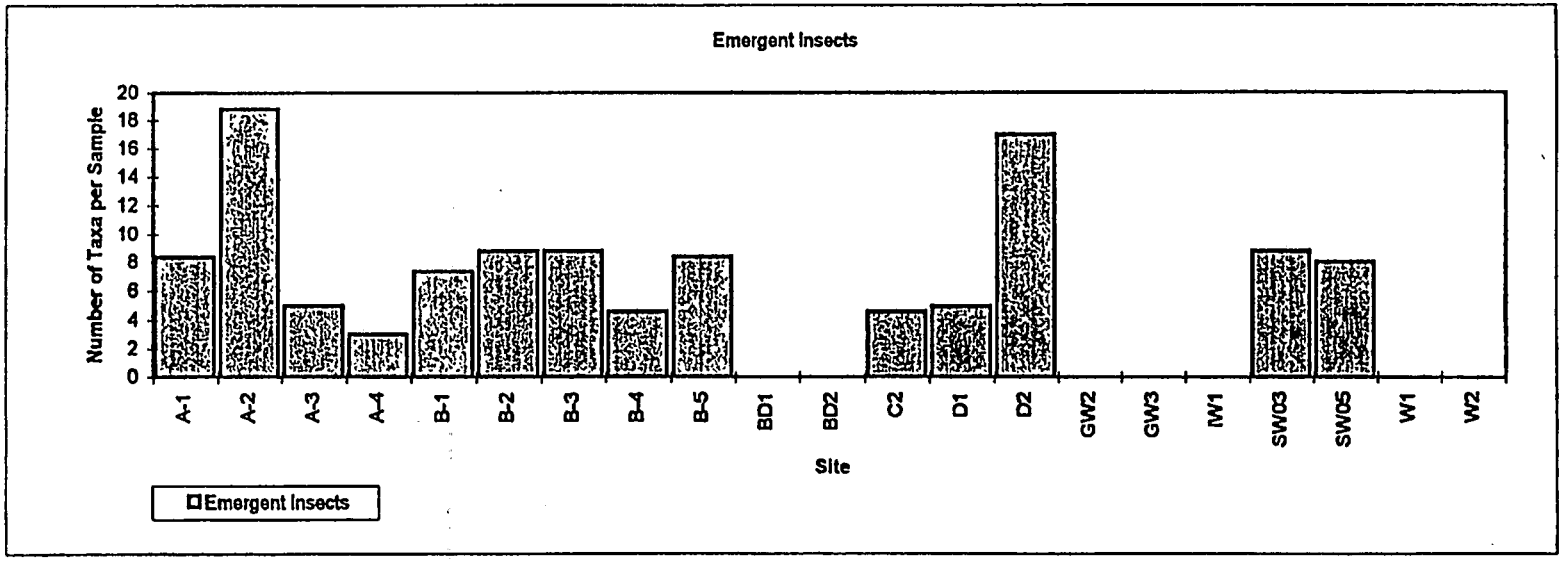
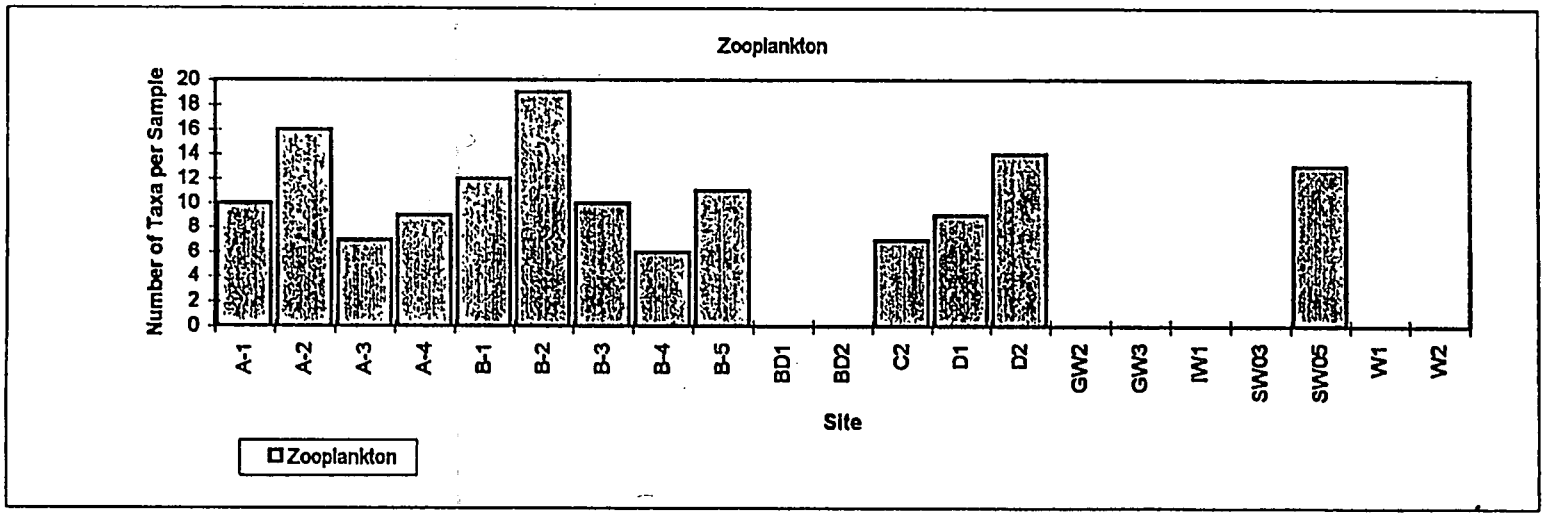


Figure D-21. Graphical Site Summary of Macrobenthic Invertebrate and Emergent Insect Richness.



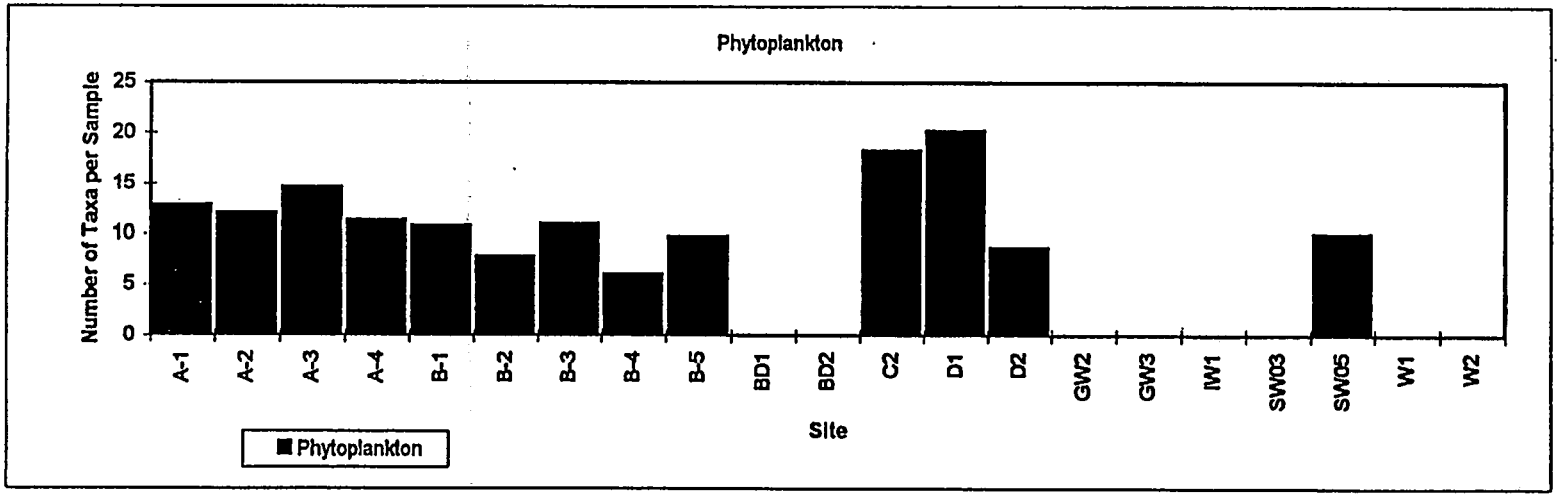


Figure D-22. Graphical Site Summary of Zooplankton and Phytoplankton Richness.

Table D-1. Aquatic Site Descriptions.

A-1	A-1 pond, North Walnut Creek drainage
A-2	A-2 pond, North Walnut Creek drainage
A-3	A-3 pond, North Walnut Creek drainage
A-4	A-4 pond, North Walnut Creek drainage
B-1	B-1 pond, South Walnut Creek drainage
B-2	B-2 pond, South Walnut Creek drainage
B-3	B-3 pond, South Walnut Creek drainage
B-4	B-4 pond, South Walnut Creek drainage
B-5	B-5 pond, South Walnut Creek drainage
BD1	Big Dry Creek downstream of Walnut Creek confluence
BD2	Big Dry Creek upstream of Walnut Creek confluence
C-1	C-1 pond, Woman Creek drainage
C-2	C-2 pond, Woman Creek drainage
D-1	D-1 pond, Smart ditch drainage
D-2	D-2 pond, Smart ditch drainage
D3	Walnut Creek downstream of Mckay confluence
D4	Walnut Creek upstream of Mckay confluence
D5	Walnut Creek downstream of A-4 pond dam
GW1	Runoff stream from GWR located east of GWR at the service road culvert
GW2	Overflow pipe emptying into Walnut Creek east of GWR
GW3	Walnut Creek east of Great Western Reservoir (GWR), downstream of diversion ditch, upstream of GWR overflow pipe
GW4	Downstream or at the end of Walnut diversion ditch at 2 small culverts
IW1	Walnut Creek west of Indiana at the culvert just inside Rocky Flats fence boundaries
SW039	Woman Creek, surface water site
SW033	Woman Creek, surface water site
SW026	Woman Creek, east of C-2 pond, surface water site
SW05	Lindsay Pond
W1	Walnut Creek west of culvert at 105 th St. and Old Wadsworth intersection
W2	Walnut Creek upstream of confluence with Big Dry Creek

Table D-2. Jaccard Similarity Index and EPT/C Community Index Formulas.

Jaccard Index, J = $\frac{a}{a+b+c}$

where:

	Factor A, present	Factor A, absent
Factor B, present	a	b
Factor B, absent	c	d

from Digby and Kempton, 1987.

EPT/C Index = $\frac{\text{\# of Ephemeroptera + Plecoptera + Tricoptera}}{\text{\# of Chironomidae}}$ (to order level) (to family level)

from EPA, 1989.

Table D-3. Analysis of Variance Tables for Macrobenthic Invertebrate Taxonomic Richness, 1994 Data.

Analysis of Variance; Macrobenthic Taxonomic Richness, all methods across all sites.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	2028.97	16	126.811	4.08	0.0000
Within Sites	2363.76	76	31.1021		
Total (Corr.)	4392.73	92			

Analysis of Variance; Macrobenthic Taxonomic Richness by sampling method.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Methods	490.928	3	163.643	3.73	0.0141
Within Methods	3901.8	89	43.8405		
Total (Corr.)	4392.73	92			

Analysis of Variance; Macrobenthic Taxonomic Richness, Core sampling method across all sites.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	1296.69	10	129.669	5.48	0.0000
Within Sites	1018.35	43	23.6826		
Total (Corr.)	2315.04	53			

Table D-3. Analysis of Variances Tables for Macrobenthic Invertebrate Taxonomic Richness, 1994 Data, continued.

Analysis of Variance; Macrobenthic Taxonomic Richness, Drift Net sampling method across all sites.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	590.313	4	147.578	3.16	0.0481
Within Sites	654.845	14	46.7747		
Total (Corr.)	1245.16	18			

Analysis of Variance; Macrobenthic Taxonomic Richness, Hand Picked Dip Net sampling method across all sites.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	83.7745	5	16.7549	0.75	0.6019
Within Sites	245.167	11	22.2879		
Total (Corr.)	328.941	16			

Table D-4. Aquatic Site Summaries for 1994.

Site	Emergent Insects			Macrobenthic Invertebrates					Phytoplankton			Zooplankton			Water Chemistry		
	Taxonomic Richness			Taxonomic Richness		EPT/C Index			Taxonomic Richness			Taxonomic Richness			Ammonium (mg/l)		
	mean	variance	sample size	mean	variance	mean	variance	sample size	mean	variance	sample size	mean	variance	sample size	mean	variance	sample size
A-1	8.4	2.3	5	18.4	60.3	0.078	0.008	5	12.8	16.7	5	10	2.7	5	N/A	N/A	N/A
A-2	18.8	15.2	5	10.6	9.8	0.003	0.00002	5	12	8.5	5	16	80.3	6	N/A	N/A	N/A
A-3	5	3.5	5	6.2	12.2	0.002	0.00003	5	14.6	6.8	5	7	1.7	5	N/A	N/A	N/A
A-4	3	4.5	5	2.6	2.3	0	0	5	11.3	6	10	9	23.1	12	0.05	N/A	1
B-1	7.4	8.3	5	16	64	1.876	5.363	5	10.8	8.7	5	12	3.2	5	N/A	N/A	N/A
B-2	8.8	2.7	5	14	56.5	0.22	0.191	5	7.8	10.7	5	19	11	5	N/A	N/A	N/A
B-3	8.8	17.7	5	4	2.5	0.01	0.0005	5	11	6.5	5	10	7.8	6	8.4	N/A	1
B-4	4.6	3.3	5	8.6	8.3	0.007	0.0003	5	6	4	5	6	1	5	N/A	N/A	N/A
B-5	8.4	23.3	5	7	5	0	0	5	9.8	28.7	5	11	19.1	6	N/A	N/A	N/A
BD1	N/A	N/A	N/A	12.6	22.8	1.923	0.525	5	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.00003	3
BD2	N/A	N/A	N/A	11.3	21.1	5.484	29.221	6	N/A	N/A	N/A	N/A	N/A	N/A	0.02	0.0001	3
C2	4.6	2.8	8	N/A	N/A	N/A	N/A	N/A	18.3	10.3	3	7	2.3	3	N/A	N/A	N/A
D1	4.9	11.6	9	6	3	0	0	5	20.2	7.7	5	9	5.6	6	N/A	N/A	N/A

Table D-4. Aquatic Site Summaries for 1994.

Site	Emergent Insects			Macrobenthic Invertebrates					Phytoplankton			Zooplankton			Water Chemistry		
	Taxonomic Richness			Taxonomic Richness		EPT/C Index			Taxonomic Richness			Taxonomic Richness			Ammonium (ppm)		
	mean	variance	sample size	mean	variance	mean	variance	sample size	mean	variance	sample size	mean	variance	sample size	mean	variance	sample size
D2	17	64.3	9	12.8	40.9	2.172	21.677	4	8.6	30.3	5	14	6.3	5	N/A	N/A	N/A
GW2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.64	0.00005	2
GW3	N/A	N/A	N/A	19.6	53	4.205	18.791	7	N/A	N/A	N/A	N/A	N/A	N/A	0.05	0.0002	2
IW1	N/A	N/A	N/A	6.7	8.3	0	0	3	N/A	N/A	N/A	N/A	N/A	N/A	0.04	0.0002	2
SW03	8.8	12.9	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SW05	8	9.8	9	19	N/A	0.04	N/A	1	10	3.5	5	13	43	5	N/A	N/A	N/A
W1	N/A	N/A	N/A	10.1	37.5	0.712	1.133	7	N/A	N/A	N/A	N/A	N/A	N/A	0.02	0.0002	2
W2	N/A	N/A	N/A	12.8	59	7.035	116.548	11	N/A	N/A	N/A	N/A	N/A	N/A	0.04	0.0001	3

Table D-5. EPT/C Index Values For All Macrobenthic Invertebrate Sites.

Site	EPT/C index (mean)	Standard Deviation	Sample Size
A1	0.078	0.088	5
A2	0.003	0.005	5
A3	0.002	0.005	5
A4	0.000	0.000	5
B1	1.876	2.316	5
B2	0.220	0.437	5
B3	0.010	0.021	5
B4	0.007	0.016	5
B5	0.000	0.000	5
BD1	1.923	0.724	5
BD2	5.484	5.406	6
D1	0.000	0.000	6
D2	2.172	4.656	5
GW3	4.205	4.335	6
IW1	0.000	0.000	2
SW05	0.040	N/A	1
W1	0.712	1.065	7
W2	7.035	10.796	11

Table D-6. Jaccard Index Matrices For Macrobenthic Invertebrates.

Macrobenthic Invertebrate Families Other Than Chironomidae.

Sites	A1	A2	A3	A4	B1	B2	B3	B4	B5	BD1	BD2	D1	D2	SW05	W1	W2
A1	1.000	0.444	0.259	0.111	0.576	0.594	0.200	0.407	0.167	0.231	0.277	0.293	0.262	0.455	0.233	0.353
A2		1.000	0.357	0.154	0.423	0.440	0.167	0.353	0.176	0.114	0.125	0.154	0.136	0.375	0.086	0.200
A3			1.000	0.429	0.231	0.292	0.231	0.286	0.364	0.100	0.053	0.100	0.088	0.217	0.100	0.140
A4				1.000	0.120	0.125	0.200	0.273	0.222	0.053	0.059	0.063	0.036	0.043	0.074	0.071
B1					1.000	0.750	0.259	0.440	0.222	0.216	0.261	0.304	0.290	0.484	0.244	0.340
B2						1.000	0.222	0.458	0.185	0.245	0.239	0.309	0.254	0.552	0.220	0.347
B3							1.000	0.333	0.308	0.070	0.135	0.140	0.085	0.154	0.129	0.133
B4								1.000	0.188	0.171	0.222	0.157	0.138	0.280	0.156	0.205
B5									1.000	0.098	0.079	0.120	0.105	0.160	0.133	0.163
BD1										1.000	0.429	0.250	0.394	0.184	0.340	0.386
BD2											1.000	0.286	0.375	0.200	0.341	0.442
D1												1.000	0.288	0.211	0.254	0.475
D2													1.000	0.206	0.286	0.448
SW05														1.000	0.146	0.235
W1															1.000	0.333
W2																1.000

Macrobenthic Invertebrate Chironomidae Family Only.

Sites	A1	A2	A3	A4	B1	B2	B3	B4	B5	BD1	BD2	D1	D2	SW05	W1	W2
A1	1.000	0.320	0.192	0.136	0.524	0.455	0.143	0.250	0.200	0.281	0.367	0.321	0.545	0.393	0.276	0.367
A2		1.000	0.294	0.231	0.353	0.353	0.071	0.400	0.235	0.185	0.280	0.167	0.313	0.579	0.120	0.231
A3			1.000	0.273	0.167	0.167	0.083	0.267	0.267	0.154	0.154	0.368	0.176	0.273	0.083	0.154
A4				1.000	0.154	0.154	0.167	0.300	0.444	0.091	0.091	0.250	0.133	0.158	0.053	0.143
B1					1.000	0.375	0.167	0.176	0.111	0.192	0.240	0.227	0.323	0.261	0.174	0.240
B2						1.000	0.077	0.250	0.176	0.240	0.409	0.174	0.367	0.381	0.227	0.348
B3							1.000	0.200	0.091	0.150	0.150	0.188	0.065	0.105	0.056	0.095
B4								1.000	0.385	0.160	0.208	0.250	0.182	0.421	0.087	0.208
B5									1.000	0.160	0.208	0.316	0.258	0.286	0.136	0.208
BD1										1.000	0.600	0.241	0.389	0.226	0.500	0.600
BD2											1.000	0.286	0.563	0.310	0.500	0.600
D1												1.000	0.314	0.308	0.185	0.286
D2													1.000	0.412	0.394	0.563
SW05														1.000	0.097	0.310
W1															1.000	0.565
W2																1.000

Table D-7. Analysis of Variance Table for Phytoplankton Richness, 1994 Data.

Analysis of Variance; Phytoplankton Taxonomic Richness across all sites sampled.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	867.598	12	72.2998	6.59	0.0000
Within Sites	603.167	55	10.9667		
Total (Corr.)	1470.76	67			

Table D-8. Jaccard Index Matrix For Phytoplankton.

Sites	A1	A2	A3	A4	B1	B2	B3	B4	B5	D1	D2	Lindsay	C2
A1	1.000	0.629	0.463	0.500	0.486	0.351	0.486	0.414	0.471	0.375	0.457	0.405	0.333
A2		1.000	0.525	0.486	0.559	0.457	0.432	0.448	0.457	0.367	0.444	0.395	0.262
A3			1.000	0.568	0.474	0.350	0.647	0.286	0.588	0.522	0.486	0.436	0.302
A4				1.000	0.429	0.412	0.515	0.258	0.455	0.455	0.400	0.351	0.389
B1					1.000	0.394	0.500	0.370	0.533	0.319	0.424	0.412	0.231
B2						1.000	0.394	0.296	0.294	0.364	0.324	0.278	0.243
B3							1.000	0.423	0.586	0.442	0.516	0.412	0.297
B4								1.000	0.346	0.214	0.286	0.276	0.194
B5									1.000	0.364	0.452	0.394	0.278
D1										1.000	0.419	0.378	0.476
D2											1.000	0.469	0.270
LIND												1.000	0.333
C2													1.000

Table D-9. Analysis of Variance Table for Zooplankton Taxonomic Richness, 1994 Data.

Analysis of Variance; Zooplankton Taxonomic Richness across all sites sampled.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	860.102	12	71.6752	6.80	0.0000
Within Sites	590.448	56	10.5437		
Total (Corr.)	1450.55	68			

Table D-10. Jaccard Index Matrix For Zooplankton.

Sites	A1	A2	A3	A4	B1	B2	B3	B4	B5	C2	D1	D2	SW05
A1	1.000	0.333	0.316	0.429	0.478	0.467	0.526	0.500	0.389	0.042	0.174	0.407	0.345
A2		1.000	0.450	0.308	0.462	0.500	0.320	0.292	0.381	0.160	0.348	0.355	0.303
A3			1.000	0.353	0.286	0.276	0.294	0.250	0.636	0.125	0.333	0.192	0.185
A4				1.000	0.391	0.355	0.350	0.316	0.438	0.211	0.316	0.286	0.233
B1					1.000	0.533	0.550	0.381	0.350	0.125	0.318	0.429	0.367
B2						1.000	0.414	0.300	0.321	0.121	0.219	0.515	0.545
B3							1.000	0.412	0.294	0.048	0.143	0.458	0.385
B4								1.000	0.333	0.000	0.100	0.320	0.259
B5									1.000	0.125	0.333	0.192	0.143
C2										1.000	0.538	0.069	0.000
D1											1.000	0.138	0.097
D2												1.000	0.500
SW05													1.000

Table D-11. Analysis of Variance Table for Emergent Insect Taxonomic Richness, 1994 Data.

Analysis of Variance; Emergent Insect Taxonomic Richness across all sites sampled.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between Sites	1745.51	13	134.27	8.64	0.0000
Within Sites	1088.05	70	15.5435		
Total (Corr.)	2833.56	83			

Table D-12. Jaccard Index Matrix For Emergent Insects.

Sites	A1	A2	A3	A4	B1	B2	B3	B4	B5	C2	D1	D2	SW03	SW05
A1	1.000	0.405	0.080	0.304	0.346	0.462	0.357	0.208	0.242	0.241	0.281	0.289	0.214	0.333
A2		1.000	0.194	0.278	0.308	0.385	0.317	0.250	0.390	0.300	0.295	0.396	0.282	0.429
A3			1.000	0.167	0.182	0.115	0.115	0.176	0.333	0.174	0.185	0.114	0.190	0.129
A4				1.000	0.261	0.455	0.391	0.278	0.207	0.250	0.250	0.209	0.217	0.267
B1					1.000	0.423	0.194	0.217	0.212	0.207	0.250	0.267	0.222	0.303
B2						1.000	0.333	0.240	0.303	0.267	0.265	0.304	0.241	0.278
B3							1.000	0.292	0.194	0.310	0.303	0.250	0.200	0.278
B4								1.000	0.259	0.381	0.308	0.133	0.421	0.194
B5									1.000	0.367	0.438	0.260	0.345	0.225
C2										1.000	0.414	0.234	0.478	0.257
D1											1.000	0.235	0.393	0.256
D2												1.000	0.191	0.375
SW03													1.000	0.313
SW05														1.000

Table D-13. Macrobenthic Invertebrate Taxonomic Composition Among ..es Sampled for 1994.

Class	Order	Family	A1	A2	A3	A4	B1	B2	B3	B4	B5	Bd1	Bd2	D1	D2	SW05	W1	W2
Arachnida	Araneae		X										X	X	X		X	X
Arachnida	Pseudoscorpiones																	X
Arachnoidea	Hydracarina		X	X			X	X				X	X	X	X	X		X
Crustacea	Cladocera		X	X	X		X	X		X	X				X	X		X
Crustacea	Cladocera	Chydoridae																
Crustacea	Cladocera	Daphnidae							X		X							
Crustacea	Copepoda	Cyclopidae					X	X			X	X		X	X		X	X
Crustacea	Copepoda	Diaptomidae	X		X			X			X	X		X	X	X		X
Crustacea	Ostracoda		X	X	X	X	X	X	X	X	X			X				X
Gastropoda		Lymnaeidae												X				X
Gastropoda	Limnophila	Physidae	X	X			X	X					X	X	X	X	X	X
Gastropoda	Limnophila	Planorbidae	X				X	X						X	X	X		
Hirudinea			X				X	X	X	X			X	X	X	X		X
Hirudinea		Glossiphoniidae																
Hydrozoa															X			X
Insecta			X				X				X	X	X	X	X	X	X	X
Insecta	Coleoptera						X		X		X		X	X	X		X	X
Insecta	Coleoptera	Anthicidae																
Insecta	Coleoptera	Dytiscidae																
Insecta	Coleoptera	Dytiscidae	X	X								X	X	X	X			X
Insecta	Coleoptera	Elmidae										X		X				X
Insecta	Coleoptera	Haliplidae						X								X		
Insecta	Coleoptera	Haliplidae	X				X	X							X			
Insecta	Coleoptera	Hydrophilidae					X							X	X			
Insecta	Coleoptera	Staphilinidae										X						

Table D-13. Macrobenthic Invertebrate Taxonomic Composition Among Sites Sampled for 1994, continued.

Class	Order	Family	A1	A2	A3	A4	B1	B2	B3	B4	B5	Bd1	Bd2	D1	D2	SW05	W1	W2
Insecta	Coleoptera	Hydrophilidae					X							X	X			
Insecta	Coleoptera	Staphilinidae										X						
Insecta	Coleoptera	Staphylinidae																
Insecta	Collembola											X		X	X		X	X
Insecta	Diptera													X	X			X
Insecta	Diptera	Ceratopogonidae	X	X			X	X		X		X	X	X		X		X
Insecta	Diptera	Chaoboridae	X	X	X		X	X	X					X		X		
Insecta	Diptera	Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Insecta	Diptera	Culicidae												X				
Insecta	Diptera	Dixidae																
Insecta	Diptera	Dolichopodidae												X				
Insecta	Diptera	Empididae										X			X			
Insecta	Diptera	Ephydridae										X						
Insecta	Diptera	Muscidae										X	X	X	X			X
Insecta	Diptera	Psychodidae																
Insecta	Diptera	Ptychopteridae																
Insecta	Diptera	Simuliidae										X	X	X	X		X	X
Insecta	Diptera	Stratiomyidae										X			X			
Insecta	Diptera	Tabanidae												X				
Insecta	Diptera	Tipulidae										X	X	X	X		X	X
Insecta	Diptera	family A												X				X
Insecta	Diptera	family B															X	
Insecta	Ephemeroptera														X			

Table D-13. Macrobenthic Invertebrate Taxonomic Composition Among Sites Sampled for 1994, continued.

Class	Order	Family	A1	A2	A3	A4	B1	B2	B3	B4	B5	Bd1	Bd2	D1	D2	SW05	W1	W2
Insecta	Ephemeroptera	Baetidae	X	X			X	X	X	X		X	X		X	X	X	X
Insecta	Ephemeroptera	Caenidae	X	X	X		X	X				X			X	X	X	X
Insecta	Ephemeroptera	Ephemerellidae																
Insecta	Ephemeroptera	Heptagenidae										X	X		X			
Insecta	Ephemeroptera	Leptophebiidae													X			
Insecta	Ephemeroptera	Leptophlebiidae																
Insecta	Ephemeroptera	Tricorythidae						X				X	X	X			X	X
Insecta	Hemiptera		X									X	X	X	X		X	X
Insecta	Hemiptera	Corixidae	X	X			X	X	X	X		X		X	X			X
Insecta	Hemiptera	Gerridae												X			X	X
Insecta	Hemiptera	Nepidae																
Insecta	Hemiptera	Notonectidae																
Insecta	Hemiptera	Veliidae																
Insecta	Lepidoptera													X				
Insecta	Lepidoptera	Noctuidae												X				
Insecta	Lepidoptera	Pyralidae														X		
Insecta	Odonata																	
Insecta	Odonata	Aeshnidae																
Insecta	Odonata	Coenagrionidae	X	X			X	X					X	X	X	X	X	X
Insecta	Odonata	Gomphidae										X	X					
Insecta	Odonata	Lestidae					X											
Insecta	Odonata	Libellulidae	X															
Insecta	Plecoptera														X			

Table D-13. Macrobenthic Invertebrate Taxonomic Composition Among Sites Sampled for 1994, continued.

Class	Order	Family	A1	A2	A3	A4	B1	B2	B3	B4	B5	Bd1	Bd2	D1	D2	SW05	W1	W2
Insecta	Ephemeroptera	Baetidae	X	X			X	X	X	X		X	X		X	X	X	X
Insecta	Ephemeroptera	Caenidae	X	X	X		X	X				X			X	X	X	X
Insecta	Ephemeroptera	Ephemerellidae																
Insecta	Ephemeroptera	Heptagenlidae										X	X		X			
Insecta	Ephemeroptera	Leptophebiidae													X			
Insecta	Ephemeroptera	Leptophlebiidae																
Insecta	Ephemeroptera	Tricorythidae						X				X	X	X			X	X
Insecta	Hemiptera		X									X	X	X	X		X	X
Insecta	Hemiptera	Corixidae	X	X			X	X	X	X		X		X	X			X
Insecta	Hemiptera	Gerridae												X			X	X
Insecta	Hemiptera	Nepidae																
Insecta	Hemiptera	Notonectidae																
Insecta	Hemiptera	Veliidae																
Insecta	Lepidoptera													X				
Insecta	Lepidoptera	Noctuidae												X				
Insecta	Lepidoptera	Pyralidae														X		
Insecta	Odonata																	
Insecta	Odonata	Aeshnidae																
Insecta	Odonata	Coenagrionidae	X	X			X	X					X	X	X	X	X	X
Insecta	Odonata	Gomphidae										X	X					
Insecta	Odonata	Lestidae					X											
Insecta	Odonata	Libellulidae	X															
Insecta	Plecoptera														X			

Table D-14. Bioassessment Values of Onsite Aquatic Systems, Based on the Calculated EPT/C Index.

D-2 as reference site (2.172)

Pond	EPT/C Index mean	Target Index by reference Index ratio	Bioassessment Value
A-1	0.078	3.59%	0
A-2	0.003	0.14%	0
A-3	0.002	0.09%	0
A-4	0.000	0.00%	0
B-1	1.876	86.37%	3
B-2	0.220	10.13%	0
B-3	0.010	0.46%	0
B-4	0.007	0.32%	0
B-5	0.000	0.00%	0
D-1	0.000	0.00%	0

A-2 as reference site (0.003), based on A-2 being highly diverse.

Pond	EPT/C Index mean	Target Index by reference Index ratio	Bioassessment Value
A-1	0.078	2600.00%	N/A
A-2	0.003	100.00%	N/A
A-3	0.002	66.67%	0
A-4	0.000	0.00%	0
B-1	1.876	62533.33%	N/A
B-2	0.220	7333.33%	N/A
B-3	0.010	333.33%	N/A
B-4	0.007	233.33%	N/A
B-5	0.000	0.00%	0
D-1	0.000	0.00%	0

B-1 as reference site (1.876)

Pond	EPT/C Index mean	Target Index by reference Index ratio	Bioassessment Value
A-1	0.078	4.16%	0
A-2	0.003	0.16%	0
A-3	0.002	0.11%	0
A-4	0	0.00%	0
B-1	1.876	100.00%	N/A
B-2	0.22	11.73%	0
B-3	0.01	0.53%	0
B-4	0.007	0.37%	0
B-5	0	0.00%	0
D-1	0	0.00%	0

BD2 as a reference site (5.484)

Stream	EPT/C Index mean	Target Index by reference Index ratio	Bioassessment Value
BD1	1.923	35.07%	0
GW3	4.205	76.68%	3
IW1	0	0.00%	0

APPENDIX E. SOIL INVERTEBRATES

Author: **M. E. Bakeman**

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BACKGROUND

Soil invertebrates are common, numerous, and massive components of terrestrial ecosystems, and play several important roles. They affect biological, chemical, and physical soil properties, primarily by their relationships with bacterial and fungal communities, litter comminution, and maintenance of soil structure (Dindal, 1990). Soil invertebrates include earthworms, mites, insects, protozoa, nematodes, flatworms, and several other forms. They range in size from microns to centimeters in length, and numbers may run from a few to millions per gram of soil. They are particularly useful organisms for biological monitoring purposes because their abundances are relatively easy to measure, they are in intimate contact with soil particles, soil water and contaminants, and they exhibit a wide range of trophic groups that are affected by soil perturbations (EA Engineering, 1991). Invertebrate analysis has several potential applications at a Superfund site in a monitoring context. Since they are relatively more sensitive to anthropogenic disturbances than many other organisms, changes in invertebrate community structure or functional groups can be used to document effects of disturbances, or just as importantly, lack of effects. Such changes may be of interest in themselves (documentation of injury for NRDA under geological resources category), or serve as an early warning signal that additional biological effects will be forthcoming. However, since there are no soil invertebrate data for the Site, initial data are needed to establish baseline conditions.

Soil samples for invertebrate analysis are relatively easy to collect. Samples are transported to a laboratory, where the living organisms are extracted into preserving fluid and then counted and identified. There is such a variety of organisms that it is impossible to extract and identify all taxa. The taxa chosen in the EcMP are protozoa, arthropods, and nematodes. Subject matter experts in these taxa supervised the identification and counting of the organisms. Invertebrates were analyzed at two levels of resolution: (a) organisms were identified and counted at the appropriate taxonomic level (family, order, species, etc.), and (b) organisms were classified into functional groups. Functional groups are based on food source, feeding mode, life history, and distribution in the soil profile.

Samples were initially collected in August-September 1993 from EcMP sites and OU 11. These data have only recently become available, because the initial taxonomic identification work from sites that have no previous records is considerable. OU 11 data are reported separately under Appendix I. The program now has an established contract with Dr. John Moore, a soil invertebrate expert at the University of Northern Colorado at Greeley. Dr. Moore has completed the initial identifications of site organisms and has also compiled a reference collection that will aid in future identifications.

OBJECTIVES

1) Characterize the taxa and functional groups of soil invertebrates from several terrestrial vegetation communities and determine sources of variation that affect seasonal, annual, and long term changes in each community. This information can be used to describe the structure of invertebrate communities associated with native vegetation and anthropogenically disturbed sites. At this time, data are only available to assess differences in community structure.
2) Determine if the Rocky Flats Plant has a unique soil fauna when compared to other offsite areas. It is anticipated that offsite data will not be collected until summer 1995, at the earliest.
3) Determine if soil faunal community structure can be correlated with other biological indices, such as ecosystem functional measurements and vegetation species diversity. In this way a conceptual model of the Rocky Flats ecosystem can be refined, and the relationships between populations, communities, and ecosystem processes clarified.

TAXONOMIC BACKGROUND

Brief descriptions of the sample taxa are given below.

1) Protozoa

Protozoa are single-celled organisms that are commonly found in terrestrial and freshwater habitats. Soil protozoa belong primarily to two phyla: Sarcomastigophora, and Ciliophora (Lousier and Bamforth, 1990). The former phylum contains the flagellates (subphylum Mastigophora) and the naked amoebae (subphylum Sarcodina). The latter phylum contains the ciliate protozoans. Flagellates are typically 5 - 20 um in length, amoebae < 50 um, and ciliates < 100 um. Protozoa physiology is controlled to a great extent by available water, since the maintenance of proper osmotic conditions is critical to a unicellar organism. Protozoa are thought to be important predators of soil bacteria, and in this way they affect the cycling of important soil nutrients (Lousier and Bamforth, 1990).

Protozoa in this study were identified to the phylum or subphylum level. Most probable number counts were expressed for flagellates, ciliates, and amoebae as number of organisms g^{-1} dry soil.

2) Nematodes

Nematodes, also called roundworms, are a group of ubiquitous soil organisms that move through the soil via water films. As with protozoa, soil water is a critical factor in their distribution. The taxonomy of free-living nematodes is not well documented (Freckman and Baldwin, 1990), primarily because much of the available work has been targeted at crop pests. Nematodes occupy a great variety of niches in the soil, acting as predators of soil arthropods, bacteria and other nematodes, fungal feeders, plant root feeders, and parasites of invertebrate and vertebrate hosts.

For this study, nematodes were classified into four functional groups:
a) Bacterial Feeders;
b) Fungal Feeders;
c) Ominivore/Predators, and
d) Plant Feeders.

Functional group determination is based on body morphology and mouth parts.

All nematode functional group data were expressed as counts of organisms g^{-1} dry soil.

3) Soil Arthropods

Soil arthropods comprise a vast array of invertebrate groups and species. Some of the representative taxa encountered in this study are insects, crustaceans, arachnids (soil mites and spiders), and myriopods (centipedes, millipedes). Arthropods were analyzed both taxonomically and by functional groups for this study. Taxonomy resolution depended on class of organisms analyzed, from family/genus for most of the collembola and mites, to order for many of the remaining groups. All organisms were classified into the following functional groups:

a) Fungivore 1 - this was a count of all the collembola in the sample - this insect class was determined separately from other fungivores because of their predominance in this functional group;

b) Fungivore 2 - all other fungivores;

c) Total Fungivores - Count of fungivore 1 + fungivore 2;

d) Detritivore 1 - small detritivores;

e) Detritivore 2 - large detritivores;

f) Total Detritivores - Count of Detritivore 1 + Detritivore 2;

g) Arthropod predators;

h) General predators;

i) Total predators - arthropod predators + general predators; and

j) Herbivores - Root Feeders.

Total counts were made of the various mite genera because finer taxonomic resolution was possible for these groups.

All arthropod counts were expressed as number of organisms m^{-2}. However, counts on an area basis are rough approximations, because sample areas are very difficult to define in the rocky soils of the Site.

HYPOTHESES

$H1_0$ Soil invertebrate community structure is not related to above-ground plant community structure.

$H1_A$ Soil invertebrate community structure is related to above-ground plant community structure.

Soil microhabitats are related to the type and quantity of vegetation and litter cover on a site. Soil invertebrate communities would be expected to reflect vegetation communities, although the relationship may not be simple or direct.

$H2_0$ Soil invertebrate functional groups are related to plant community type.

$H2_A$ Soil invertebrate functional groups are not related to plant community type.

Invertebrate functional groups would be expected to be related to the type and quantity of vegetation carbon substrate available (foliage, litter and roots) for herbivores and detritivores. Fungivores and bacterial feeders are related to soil microbial communities, which are correlated with soil carbon and root activity. Omnivores and predators then feed on taxa in these lower trophic levels.

$H3_0$ Invertebrate functional groups will not be related to levels of soil carbon, nitrogen, phosphorus, available moisture and depth.

$H3_A$ Invertebrate functional groups will be related to levels of soil carbon, nitrogen, phosphorus, available moisture and depth.

Functional groups are related not only to carbon source, but also to availability of mineral nutrients and available water. Although soil invertebrates are often adapted to dry soil conditions, numbers and activity increase considerably in surface horizons with increases in soil moisture. This hypothesis will be explored in future data analysis activities.

$H4_0$ Variation in soil invertebrate populations will be greater within-a-season (on average) than between seasons, within the same year.

$H4_A$ Variation in soil invertebrate populations will be greater between seasons (on average)

than within-a-season, within the same year.

At this time, data are not available to evaluate within or between season trends, but the proposed 1995 sampling program will provide the necessary data for these comparisons.

$H5_0$ The distribution of soil invertebrate taxa will not differ by soil depth.
$H5_A$ The distribution of soil taxa will differ by soil depth.

Soil invertebrate activities are very moisture dependent; this is often reflected in their distribution in the profile. Organisms adapted to drier conditions are often found closer to the surface, while more intolerant organisms utilize deeper, wetter areas, or migrate to such areas as the profile dries out.

SAMPLING SITES

Soil samples from 0-5 and 5-10 cm depths were collected from 12 EcMP terrestrial sites (TR01-TR12) in the Buffer Zone (see Figure 1, Technical Summary) and from 12 plots (5 samples/plot) in OU 11. The twelve EcMP sites are broken into five community types: mesic mixed grasslands, xeric mixed grasslands, reclaimed grasslands, riparian north (north side of stream) , and riparian south (south side of stream). Sites were sampled in random order within a community type. That is, a single site within each community type was randomly selected (yielding five sites), and the process was repeated (once a site was selected, it was not replaced in the potential sampling pool) until all potential sample areas were selected. Sample selection was conducted in this way to prevent confounding time and community location effects

SAMPLE BREAKDOWN

Three-hundred and forty soil invertebrate samples were collected from the 12 EcMP sites. The sampling at a single site consisted of a separate arthropod sample at both depths and a protozoa + nematode sample at both depths; samples were composited from five transect locations on the EcMP TR sites. The north and south sides of riparian areas were sampled separately because all variables measured were expected to have greater variation than grassland sites. A total of 85 EcMP TR transects were sampled, including QA samples.

Two hundred and sixty-four samples were also collected from 12 OU 11 sites to support the Environmental Evaluation being conducted there by Ecology staff. The results of that study are reported in Appendix I. OU 11 Ecological Effects.

SCHEDULE

1) Field Sampling

Soil samples for invertebrate analysis were collected from mid-August 1993 until the end of September. Samples were collected by EcMP staff and subcontractors under EcMP supervision. All invertebrate samples were collocated with ecosystem function and soil physical and chemical samples.

2) Laboratory Schedule

All samples were delivered to the University of Northern Colorado Biology Laboratory by September 30, 1993. This laboratory is under the direction of Dr. John Moore, a prominent soil invertebrate ecologist. Protozoa and nematode data were delivered in 1994. Arthropod

identifications took much longer, and the final data were not delivered until March, 1995.

METHODS

1) Field Methods

At grassland sites, soil samples were collected on a transect basis; a single sample was a composite of five subsamples from randomly located quadrats along the transect. In riparian areas, a single soil sample was a composite of three subsamples collected randomly along the transect. All random locations were determined from randomly generated X and Y coordinates, with the field transect serving as the X axis. All samples were collected with hand tools after coring tools proved futile in the stony soils at the Site. Samples were placed in labeled plastic bags and transferred to coolers with blue ice. Coolers were stored in the locked EG&G Biota trailer (T891G) until information was logged onto chain-of-custody forms and samples shipped to the laboratory. Detailed procedures can be found in the September 29, 1993 EG&G report entitled: Ecological Monitoring Program Program Management/Technical Performance Report (93-RF-11615).

2) Laboratory Methods, Quality Assurance/Quality Control

After soil samples were delivered to the laboratory, they were immediately extracted or plated. Dynamic extraction was used for nematodes and arthropods; the sample was slowly dried out and the living organisms were forced to migrate either freely or in water films into an extraction vial. Organisms were then viewed under a binocular microscope, where they were counted and identified. Protozoa were plated out in a series of dilutions, and then identified and numbers estimated by most probable number counts. Quality assurance was provided by the use of standard published methods, collection of duplicate field samples and the use of a reference collection for the arthropods.

DATA MANAGEMENT

All qualifying field data, such as dates, locations and technician names, were recorded on field forms and chain-of-custody forms. These data were entered electronically and then merged with laboratory results using the common observation number (obsnum) identifier. Data are undergoing final proofreading steps before inclusion into the EcMP and Sitewide Ecological databases.

RESULTS

1) Statistical Approach

A two factor Analysis of Variance (ANOVA) model was used to evaluate the effect of community and depth on soil invertebrates. A significant community effect indicates that at least two of the community means are significantly different. A significant depth effect indicates that the means of the 0-5 and the 5-10 cm depths are significantly different. This model detected if there were significant differences in invertebrates among communities (five levels: xeric grassland, mesic grassland, reclaimed grassland, riparian north side of stream, and riparian south side of stream), and by depth (two levels, 0-5 cm [surface] and 5-10 cm [subsurface]). The model also detected if there was a significant community-by-depth interaction. Variables analyzed in this model included the three protozoan phyla counts, the nematode functional group counts, and the arthropod functional counts.

In addition to the above model, a one-way ANOVA was run with Site as the factor (site means are

calculated from values from both depths). A significant site effect indicates that at least two of the fourteen or fifteen sites are significantly different. There are eight or nine grassland sites, and three riparian sites, each with a north and south side (protozoa data are not available for site TR07, a reclaimed grassland site). Caution must be used in the interpretation of a significant site effect, because differences may simply reflect sampling time. It was impossible to collect all samples from all sites at the same time, and differences may reflect varying site conditions of vegetation phenology and soil moisture over the 1-month sampling period.

The assumptions of an ANOVA model do not always hold for count data because of the large variability in these data. Numbers of individuals in the same factor level may range from 0 to values in the thousands. Variances among group means are often not equal; although this does not necessarily disqualify the robust ANOVA model. Also, as sample sizes of each factor level mean increase, the sample tends to become normally distributed. Community level means had sample sizes of 20-30 observations, depth means had 70 observations, and site means had 10 observations; these sample sizes are generally considered to be moderate to large. Most of the residuals that were examined in the analyses were normally distributed, lending credence to this model. If a significant main effect was found, means were separated by the conservative Tukey honestly significant difference (HSD) method, which produces wide confidence intervals, making it more difficult to detect statistically significant differences than other means separation procedures, such as Duncan's or LSD.

An alpha level (α) of 0.10 was generally used to consider if an effect was statistically significant; this is appropriate for such variable data.

Results are presented for protozoa phyla, and nematode and arthropod functional groups. Initial taxonomic analyses were performed for two arthropod groups.

2) Protozoa

Surface horizons are dominated by amoebae and flagellates, with mean values of 6799 and 6776 organisms g^{-1} soil respectively, all samples. Ciliates are much less abundant, with a mean of 34 ciliates g^{-1} soil. These data are extremely variable, especially the amoebae and flagellate data, with count values ranging from a few dozen to tens of thousands. These same general relationships hold for the subsurface horizon, except that all counts are less than the surface horizon (5126 amoebae g^{-1} soil, 5269 flagellates g^{-1} soil, and 14 ciliates g^{-1} soil, all samples).

The two factor ANOVA for amoebae, flagellates, and ciliates are presented in Tables E-1, E-3, and E-5. Site effects are presented in Tables E-2, E-4 and E-6. Summary statistics are also presented in these tables by community type, depth and site, respectively. The number of observations within factor levels was often not equal, because the plating technique failed for some samples. No data are available for site TR07.

Amoebae numbers showed a significant community effect at the α=0.1 level (p=0.0954, Table E-1). The north side of the riparian community type (riparian north) had the highest mean numbers of amoebae, (mean 9865 amoebae g^{-1} dry soil), followed closely by riparian south (6533) and xeric types 5999), while the mesic and reclaimed community types had the lowest means (3194 and 3310 respectively)[Figure E-1]. The riparian north and mesic community types were significantly different at the α = 0.1 level. Although there were more amoebae in the 0-5 cm layer than the 5-10 (means 6799 vs. 5126), the difference was not statistically significant.

Amoebae numbers also showed a significant site effect (p=0.0546). The north side of TR05 had a significantly higher mean count (15444 amoebae) than TR09 (mean = 369) at an α of 0.1 (Table E-2, Figure E-2).

Flagellate numbers showed a highly significant community effect (p=0.0113), with the riparian north community showing the highest mean count (13,239 flagellates g^{-1} dry soil), followed by riparian south, reclaimed, xeric and mesic communities (Table E-3 and Figure E-3). As with amoebae, there were more flagellates in the 0-5 cm layer than the 5-10 although the difference was not significant.

Flagellate counts also showed a highly significant site effect (p = 0.0007, Table E-4), with the north side of TR05 (TR05N) being significantly higher than most of the other sites (Figure E-4).

Neither community, depth, or site effects were significant for soil ciliate numbers, although the pattern of community counts was similar to those for amoebae and flagellates (Tables E-5 and E-6). The patterns of residuals on these analyses did not appear to be normally distributed in some cases (community), and the model may not be appropriate for ciliate data.

3) Nematode Functional Groups

Bacterial and fungal feeding nematodes dominated other functional groups in the surface 0-5 cm (4846 and 4264 nematodes g^{-1} soil, respectively, all samples). Mean plant feeder counts were ranked next (988 g^{-1} soil), followed by omnivore/predators (803 g^{-1} soil). On the average, a single g of dry soil (0-5 cm) harbors approximately 10,901 nematodes. Average subsurface nematode functional group distribution follows the same general trend, except that bacterial feeder, fungal feeder, and plant feeder numbers all diminish with depth; omnivore/predator counts are relatively insensitive to depth. Subsurface means are: 3848 bacterial feeders; 3147 fungal feeders; 485 omnivore/predators, and 982 plant feeders g^{-1} soil.

Four nematode functional groups were analyzed using the same ANOVA model used for protozoa. As before, treatment means are not always balanced because of extraction failures. Sites TR05 north and south had only 5 observations each, rather than the normal 10.

In general, bacterial feeding nematodes had the highest average count (4351 nematodes g^{-1} dry soil, 0-10 cm), followed by fungal feeders (mean 3710), plant parasitic (mean 985) and omnivore/predators (mean 645). If all functional groups are summed, an average gram of dry soil contains 9691 nematodes (0-10 cm depth).

None of the functional group populations had a significant community effect at an α of 0.1 (Tables E-7, E-9, E-11, and E-13), although fungal feeders, bacterial feeders, and omnivore/predator functional groups were all significant at p-values slightly higher than $\alpha = 0.1$ (fungal feeders [p=.1136], bacterial feeders [p=.12], and omnivores/predators [p=0.12]). Omivores/predators showed a significant depth effect, with significantly more in the 0-5 cm layer (mean count = 803) than the 5-10 cm layer (mean 485, p=0.0197). All functional groups had higher 0-5 cm layer means.

All four nematode functional groups showed a significant site effect at an α of 0.1 (Tables E-8, E-10, E-12, and E-14). For fungal feeders, site means ranged from a high of 8649 (TR11) to a low of 616 (TR01, Figure E-5). Most of the 15 site means from 2000 to 6000 fungal feeders per g soil and were not significantly different.

For bacterial feeders, two sites, TR06 and TR11, had significantly more nematodes (means 10,649 and 8358 respectively, Figure E-6) than most of the other sites.

The omnivore/predator group generally had the lowest counts and highest variability of all the functional groups. Abundance values ranged from mean site counts of 1401 (TR10S) to 124 nematodes g^{-1} soil (TR03S). This large variability increased the site confidence intervals, and most of the site means were not significantly different from each other (Figure E-7).

Plant feeder nematode counts ranged from 1693 nematodes in site TR05N to 173 in site TR09. Site means for TR05N and TR07 were significantly different than many of the other sites (Figure E-8).

Nematode functional group numbers showed a much more individual affinity for community types that did the protozoa. That is, a community type might have very high numbers of one functional group and very low numbers of another. For example, xeric communities had the lowest mean number of plant parasitic nematodes, but the highest mean number of bacterial feeders. Community ranking seems to be related to the functional group studied, and multivariate techniques will be used to further explore these relationships in the future.

4) Arthropods

Functional Groups

Arthropod numbers were dominated by the total fungivore functional group in the surface 0-5 cm, with 3645 fungivores m^{-2}, all samples. Small detritivores (detritivore 1) were the fewest in number (mean 140 m^{-2}), but total detritivores were numerous (mean, 1704 m^{-2}). Total predators were the fewest of these three functional groups (mean 874 m^{-2}), as expected. Within surface horizon mite taxa, the Prostigmata were the most numerous (mean 3209 m^{-2}), and the Astigmata the least (207 m^{-2}). These same relative relationships hold for the subsurface horizon, but all functional group and taxa counts were fewer than the surface horizon.

Arthropod numbers were analyzed on both a taxonomic and functional group basis, although the two are often closely related (a functional group is often dominated by a particular taxon). A total of ten functional groups were analyzed, including the calculated variables of total fungivores, total detritivores, and total predators. Two families of mites were also analyzed for richness (number of families represented in a sample); all analyses used the same ANOVA models previously discussed.

Fungal feeder group 1 is comprised exclusively of seven families of collembolan insects. Community, depth, and community x depth interactions were all significant at p=0.1 (Table E-15, Figure E-9). A significant interaction indicates that only simple effects, such as the comparison of two communities at a single depth can be evaluated. In general, the examination of simple effects were not explored because the more general questions stated in the hypotheses were of greater ecological significance.

Differences in site fungal feeder 1 means were highly significant (p=0.00, Table E-16, Figure E-1). Four sites had mean values of 0 and 7 out of the 15 sites had mean counts less than 100. Site TR05S had the highest mean count of 3213 fungal feeders 1.

Fungal feeder group 2 included all other fungal feeders, primarily prostigmatid mites. The community effect was not significant (p=0.2919), but the difference in distribution by depth was highly significant (p=0.0003, Table E-17, Figure E-11). These feeders were more than two times more abundant in surface than subsurface soil.

The site effect was also not significant for this functional group (p=0.4255, Table E-18).

Total fungivores (Table E-25) showed the same pattern as fungal feeders 1, with community, depth, and community x depth interactions all significant (p=0.0339, 0.0001, and 0.0587, respectively). Again, the significant interaction confounds the interpretation of main effects.

Detritivore group 1 was a mixed group of small invertebrates from insecta, crustacea, and myriopoda taxa. They were few in number, but showed a highly significant community effect

(p=0.0001, Table E-19). The southern riparian site was significantly greater in mean detritivore 1 abundance than the grassland sites (Figure E-12), although the northern riparian areas were not.

Detritivore group 1 also showed a significant site effect (Table E-20, Figure E-13). Site TR10S had a significantly higher mean abundance of detritivores than all other sites.

Detritivore group 2 was primarily cryptostigmatid mites; this group generally exceeded group 1 detritivores. The ANOVA produced similar results to the analysis of detritivore group 1, with a significant community effect (Table E-21, p=0.0454), and a similar ordination of communities (Figure E-14).

This functional group did not show a significant site effect (p=.1925, Table E-22). Site mean counts varied considerably, from 49 to 4605, but variances were also high and shadowed significant effects.

Total detritivore (the sum of groups 1 and 2) abundance also had a significant community effect (Table E-23, p=0.0208), and the depth effect was nearly significant at the α=.1 level (p=0.1095). Again, the riparian south community type was significantly higher than three of the other communities (Figure E-15).
Total detritivore counts showed a significant site effect (p=0.077, Table E-24). Site TR10S was significantly different than all other sites (Figure E-16), similar to the results of the detritivore 1 analysis.

The three functional predator groups, general predators, arthropod predators, and total predators, showed significant community and depth effects (Tables E-27, E-29, and E-31). General predators also showed a significant community by depth interaction (p=0.0762) and main effects were not further investigated. All surface soils had higher predator counts than subsurface soils. Community means typically showed that riparian areas had higher counts than grassland areas, but arthropod predators in reclaimed communities were significantly greater than riparian and most grassland communities (see Figures E-18 and E-20).

All three of the predator functional groups showed significant site effects (Tables E-28, E-30, and E-32). General predator mean counts were higher in both TR05 sites than most other sites (Figure E-17); arthropod predators were more numerous in TR07 and TR10S than most other sites (Figure E-19), and total predators were higher in sites TR05S and TR06 than other sites, but most mean comparisons were not significantly different at.

Arthropod herbivores showed both significant community and depth effects (Table E-33, p=0.0031 and 0.0309 respectively). As with arthropod predators, herbivores were also greater in the reclaimed community type, with the other communities showing similar means (Figure E-22). Site differences were also highly significant (p=0.00, Table E-34), with site TR07 being significantly greater than all other sites (Figure E-23).

Taxonomic Analyses

Preliminary taxonomic analyses were conducted on two mite taxa that had sufficient resolution. The Cryptosigmatid mites were identified to 10 superfamily groups, and the Prostigmatid mites were identified to 12 family groups. The total number of superfamilies (Cryptostigmata) or families (Prostigmata) present in each sample were then calculated; this sum is referred to as richness.

Cryptostigmata richness showed significant depth and community x depth interaction effects. Richness was higher in the 0-5 cm layer, but community types showed relatively small differences, ranging from 1.60 to 2.0 superfamily groups (Table E-35). Differences among sites were significant (p=0.0002, Table E-36), and richness values ranged from 0.4 to 3.1.

Prostigmatid mite richness was not different by community type, but the 0-5 cm layer mean richness was greater than the 5-10 cm layer (mean 4.9 versus 4.1 families, p=0:0392, Table E-37). Richness differences in the site factor were highly significant (p=0.000, Table E-38), with sites TR02, TR06 and TR07 having the highest values. Interestingly, these sites represent mesic, xeric and reclaimed grassland community types.

DISCUSSION

The results presented investigate the effects of three major factors on distributions of soil invertebrate populations: community type, depth, and site differences.

Analysis of community differences was conducted on the three major groups of soil invertebrates: protozoa, nematodes, and arthropods. Community analysis can provide several levels of information that will answer questions such as:

1) Do community populations differ (that is, are at least two community means significantly different)? If they do, then general statements can be attributed to average values and variances associated with community types; if no community types differ, such statements cannot be made;
2) If some communities differ (a significant community effect), then how different are they? Are the relatively undisturbed xeric grassland types significantly different than the more disturbed reclaimed and mesic grassland types? Are riparian types different than grassland types? If significant differences are apparent between several community types and patterns of differences emerge, statements regarding community differences can then be further refined;
3) Are some of the variables analyzed more sensitive to the community effect than others?; and
4) If differences occur, what causes them?

Seventeen functional group variables were analyzed for community differences, and the significance of community effects are summarized in Table E-39. Eleven of the 17 variables showed a significant community effect; 3 of the 11 significant variables also showed a significant depth by community interaction, so that statements regarding the main effect of community must be made with caution. The remaining community discussion will deal only with the 8 variables that showed a statistically significant community effect ($\alpha = 0.10$) and no significant interaction term. These include amoebae, flagellates, and 6 arthropod functional groups (none of the nematode functional groups showed a significant community effect). Although there was an overall community effect in these cases, many of the means of the five community types were not statistically significantly different from each other. For instance, 90% confidence intervals for xeric and mesic grassland community types overlapped for all eight variables, indicating that these community types cannot be differentiated by the data here. The xeric community type had higher protozoa counts than the mesic type (up to 2 times greater) and four of the six xeric mean arthropod variables were higher than mesic types, yet means could not be differentiated because of high variability in these data.

The remaining grassland community, reclaimed grassland, showed surprisingly high arthropod predator and herbivore means, being statistically different at $\alpha = 0.10$ than almost all other community types (see Figures E-18 and E-22). It appears that this community type can be distinguished from all others by these variables.

The riparian north community type had the highest mean protozoa counts; the flagellate population in the riparian north type was significantly different than mesic and xeric grassland types, and the amoebae population in the riparian north type was significantly different than the mesic grassland type. Riparian community types were also higher for all arthropod detritivore functional group means than the other community types. The riparian south type could be distinguished from all grassland types by detritivore group 1 and total detritivore functional groups. Several other

arthropod functional groups that did not show a statistically significant community effect also had the highest mean counts in these types (fungal feeder 1, total fungivore, and general predators groups). Thus, it appears that in general, riparian community types often have the highest protozoa and arthropod populations, which are statistically different in some cases from all grassland community types. It is interesting to note that riparian north and south community types were not significantly different for any of the variables analyzed. However, for some variables, only the north or the south side (but not both) showed significant differences from grassland community types.

None of the nematode functional groups showed significant community differences, and no trends in ranking of community means was apparent.

Depth was evaluated as a factor at two levels: 0-5 cm and 5-10 cm. The surface layer was sampled with intact vegetation and also included litter, so it would be expected to have a greater diversity of microhabitats for the various taxa, which might translate to a greater diversity of functional group members. All surface layers had higher mean counts for all functional groups and mite richness values, but differences were only statistically significant for soil arthropods. Of those functional groups that had statistically significant depth differences, only four did not have significant depth x community interactions (fungal feeders 2, arthropod predators, total predators, and total herbivore groups, Table E-39). In those cases, the surface soil had approximately two times more organisms than the subsurface horizon.

Site was explored as a factor to see if the 12 EcMP sites could be distinguished from one another through several functional variables. Many of the questions regarding this factor are similar to the analysis of community effects. Ideally, the "natural" or noncontaminated (in the CERCLA sense) distributions of soil invertebrates can be discerned from site-to-site. It would be expected that contaminated sites have very different distributions than these natural sites, although this can only be evaluated through contaminant treatments. And if sites are significantly different, how different are they? It would be expected that sites from the same community types to be more similar than sites from other community types; does this relationship hold?

As previously discussed, significant site differences must be interpreted with caution because of the possible confounding effect of sample timing on the results.

As with community analysis, three major taxa (protozoa, nematodes and arthropods) were analyzed by functional groups and two mite taxa richness classes for site effects. Seventeen functional group analyses were conducted for these taxa; thirteen showed a significant site effect at an $\alpha = 0.10$ level (Table E-39). This included two of the three protozoa, four of four nematode functional groups, and seven of the ten arthropod functional groups. Both Cryptosigmatid and Prostigmatid mite richness values also showed significant site differences (Table E-36 and E-38).

Protozoa showed a general site trend, with highest mean counts of amoebae and flagella in the TR05 sites (Walnut Creek), and the remaining sites clustered together (Figure E-2 and E-4). The TR05N site was significantly higher in flagellate counts than all grassland sites.

Nematode population site means generally fell into two site groupings; group one consisted of a few sites that were significantly greater than all other sites, which constituted group 2 (Figure E-5 through E-8). A riparian site functional group mean was always ranked as one of the greatest three of fifteen possible site means for the four functional groups, and was also ranked as one of the lowest three mean values for 3 functional groups. Omnivore/predators were the only functional group that did not have any significant differences between any of the grassland sites. For fungal feeders, the TR11 mean abundance (a mesic community type) was significantly greater than TR01, TR02, TR03N and S, TR07, TR10N and S, and TR12. A very similar relationship existed between TR11 and the other site means for bacterial feeders. Site TR07 mean plant parasitic nematode counts were significantly greater than most other grassland sites and two of the riparian

sites as well. These data illustrate that sites within a particular community type can have significant differences in functional group counts, and that variation between sites within a community type may exceed site variation between community types.

Arthropod functional groups had more consistent site differences than did nematode functional groups. Site differences were often due to one or more riparian sites having higher mean populations than all other sites. Arthropod predators were the only functional group that had a significant difference between grassland sites (the TR07 mean count was significantly greater than four other grassland sites).

These data have applicability for activities at the Site in several ways. The most obvious application is to determine if adverse ecological effects have occurred as a result of Site activities, be they construction, remediation, or accidental contamination. In the injury definition section of Natural Resource Damage Assessment guidelines (43 CFR 11.62), "concentrations in the soil of substances sufficient to cause a toxic response to soil invertebrates" are specifically mentioned. These data are the beginning of the baseline information that is necessary to determine if injury has occurred.

Soil invertebrate means and 90% confidence intervals are available for some community types, as measured by several soil invertebrate functional group variables. For other community types where this resolution is not yet available, ranges and variabilities have been established that can guide interpretation of potential injury. For instance, if an area is damaged in some way where injury to ecological receptors is suspected (or claimed by Natural Resource Trustees), soil invertebrate measurements of the area may be taken. If the appropriate organism counts are below the known range of values for the Site, then injury may have occurred. If values fall within the Site range, ecologists may determine if comparisons to appropriate sites are available.

The above scenario assumes that soil invertebrate measurements are collected following the potentially damaging action. However, if injury is suspected as a result of a planned activity, these measurements can be collected both before and after the activity, and information is available to guide these sampling efforts to determine if real differences have occurred.

It is important to realize that the above scenarios are quantitative data exercises, where means and confidence intervals are generated. Therefore, the approach is both defensible and repeatable.

Finally, these data will contribute towards the description and understanding of the Rocky Flats ecosystem. The future use of the Site is becoming an increasingly important topic, and biodiversity values are important factors in land use planning and conservation. Two of Rocky Flats' major neighbors, Jefferson and Boulder Counties, are very interested in the natural value of landscapes, and data reported here can have region-wide applications. Recently, arthropod inventories and assemblages are being used more in such efforts to categorize and prioritize areas for conservation efforts.

FUTURE ANALYSES

The data presented here deal almost exclusively with soil invertebrate populations, and many relationships remain unexplored at this time. Multivariate community analysis may provide insights into better ways to classify communities and new ways to analyze data. For example, ordinations may show new relationships among sample units that will better distinguish mixed mesic and xeric grassland communities. Soil invertebrate data also must be analyzed relative to many of the other collocated data that were gathered, such as soil physical/chemical properties, ecosystem functions, and vegetation production and composition. Finally, these measurements represent data from a single year and single season, and annual and seasonal variation are unknown. Sampling efforts

in 1995 will provide new data to answer those questions.

CONCLUSIONS

Protozoa, nematode, and arthropod data collected in 1993 were analyzed for community, depth, and site effects to assign mean values and confidence intervals from selected variables to particular areas by community classification or other classification means. Eight of seventeen functional group variables (all taxa) showed a significant community effect; riparian community types were significantly different than some or all grassland types when measured by amoebae, flagellate, or arthropod detritivore functional groups.

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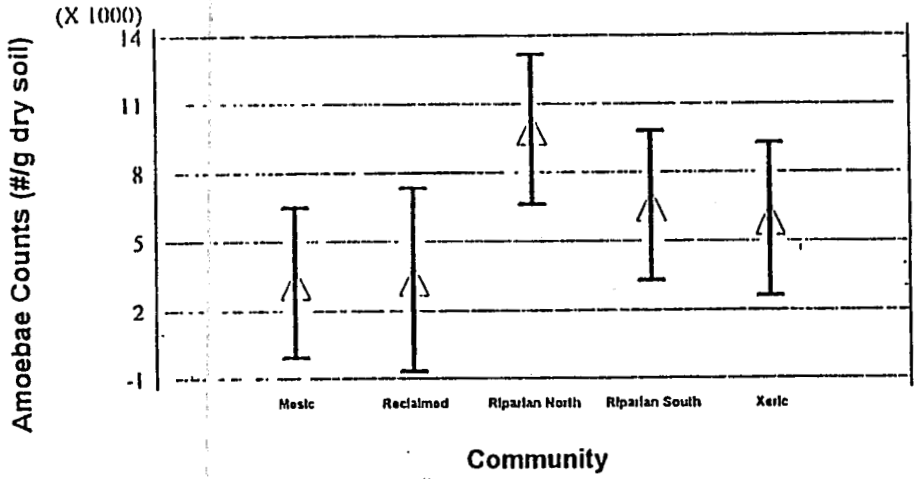

Figure E-1. Amoebae Means By Community and Tukey 90% HSD Intervals

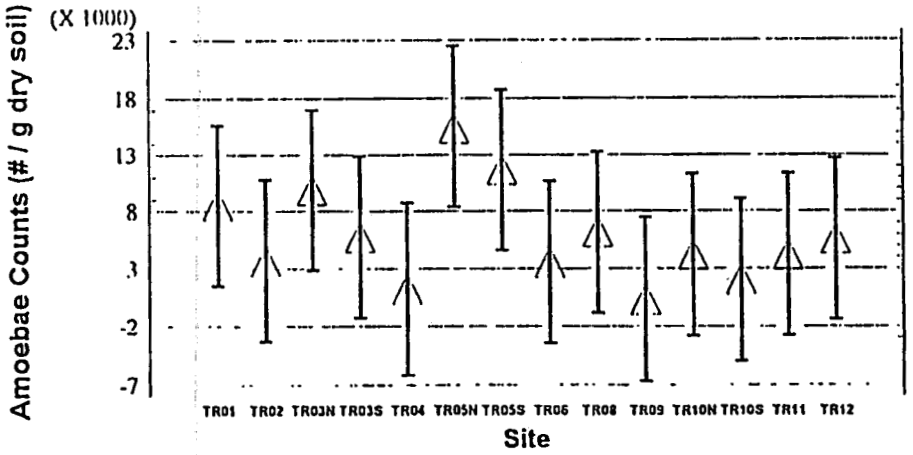

Figure E-2. Amoebae Means by Site and Tukey 90% HSD Intervals

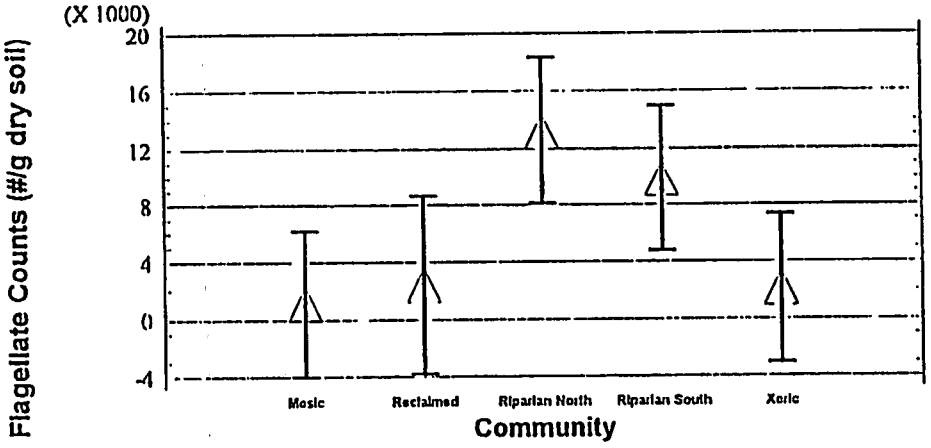

Figure E-3. Flagellate Means by Community and Tukey 90% HSD Intervals

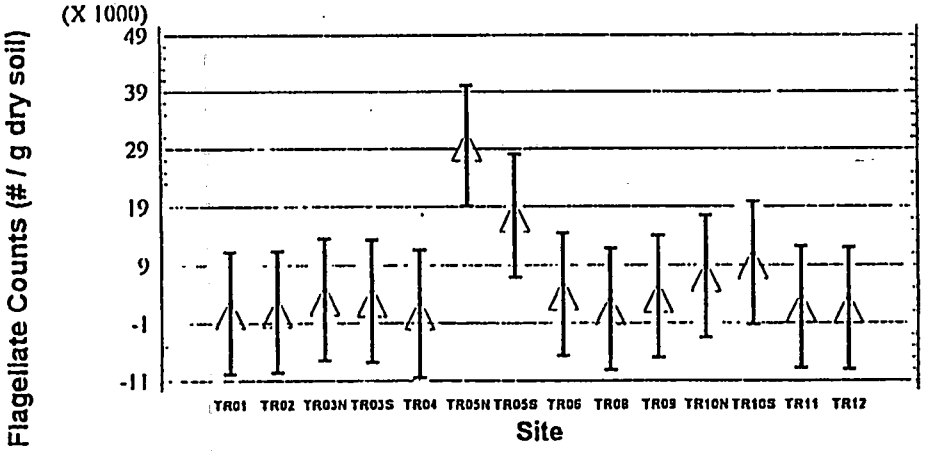

Figure E-4. Flagellate Means by Site and Tukey 90% HSD Intervals

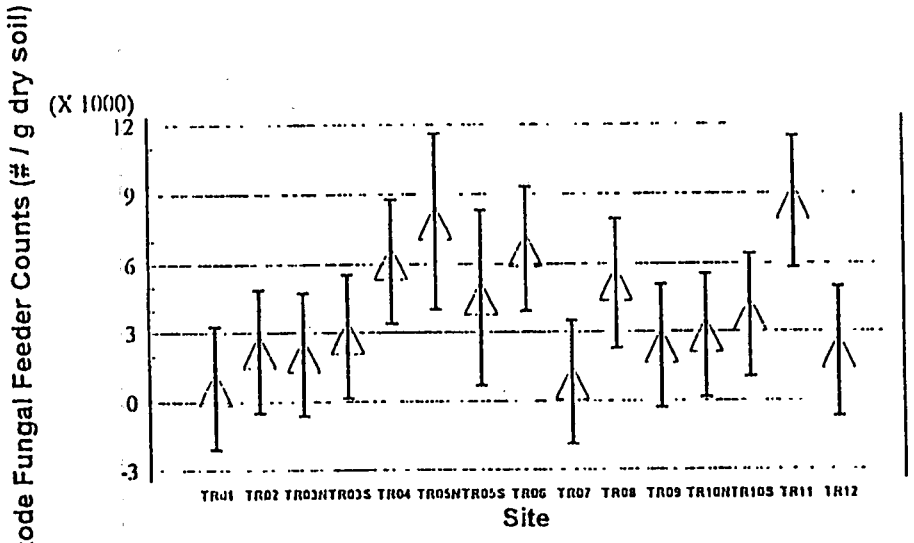

Figure E-5. Nematode Fungal Feeders by Site and Tukey 90% HSD Intervals

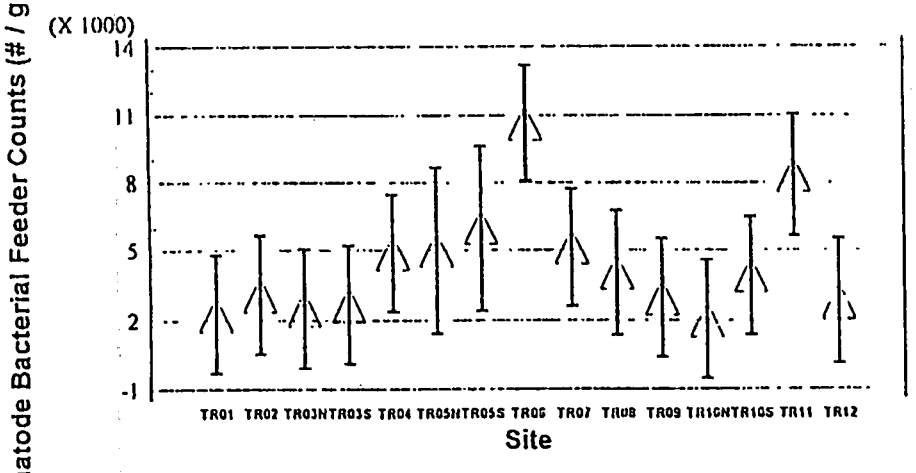

Figure E-6. Nematode Bacter eeders by Site and Tukey 90% HSD Intervals

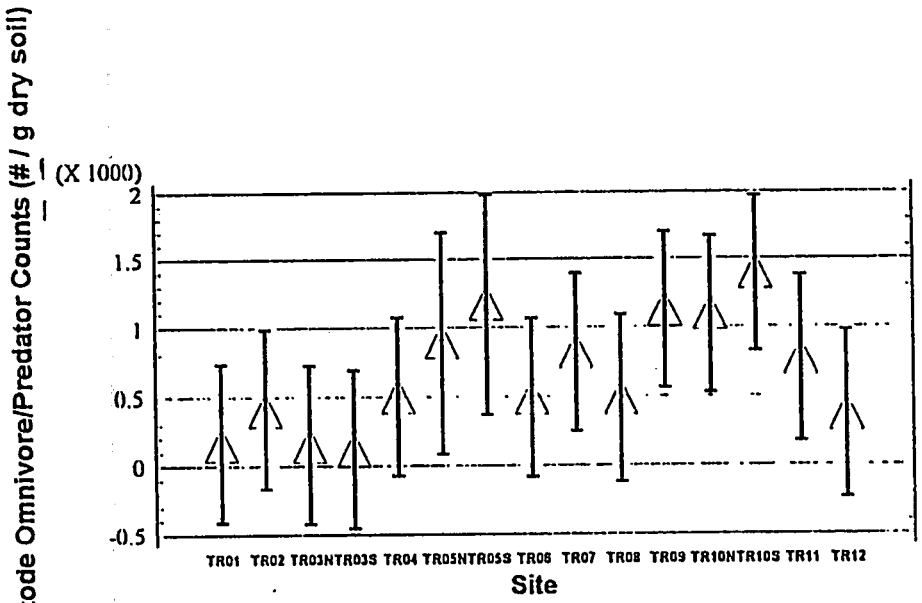

Figure E-7. Nematode Omnivore/Predators by Site and 90% Tukey HSD Intervals

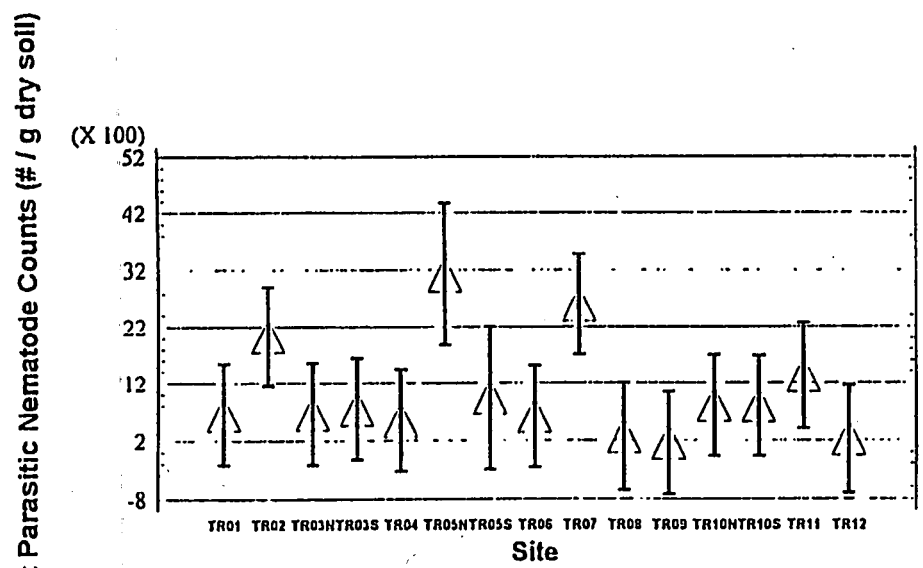

Figure E-8. Plant Parasitic Nematodes by Site and 90% Tukey HSD Intervals

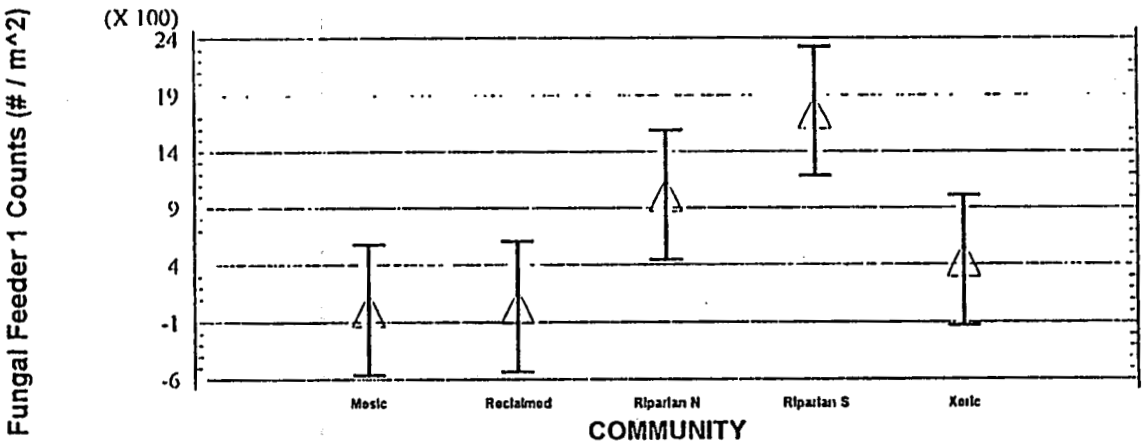

Figure E-9. Arthropod Fungal Feeders 1 Means by Community & 90% Tukey HSD Intervals

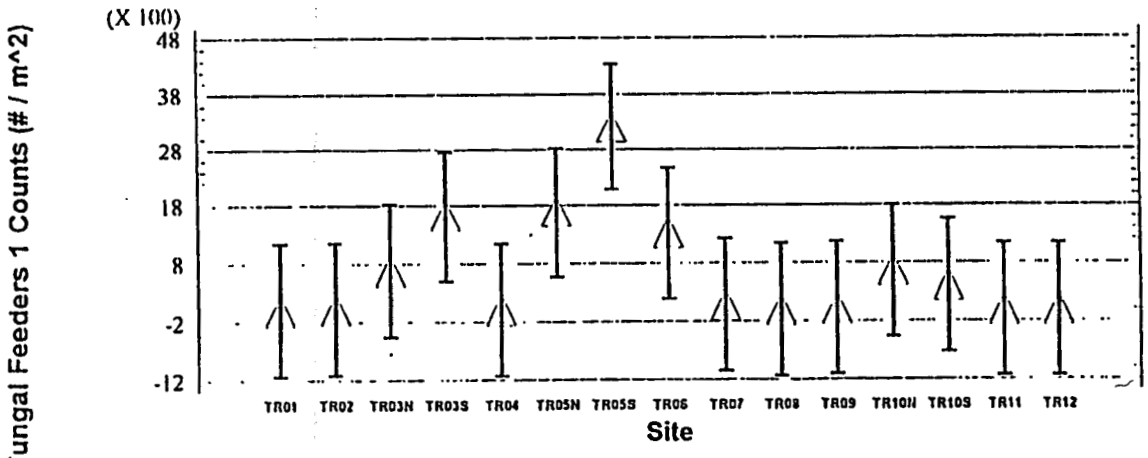

Figure E-10. Arthropod Fungal Feeders 1 [illegible] Site & 90% Tukey HSD Intervals

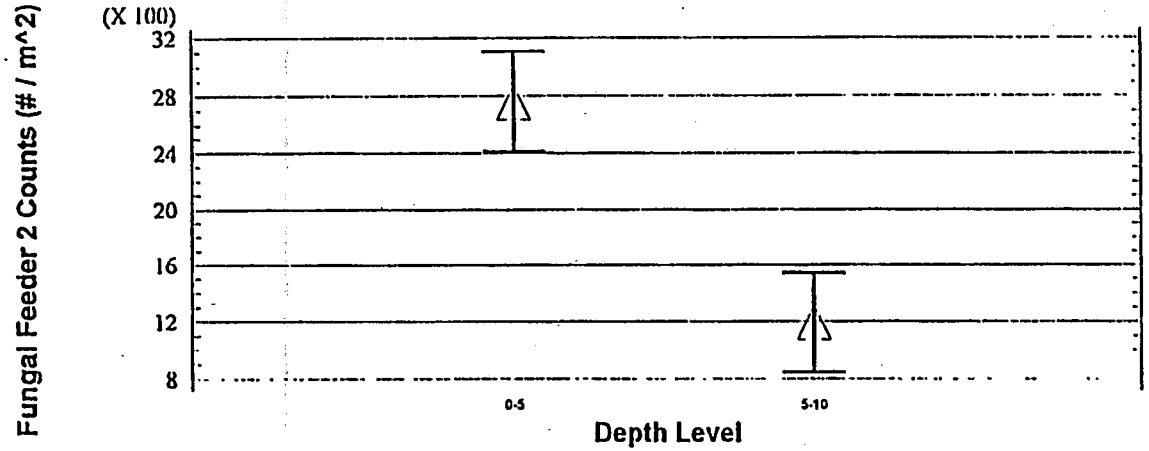

Figure E-11. Arthropod Fungal Feeders 2 by Depth and 90% Tukey HSD Intervals

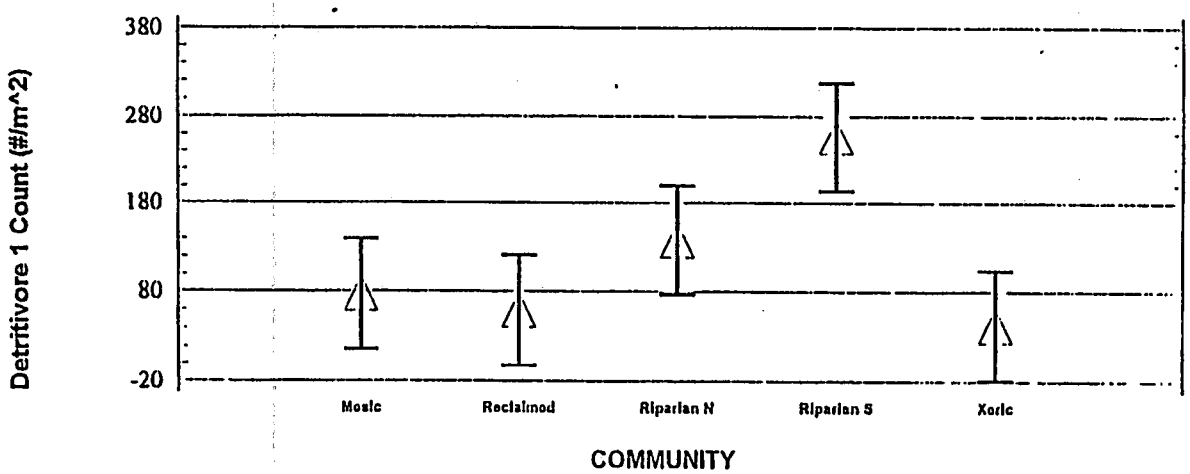

Figure E-12. Arthropod Detritivore 1 Means by Community and Tukey 90% HSD Intervals

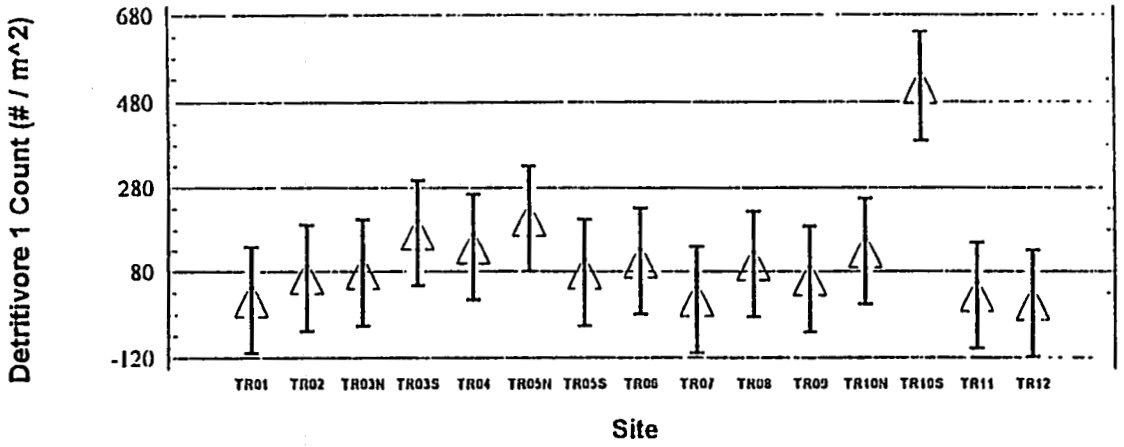

Figure E-13. Arthropod Detritivore 1 Means by Site and 90% Tukey HSD Intervals

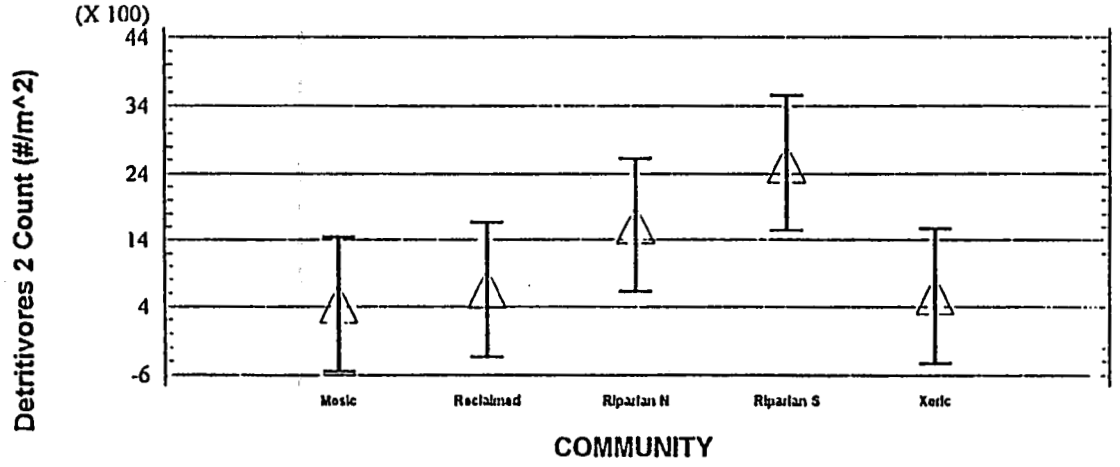

Figure E-14. Arthropod Detritivore 2 Means by Community and Tukey 90% HSD Intervals

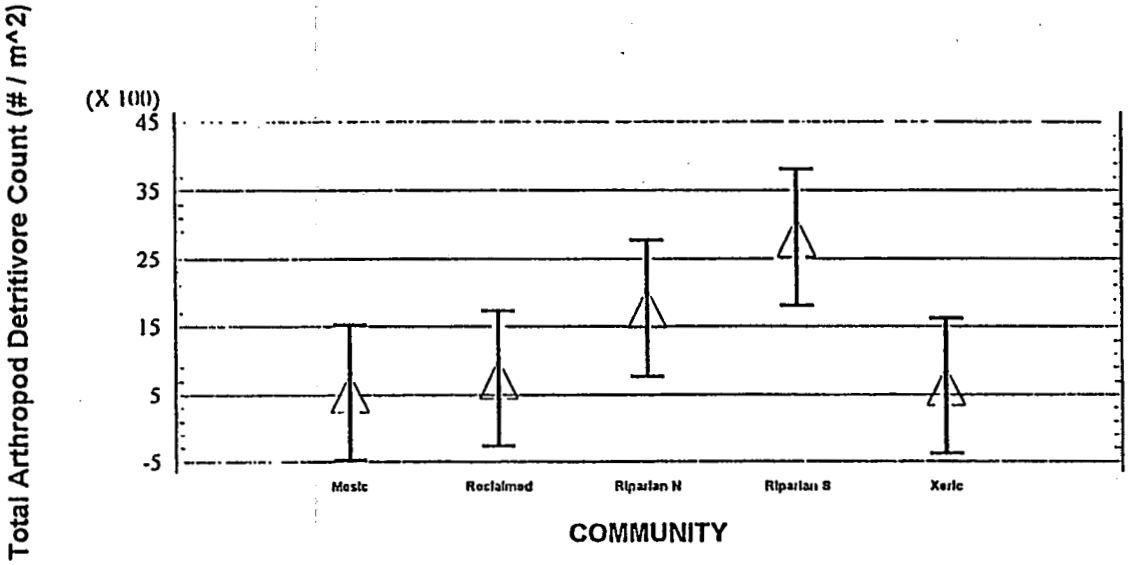

Figure E-15. Arthropod Total Detritivore Means by Community and 90% Tukey HSD Intervals

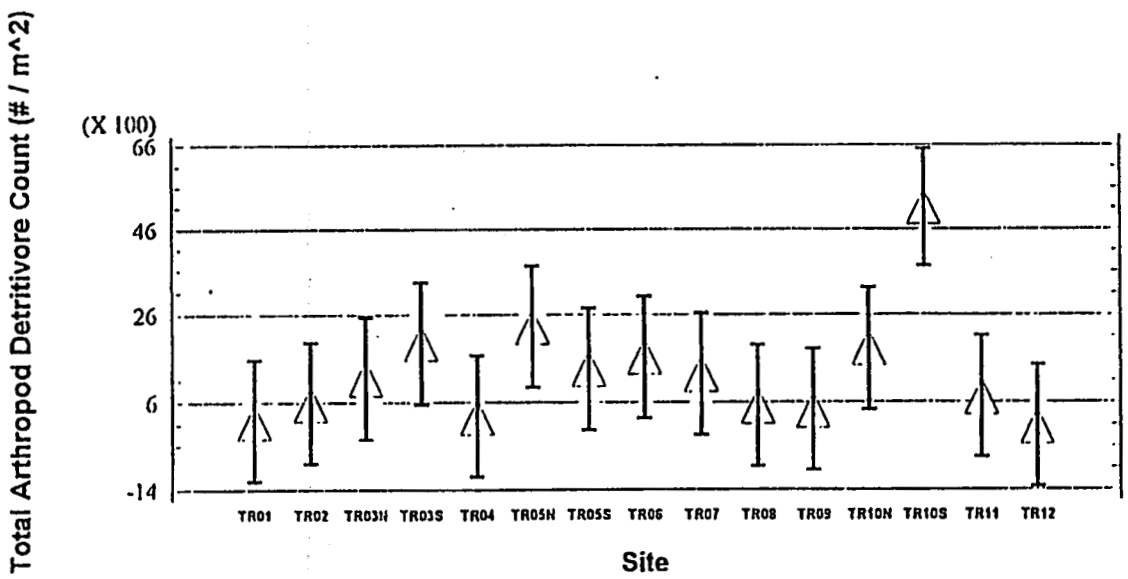

Figure E-16. Arthropod Total Detritivore Means by Site and 90% Tukey HSD Intervals

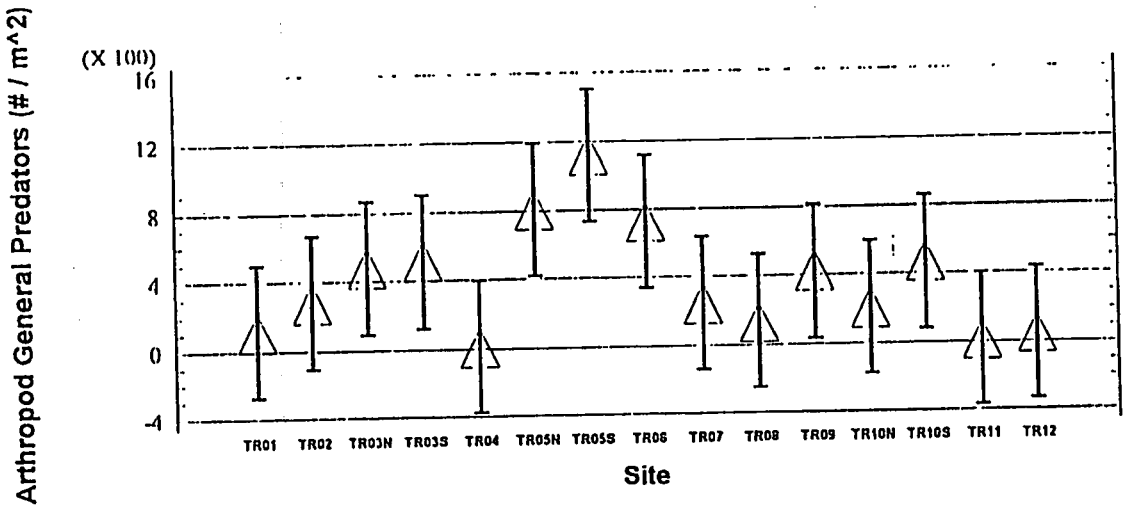

Figure E-17. Arthropod General Predators by Site and 90% Tukey HSD Intervals

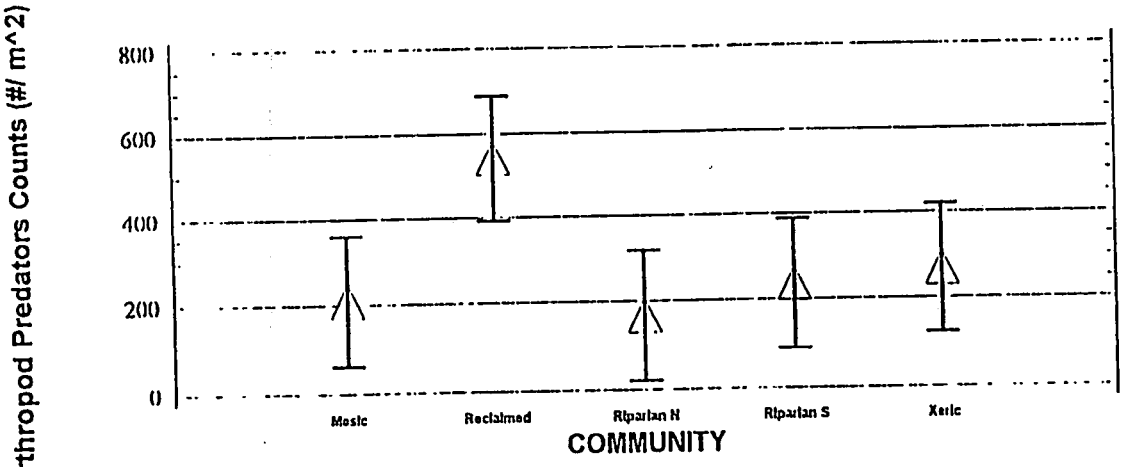

Figure E-18. Arthropod Predator Means by Community and 90% Tukey HSD Intervals

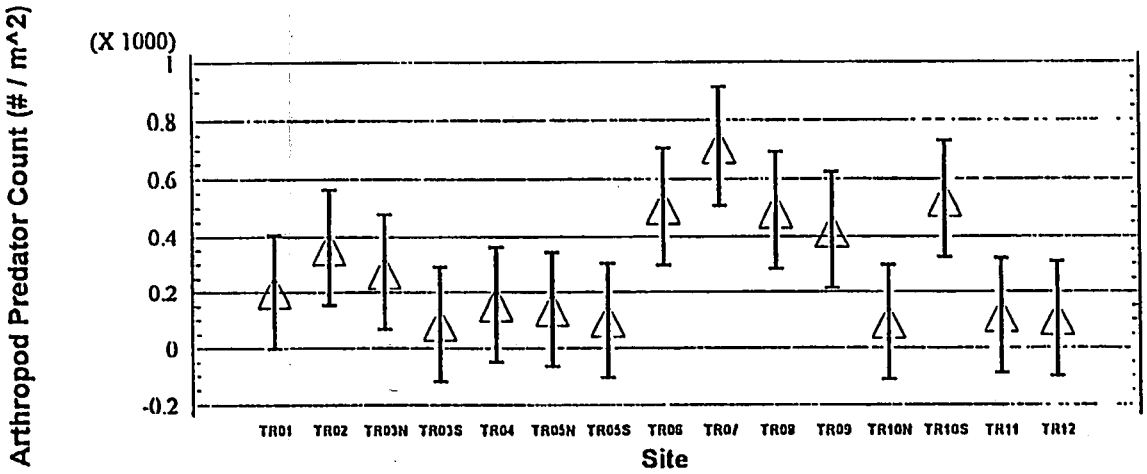

Figure E-19. Arthropod Predator Means by Site and 90% Tukey HSD Intervals

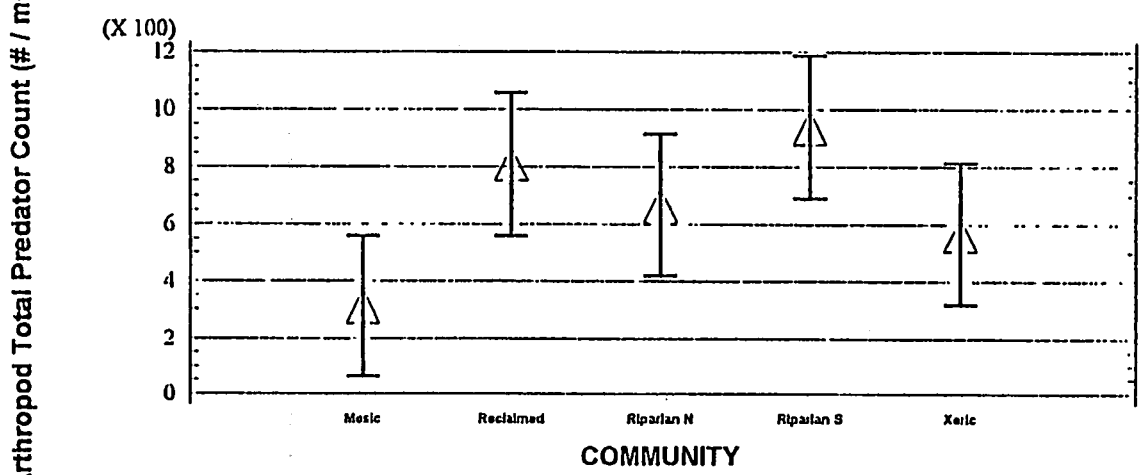

Figure E-20. Arthropod Total Predators by Community and 90% Tukey HSD Intervals

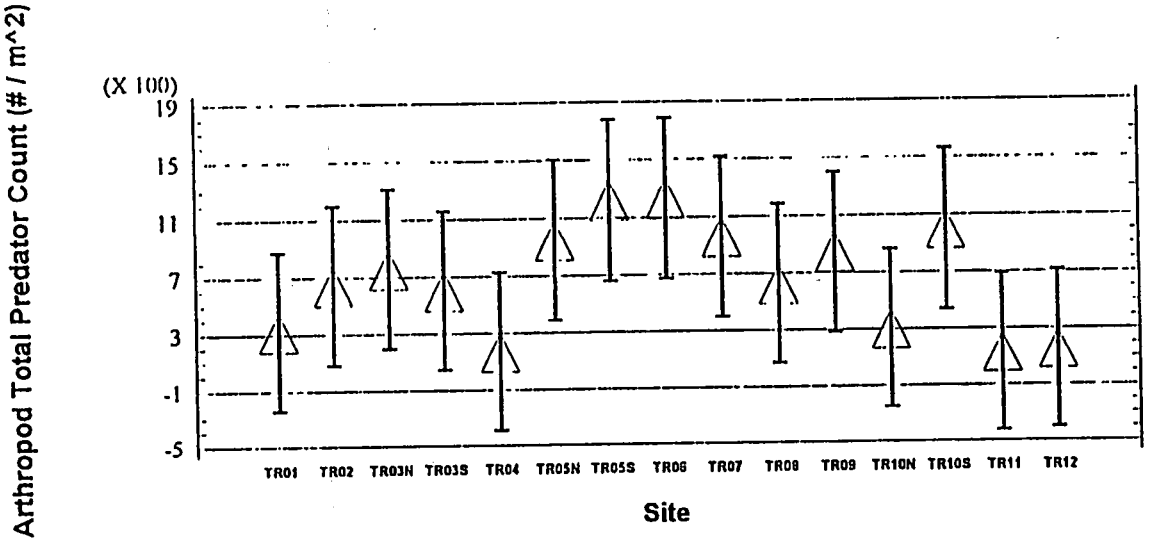

Figure E-21. Arthropod Total Predators by Site and 90% Tukey HSD Intervals

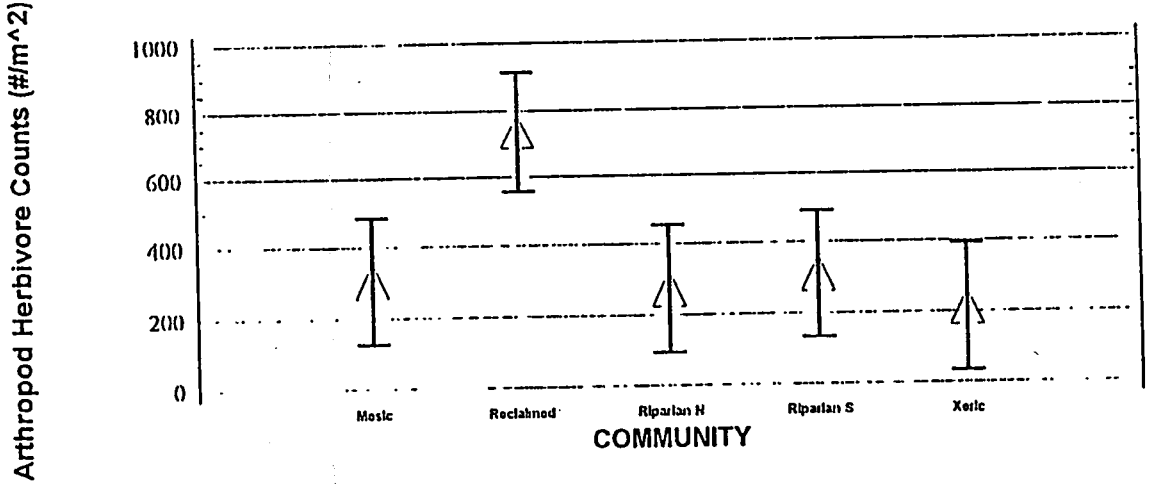

Figure E-22. Arthropod Herbivore M ns by Community and Tukey 90% HSD Intervals

Table E-1. Analysis of Variance, EcMP Soil Amoebae By Community and Depth

		Sum of Squares	df	Mean Square	F-ratio	p-value
	Community	837328000	4	209332000	2.02	0.0954
	Depth	96353400	1	96353400	0.93	0.347
	Community x Depth	388498000	4	97124600	0.94	0.4447
Residual		13368300000	129	103630000		
Total		14691500000	138			

Means by Community and Depth **Amoebae**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	30	3193.89	10589700	120.92	12550.1	12429.2	101.888
Reclaimed	20	3309.52	69512200	122.84	37706.9	37584.1	251.922
Riparian North	30	9864.89	243183000	126.5	85279.7	85153.2	158.079
Riparian South	30	6533.26	47147000	123.01	24223.8	24100.8	105.099
Xeric	29	5998.98	135954000	355.33	63908.3	63553	194.365
Depth							
0-5 cm	69	6798.84	138034000	120.92	85279.7	85158.8	172.805
5-10 cm	70	5125.74	75477400	123.01	63908.3	63785.3	169.493

Table E-2. Analysis of Variance, EcMP Soil Amoebae By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	2285760000	13	175828000	1.77	0.0546
Residual	12405700000	125	99245900		
Total	14691500000	138			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	8610.41	382459000	355.33	63908.3	63553	227.127
TR02	10	3741.67	13552500	643.7	12096.5	11452.8	98.3886
TR03N	10	9928.82	43334900	1312.46	22569.2	21256.7	66.3012
TR03S	10	5809.49	20973500	374.75	13787.3	13412.5	78.831
TR04	9	1263.72	3768950	120.92	6341.6	6220.68	153.624
TR05N	10	15444.5	619923000	2362.23	85279.7	82917.5	161.211
TR05S	10	11704.1	74632900	796.14	24223.8	23427.7	73.8121
TR06	10	3572.56	6532890	755.17	7923.47	7168.3	71.5441
TR08	10	6249.84	127310000	374.18	37706.9	37332.7	180.536
TR09	10	369.196	225752	122.84	1696.74	1573.9	128.694
TR10N	10	4221.34	50347700	126.5	23464.6	23338.1	168.089
TR10S	10	2086.2	4047570	123.01	6581.03	6458.02	96.4363
TR11	10	4258.34	11728400	1209.78	12550.1	11340.3	80.4227
TR12	10	5658.4	19997900	1173.23	11918.8	10745.6	79.0312

All means are in number protozoa / g dry soil

Table E-3. Analysis of Variance, EcMP Soil Flagellates By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	3422380000	4	855596000	3.39	0.0113
	Depth	66145500	1	66145500	0 26	0.6151
	Community x Depth	239770000	4	59942600	0 24	0.9168
Residual		32571900000	129	252496000		
Total		36314900000	138			

Means by Community and Depth **Flagellates**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	30	1102.8	860798	119.3	3602.75	3483.45	84.1309
Reclaimed	20	2436.04	14262100	36.56	12509.4	12472.8	155.027
Riparian North	30	13238.9	771519000	124.06	108520	108396	209.807
Riparian South	30	9864.3	330918000	74.89	77941.3	77866.4	184.414
Xeric	29	2120.79	22082900	118.07	25632.9	25514.8	221.58
Depth							
0-5 cm	69	6776.49	266497000	36 56	85279.7	85243.1	240.903
5-10 cm	70	5268.96	262523000	74.89	108520	108445	307.51

Table E-4. Analysis of Variance, EcMP Soil Flagellates By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	8681640000	13	667818000	3.02	0.0007
Residual	27633200000	125	221066000		
Total	36314900000	138			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	764.241	331661	210.87	2091.53	1880.66	75.3786
TR02	10	954.444	328956	221 1	2165.18	1944.08	60.0923
TR03N	10	3079.26	1763430	231.88	4698.17	4466.29	43.1253
TR03S	10	2815.13	15861500	74.89	13787.3	13712.4	141.473
TR04	9	586.934	461430	119.3	2143.47	2024.17	115 735
TR05N	10	29597.1	1894690000	231.83	108520	108288	147.069
TR05S	10	17458.6	793306000	145 11	77941.3	77796.2	161.329
TR06	10	3930.89	58821800	401.81	25632.9	25231.1	195.109
TR08	10	1361.08	3895380	125 69	6652.86	6527.17	145 008
TR09	10	3511	23645500	36.56	12509 4	12472 8	138.498
TR10N	10	7040.48	134850000	124 06	39005	38880.9	164 939
TR10S	10	9319.17	137501000	229 84	36769.6	36539.8	125.828
TR11	10	1747.08	1271650	382.48	3602 75	3220 27	64 5464
TR12	10	1533 78	3678380	118 07	6277.13	6159 06	125 045

All means ar. .mber protozoa / g dry soil

Table E-5. Analysis of Variance, EcMP Soil Ciliates By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	18198.5	4	4549.61	0.86	0.4896
	Depth	11035.4	1	11035.4	2.09	0.151
	Community x Depth	19992.9	4	4998.24	0.95	0.44
Residual		682007	129	5286.87		
Total		732922	138			

Means by Community and Depth **Flagellates**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	30	16.0337	251.103	0	63.91	63.91	98.831
Reclaimed	20	10.109	81.0553	0	37.7	37.7	89.06
Riparian North	30	43.8243	23441.6	0	851.6	851.6	349.364
Riparian South	30	20.2427	568.345	0	121.91	121.91	117.771
Xeric	29	26.6703	344.359	0	63.07	63.07	69.5788
Depth							
0-5 cm	69	33.9361	10389	0	851.6	851.6	300.348
5-10 cm	70	14.815	199.512	0	63.91	63.91	95 3418

All means are in #/g dry soil

Table E-6. Analysis of Variance, EcMP Soil Ciliates By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	76703.1	13	5900.24	1.12	0.3453
Residual	656219.0	125	5249.75		
Total	732922.0	138			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	17.785	110.52	5.2	35.94	30.74	59.1109
TR02	10	8.449	36.7333	0	21.53	21.53	71.734
TR03N	10	17.171	240.885	0	46 95	46.95	90.3877
TR03S	10	15 968	202.253	0	41.17	41.17	89 063
TR04	9	8.29889	12.9418	5.19	12.41	7.22	43.3488
TR05N	10	101.484	69618.5	0	851.6	851.6	259 995
TR05S	10	17.727	334.147	0	61.19	61.19	103.118
TR06	10	17.729	177.105	0	45 69	45.69	75 0638
TR08	10	11.841	110.262	0	37.7	37.7	88.6796
TR09	10	8.377	54.1889	0	21.89	21.89	87 8753
TR10N	10	12.818	123.032	0	38.83	38 83	86.5345
TR10S	10	27.033	1216.37	5.59	121.91	116.32	129.014
TR11	10	29.55	422.358	5.3	63.91	58.61	69 5477
TR12	10	44.463	255.42	20.95	63.07	42.12	35 9442

All means are in number protozoa / g dry soil

Table E-7. Analysis of Variance, EcMP Soil Nematode Fungal Feeders By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	131656000	4	32914100	1.9	0.1136
	Depth	38321600	1	38321600	2.22	0.1389
	Community x Depth	79169700	4	19792400	1.15	0.3383
Residual		2194620000	127	17280500		
Total		2453210000	136			

Means by Community and Depth — **Fungal Feeders**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	29	5548.56	28583100	0	16797.2	16797.2	96.355
Reclaimed	29	2706.51	12374000	125.678	18172.9	18047.2	129.971
Riparian North	25	3533.95	22507700	102.711	15436	15333.3	134.247
Riparian South	25	3547.8	11560200	0	17268.4	17268.4	95.8348
Xeric	29	3164.55	12553300	0	13491	13491	111.961
Depth							
0-5 cm	69	4264.27	24079200	0	18172.9	18172.9	115.074
5-10 cm	68	3146.74	11538200	0	14243.1	14243.1	107.946

Table E-8. Analysis of Variance, EcMP Soil Nematode Fungal Feeders By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	749042000	14	53503000	3.83	0.00
Residual	1704170000	122	13968600		
Total	2453210000	136			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	616.872	119668	258.931	1207.76	948.825	56.0783
TR02	10	2219.27	2067330	534.737	4657.83	4123.09	64 7882
TR03N	10	2065.31	7084940	102.711	8852.44	8749.73	128 879
TR03S	10	2850.16	3481690	0	6042.81	6042.81	65.4674
TR04	10	6087.43	36371900	0	15919.8	15919.8	99 0716
TR05N	5	7816.53	42971700	723.044	14243.1	13520	83 8642
TR05S	5	4519.03	4106880	2144.8	7368.12	5223.33	44 8446
TR06	10	6630.35	11673900	2109.93	13491	11381.1	51.5314
TR07	10	832.549	330864	125.678	1873.29	1747.61	69 0899
TR08	9	5137.06	26560400	256.113	18172.9	17916.7	100 324
TR09	10	2392.99	4638100	222.316	6993.64	6771.33	89 9973
TR10N	10	2861.29	20748600	157.792	15436	15278 2	159.196
TR10S	10	3759.83	24405500	499.287	17268 4	16769.1	131.394
TR11	9	8649.03	31763900	2479.86	16797.2	14317.3	65.1628
TR12	9	2144.41	6369780	0	8077.33	8077.33	117 694

All means are in ;r of nematodes / g dry soil

Table E-9. Analysis of Variance, EcMP Soil Nematode Bacterial Feeders By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	123241000	4	30810400	1.87	0.12
	Depth	27280300	1	27280300	1.65	0.2007
	Community x Depth	80602400	4	20150600	1.22	0.3048
Residual		2094330000	127	16490800		
Total		2330250000	136			

Means by Community and Depth **Bacterial Feeders**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	29	5374.55	21373400	0	16588.5	16588.5	86.0192
Reclaimed	29	4079.37	5339630	102.445	8231.93	8129.48	56.6451
Riparian North	25	2826.35	12884500	0	14143.6	14143.6	127.001
Riparian South	25	3859.79	17646400	0	19556.4	19556.4	108.834
Xeric	29	5335.46	25884700	50.463	23302.4	23251.9	95.3564
Depth							
0-5 cm	69	4846.33	18199900	0	19556.4	19556.4	88.0282
5-10 cm	68	3847.78	15798600	0	23302.4	23302.4	103.3

Table E-10. Analysis of Variance, EcMP Soil Nematode Bacterial Feeders By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	784027000	14	56001900	4.42	0.00
Residual	1546220000	122	12674000		
Total	2330250000	136			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	2268.74	735870	992.569	3957.12	2964.55	37.8108
TR02	10	3126.11	2041850	1094 81	5094.5	3999.7	45.7096
TR03N	10	2509.54	18546000	0	14143.6	14143.6	171.605
TR03S	10	2688.4	4171990	0	5483.7	5483.7	75.9762
TR04	10	4937.66	25587700	0	13542.2	13542.2	102.446
TR05N	5	5060.51	18981800	276.458	10504.2	10227.7	86.0943
TR05S	5	6036.6	14182700	2359.49	11769.9	9410.37	62.386
TR06	10	10648.7	26698800	6548.89	23302.4	16753.5	48.5234
TR07	10	5182.04	5085370	1849.82	8231.93	6382.1	43 5172
TR08	9	4083.44	5230340	102.445	7215.42	7112.98	56 0065
TR09	10	2973.04	4166670	689.18	6950.21	6261.03	68.6584
TR10N	10	2026.07	3780030	112.708	6473.18	6360.47	95.9604
TR10S	10	3942.77	32416900	612.87	19556.4	18943.6	144.406
TR11	9	8358.23	27150700	3547.34	16588.5	13041.2	62.3414
TR12	9	2839.36	5679620	50.463	7875.4	7824.93	83 9341

All means are in number of nematodes / g dry soil

Table E-11. Analysis of Variance, EcMP Soil Nematode Omnivore/Predators By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	5115760	4	1278940	1.86	0 1217
	Depth	3838710	1	3838710	5 58	0.0197
	Community x Depth	3115830	4	778958	1.13	0.3443
Residual		87366700	127	687926		
Total		98940700	136			

Means by Community and Depth **Omnivore/Predators**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	29	559.174	392428	0	2086.61	2086.61	112.03
Reclaimed	29	828.151	354762	0	2519.45	2519.45	71.9216
Riparian North	25	681.991	643249	0	2499.23	2499.23	117.601
Riparian South	25	845.961	2124260	0	6346.13	6346.13	172.288
Xeric	29	343.586	240507	0	2423.2	2423.2	142.734
Depth							
0-5 cm	69	802.687	1091630	0	6346.13	6346.13	130.164
5-10 cm	68	485.438	317359	0	2519.45	2519.45	116.049

Table E-12. Analysis of Variance, EcMP Soil Nematode Omnivore/Preditors By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	21726600	14	1551900	2.45	0.0044
Residual	77214200	122	632903		
Total	98940700	136			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	164 299	4417.25	22.528	251.109	228.581	40.4522
TR02	10	414 253	49271.8	128.337	846.179	717.842	53.5839
TR03N	10	152.815	39011.5	0	603.148	603.148	129.25
TR03S	10	123.636	14692	0	328.243	328.243	98.0382
TR04	10	506.624	446595	0	1759.11	1759.11	131.908
TR05N	5	898.873	628642	22 049	1848.03	1825.99	88.2071
TR05S	5	1180.34	2549740	136.902	3900.38	3763.48	135 283
TR06	10	495 387	150160	47.223	1165.12	1117.9	78 2227
TR07	10	826.303	163657	110.108	1485.71	1375 6	48.9585
TR08	9	490.012	237594	0	1690.95	1690.95	99.4743
TR09	10	1134 32	510354	298.815	2519.45	2220.63	62.9794
TR10N	10	1102.73	862962	45 083	2499.23	2454.15	84 2418
TR10S	10	1401.1	3532530	181.591	6346.13	6164.54	134 145
TR11	9	778.586	731786	0	2086.61	2086.61	109 872
TR12	9	374.127	597840	0	2423.2	2423.2	206 668

All means are in r of nematodes / g dry soil

Table E-13. Analysis of Variance, EcMP Soil Nematode Plant Feeders By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	10985200	4	2746300	1.42	0.2302
	Depth	13962.9	1	13962.9	0.01	0.9333
	Community x Depth	10781400	4	2695340	1.4	0.239
Residual		245155000	127	1930360		
Total		267518000	136			

Means by Community and Depth **Plant Parasitic**

Community	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
Mesic	29	1315.27	3463030	0	9253.93	9253.93	141.486
Reclaimed	29	1045.33	1747290	0	4386.04	4386.04	126.452
Riparian North	25	1227.61	3503090	0	6595.78	6595.78	152.463
Riparian South	25	823.377	798239	0	3919.97	3919.97	108.51
Xeric	29	523.146	243497	0	1757.63	1757.63	94.3244
Depth							
0-5 cm	69	987.575	2391100	0	9253.93	9253.93	156.577
5-10 cm	68	981.776	1566010	0	6595.78	6595.78	127.463

Table E-14. Analysis of Variance, EcMP Soil Nematode Plant Feeders By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	83554700	14	5968190	3.96	0.00
Residual	183963000	122	1507900		
Total	267518000	136			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	670.811	130599	334.812	1368.23	1033.42	53.8727
TR02	10	2041.3	1153660	770.021	4142.07	3372.05	52 6177
TR03N	10	677.808	1163390	0	3306.95	3306.95	159.131
TR03S	10	763.165	1517140	0	3919.97	3919.97	161.397
TR04	10	561.773	403347	0	2067.5	2067.5	113.052
TR05N	5	3134.28	9491880	198.444	6595.78	6397.34	98.2967
TR05S	5	959.867	451700	216 688	1843.66	1626.97	70.0187
TR06	10	630.708	417833	28.903	1757.63	1728.73	102.488
TR07	10	2601.09	1218020	814.802	4386.04	3571.24	42.4298
TR08	9	285.829	76384.2	0	845.249	845.249	96 6932
TR09	10	173.138	38689.4	0	564.704	564.704	113.608
TR10N	10	824.089	1423140	45.553	3983.49	3937.94	144.76
TR10S	10	815.342	396286	113.121	1795.43	1682.31	77.2084
TR11	9	1345.78	8999330	0	9253.93	9253.93	222.911
TR12	9	239.56	103062	0	1009.67	1009 67	134 01

All means are in number of nematodes / g dry soil

Table E-15. Analysis of Variance, EcMP Soil Arthropod Fungal Feeders 1 By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	6.5412200E+00	4	16353000	6.36	0.0001
	Depth	8.210280E+00	1	8210280	3.19	0.0761
	Community x Depth	26359000	4	6589750	2.56	0.0411
Residual		360031000	140	2571650		
Total			149			

Means by Community and Depth

Community	Fungal Feeders 1 (#/m^2)	n
Mesic	8.889	30
Reclaimed	36.889	30
Riparian North	1017.33	30
Riparian South	1752.45	30
Xeric	442.222	30
Depth		
0-5 cm	885.511	75
5-10 cm	417.6	75

Table E-16. Analysis of Variance, EcMP Soil Arthropod Fungal Feeders 1 By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	123366000	14	8811840	3.53	0.0001
Residual	336647000	135	2493680		
Total	460013000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	0	0	0	0	0	
TR02	10	20	800	0	80	80	141.421
TR03N	10	686.666	514615	0	2333.33	2333.3	104.471
TR03S	10	1626.67	9279210	66.67	10200	10133	187.265
TR04	10	6.667	444.489	0	66.67	66.67	316.228
TR05N	10	1693.33	3575510	0	5733.33	5733.3	111.667
TR05S	10	3213.33	17883200	0	13933.3	13933	131.603
TR06	10	1326.67	3632050	0	6600	6600	143.653
TR07	10	84	20071.1	0	440	440	168.658
TR08	10	0	0	0	0	0	
TR09	10	26.667	4148.18	0	200	200	241.521
TR10N	10	672	2383930	0	5000	5000	229.762
TR10S	10	417.334	111172	66.67	933.33	866.66	79.8941
TR11	10	0	0	0	0	0	
TR12	10	0	0	0	0	0	

All Arthrop . are in Count / m^2

Table E-17. Analysis of Variance, EcMP Arthropod Fungal Feeders 2 By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	32821700	4	8205430	1.25	0.2919
	Depth	91885100	1	91885100	14.02	0.0003
	Community x Depth	24605900	4	6151480	0.94	0.4436
Residual		917465000	140	6553320		
Total		1066780000	149			

Means by Community and Depth

Community	Fungal Feeders 2 (#/m^2)	n
Mesic	1740.89	30
Reclaimed	2687.33	30
Riparian North	1585.78	30
Riparian South	2368.89	30
Xeric	1500.44	30
Depth		
0-5 cm	2759.33	75
5-10 cm	1194	75

Table E-18. Analysis of Variance, EcMP Soil Arthropod Fungal Feeders 2 By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	103154000	14	7368170	1.03	0.4255
Residual	963623000	135	7137950		
Total	1066780000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	1000	446933	120	1960	1840	66.8531
TR02	10	3076	16474800	0	13880	13880	131.954
TR03N	10	1420	1769930	0	4066.67	4066.7	93.6893
TR03S	10	1226.67	1898460	66.67	3933.33	3866.7	112.324
TR04	10	550	548210	0	2300	2300	134.62
TR05N	10	1006.67	3004890	133.33	5866.67	5733.3	172.198
TR05S	10	2600	10614300	0	11400	11400	125.306
TR06	10	2143.33	1923470	0	4200	4200	64.7072
TR07	10	2792	4931840	0	7240	7240	79.5406
TR08	10	2583.33	14506700	0	11900	11900	147.436
TR09	10	2686.67	7532140	333.33	7800	7466.7	102.152
TR10N	10	2330.67	5115130	133.33	6933.33	6800	97.0395
TR10S	10	3280	24571700	200	15866.7	15667	151.127
TR11	10	1596.67	10910400	0	10900	10900	206.874
TR12	10	1358	2820290	0	4600	4600	123.665

All Arthropod Data are in Count / m^2

Table E-19. Analysis of Variance, EcMP Arthropod Detritivores 1 By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	903365	4	225841	6.11	0.0001
	Depth	93917.1	1	93917.1	2.54	0.1132
	Community x Depth	116265	4	29066.3	0.79	0.5359
Residual		5175540	140	36968.2		
Total		6289090	149			

Means by Community and Depth

Community	Detritivores 1 (#/m^2)	n
Mesic	78.2227	30
Reclaimed	60	30
Riparian North	138.667	30
Riparian South	256.446	30
Xeric	43.111	30
Depth		
0-5 cm	140.311	75
5-10 cm	90.2669	75

Table E-20. Analysis of Variance, EcMP Soil Arthropod Detritivores 1 By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	2201320	14	157237	5.19	0.00
Residual	4087770	135	30279.8		
Total	6289090	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	16	782.222	0	80	80	174.801
TR02	10	68	6062.22	0	200	200	114.5
TR03N	10	80.001	8691.43	0	266.67	266.67	116.533
TR03S	10	173.335	32790	0	600	600	104.468
TR04	10	140.001	75259.1	0	900	900	195.951
TR05N	10	206.666	84394.3	0	933.33	933.33	140.568
TR05S	10	80.001	10666.8	0	266.67	266.67	129.099
TR06	10	106.666	15999.9	0	333.33	333.33	118.586
TR07	10	16	782.222	0	80	80	174.801
TR08	10	100	33580.2	0	600	600	183.249
TR09	10	64	2787.06	0	133.33	133.33	82.4885
TR10N	10	129.333	22717.8	0	440	440	116.54
TR10S	10	516.001	157869	66.67	1266.67	1200	77.0012
TR11	10	26.667	1370.4	0	100	100	138.819
TR12	10	6.667	444.489	0	66.67	66.67	316.228

All Arthrop a are in Count / m^2

Table E-21. Analysis of Variance, EcMP Arthropod Detritivores 2 By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	97587600	4	24396900	2.5	0.0454
	Depth	222285100	1	22285100	2.28	0.1332
	Community x Depth	49333200	4	12333300	1.26	0.2875
Residual		1367290000	140	9766360		
Total		1536500000	149			

Means by Community and Depth

Community	Detritivores 2 (#/m^2)	n
Mesic	451.222	30
Reclaimed	672.667	30
Riparian North	1633.33	30
Riparian South	2557.33	30
Xeric	578.444	30
Depth		
0-5 cm	1564.04	75
5-10 cm	793.155	75

Table E-22. Analysis of Variance, EcMP Soil Arthropod Detritivores 2 By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	187378000	14	13384200	1.34	0.1925
Residual	1349120000	135	9993470		
Total	1536500000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	156	10115.6	40	320	280	64.4719
TR02	10	512	100196	0	1160	1160	61.8236
TR03N	10	1073.33	941678	66.67	2800	2733.3	90.41
TR03S	10	1780	2510670	0	4600	4600	89.0174
TR04	10	140	28839.3	0	533.33	533.33	121.301
TR05N	10	2126.67	17645900	0	13266.7	13267	197.525
TR05S	10	1286.67	2797090	0	4533.33	4533.3	129.983
TR06	10	1530	1923570	0	3733.33	3733.3	90.6489
TR07	10	1236	788427	360	3080	2720	71.8393
TR08	10	416.667	176358	0	1300	1300	100.788
TR09	10	365.333	222714	0	1400	1400	129.177
TR10N	10	1700	4860770	0	7133.33	7133.3	129.689
TR10S	10	4605.33	117286000	160	35266.7	35107	235.159
TR11	10	701.666	605150	0	2200	2200	110.867
TR12	10	49.334	4505.7	0	200	200	136.061

All Arthropod Data are in Count / m^2

Table E-23. Analysis of Variance, EcMP Arthropod Total Detritivores By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	116701000	4	29175200	3	0.0208
	Depth	25272500	1	25272500	2.59	0.1095
	Community x Depth	52054100	4	13013500	1.34	0.2596
Residual		1363630000	140	9740220		
Total		1557660000	149			

Means by Community and Depth

Community	Total Detritivores (#/m^2)	n
Mesic	529.444	30
Reclaimed	732.667	30
Riparian North	1772	30
Riparian South	2813.78	30
Xeric	621.555	30
Depth		
0-5 cm	1704.36	75
5-10 cm	883.422	75

Table E-24. Analysis of Variance, EcMP Soil Arthropod Total Detritivores By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	225956000	14	16139700	1.64	0.077
Residual	1331700000	135	9864460		
Total	1557660000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	172	14951.1	40	400	360	71.09
TR02	10	580	137333	40	1360	1320	63.894
TR03N	10	1153.33	1015360	66.67	2866.67	2800	87.3684
TR03S	10	1953.33	2441530	0	4666.67	4666.7	79.9935
TR04	10	280	92394.9	0	1000	1000	108.559
TR05N	10	2333.33	18323000	0	13666.7	13667	183.451
TR05S	10	1366.67	3059010	0	4733.33	4733.3	127.976
TR06	10	1636.67	2024800	0	4000	4000	86.9423
TR07	10	1252	798951	360	3080	2720	71.393
TR08	10	516.667	270185	0	1600	1600	100.605
TR09	10	429.333	228228	0	1533.33	1533.3	111.273
TR10N	10	1829.33	4880820	120	7200	7080	120.769
TR10S	10	5121.33	114030000	320	35333.3	35013	208.509
TR11	10	728.333	645620	0	2300	2300	110.321
TR12	10	56	5206.86	0	200	200	128.855

All Arthropo[illegible] are in Count / m^2

Table E-25 . Analysis of Variance, EcMP Soil Arthropod Total Fungivores By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	104426000	4	26106600	2.69	0.0339
	Depth	155028000	1	155028000	15.95	0.0001
	Community x Depth	90723900	4	22681000	2.33	0.0587
Residual		1361040000	140	9721740		
Total		1711220000	149			

Means by Community and Depth

Community	Total Fungivores (#/m^2)	n
Mesic	1749.78	30
Reclaimed	2724.22	30
Riparian North	2603.11	30
Riparian South	4121.33	30
Xeric	1942.67	30
Depth		
0-5 cm	3644.84	75
5-10 cm	1611.6	75

Table E-26. Analysis of Variance, EcMP Soil Arthropod Total Fungivores By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	223741000	14	15981500	1.45	0.1386
Residual	1487480000	135	11018400		
Total	1711220000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	1000	446933	120	1960	1840	66.8531
TR02	10	3096	16526300	0	13920	13920	131.307
TR03N	10	2106.67	3655510	133.33	5200	5066.7	90.7566
TR03S	10	2853.33	16881800	400	14133.3	13733	143.998
TR04	10	556.666	553346	0	2300	2300	133.63
TR05N	10	2700	8082220	266.67	8866.67	8600	105.293
TR05S	10	5813.33	35916800	0	17600	17600	103.092
TR06	10	3470	8052950	0	10100	10100	81.7802
TR07	10	2876	5177050	0	7240	7240	79.1138
TR08	10	2583.33	14506700	0	11900	11900	147.436
TR09	10	2713.33	7794860	333.33	8000	7666.7	102.897
TR10N	10	3002.67	7780850	133.33	7733.33	7600	92.898
TR10S	10	3697.33	26169700	280	16533.3	16253	138.36
TR11	10	1596.67	10910400	0	10900	10900	206.874
TR12	10	1358	2820290	0	4600	4600	123.665

All Arthropod Data are in Count / m^2

Table E-27. Analysis of Variance, EcMP Soil Arthropod General Predators By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	6418920	4	1604730	5.24	0.0006
	Depth	1904810	1	1904810	6.22	0.0138
	Community x Depth	2648250	4	662064	2.16	0.0762
Residual		42845200	140	306037		
Total		53817200	149			

Means by Community and Depth

Community	General Predators(#/m^2)	n
Mesic	101.667	30
Reclaimed	270.223	30
Riparian North	498.667	30
Riparian South	701.777	30
Xeric	296.222	30
Depth		
0-5 cm	486.4	75
5-10 cm	261.022	75

Table E-28. Analysis of Variance, EcMP Soil Arthropod General Predators By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	14542000	14	1038710	3.57	0.0001
Residual	39275200	135	290928		
Total	53817200	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	112	16284.4	0	440	440	113.938
TR02	10	280	33066.7	80	680	600	64.9437
TR03N	10	479.999	198321	0	1400	1400	92.7777
TR03S	10	513.333	269679	0	1466.67	1466.7	101.164
TR04	10	10	1000	0	100	100	316.228
TR05N	10	806.667	320446	133.33	1600	1466.7	70.1751
TR05S	10	1120	2143020	0	4800	4800	130.706
TR06	10	726.666	634518	0	2800	2800	109.619
TR07	10	248	74595.6	0	720	720	110.13
TR08	10	136.667	31962.9	0	500	500	130.816
TR09	10	426.001	266770	66.67	1600	1533.3	121.243
TR10N	10	209.334	118915	0	1133.33	1133.3	164.732
TR10S	10	472	244512	0	1466.67	1466.7	104.763
TR11	10	15	1138.89	0	100	100	224.983
TR12	10	50	9691.31	0	300	300	196.889

All Arthropo[illegible] are in Count / m^2

Table E-29. Analysis of Variance, EcMP Soil Invertebrate Arthropod Predators By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	2599900	4	649974	3.02	0.0199
	Depth	1557870	1	1557870	7.25	0.008
	Community x Depth	305420	4	76354.9	0.36	0.8401
Residual		30103000	140	215022		
Total		34566200	149			

Means by Community and Depth

Community	Arthropod Predators(#/m^2)	n
Mesic	211.111	30
Reclaimed	540.889	30
Riparian North	169.333	30
Riparian South	238.667	30
Xeric	270.667	30
Depth		
0-5 cm	388.044	75
5-10 cm	184.223	75

Table E-30. Analysis of Variance, EcMP Soil Invertebrate Arthropod Predators By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	5705680	14	407548	1.91	0.0307
Residual	28860500	135	213782		
Total	34566200	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	204	46382.2	40	760	720	105.571
TR02	10	360	79288.9	0	880	880	78.2175
TR03N	10	273.333	82419.5	0	800	800	105.032
TR03S	10	86.668	15851.8	0	400	400	145.271
TR04	10	156.667	24209.9	0	500	500	99.316
TR05N	10	140	25135.8	0	400	400	113.245
TR05S	10	100.001	12098.5	0	333.33	333.33	109.992
TR06	10	503.333	580850	0	2533.33	2533.3	151.418
TR07	10	712	1002240	0	3400	3400	140.607
TR08	10	490	534580	0	1900	1900	149.214
TR09	10	420.667	160637	0	1200	1200	95.2761
TR10N	10	94.667	15938.7	0	400	400	133.361
TR10S	10	529.333	585840	0	2400	2400	144.597
TR11	10	116.667	15555.7	0	300	300	106.905
TR12	10	104.667	25699.2	0	400	400	153.162

All Arthropod Data are in Count / m^2

Table E-31. Analysis of Variance, EcMP Soil Invertebrate Total Arthropod Predators By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	6923410	4	1730850	2.89	0.0246
	Depth	6907970	1	6907970	11.53	0.0009
	Community x Depth	4256790	4	1064200	1.78	0.1369
Residual		83860000	140	599000		
Total		101948000	149			

Means by Community and Depth

Community	Total Arthropod Predators(#/m^2)	n
Mesic	312.778	30
Reclaimed	811.111	30
Riparian North	668	30
Riparian South	940.444	30
Xeric	566.889	30
Depth		
0-5 cm	874.445	75
5-10 cm	445.245	75

Table E-32. Analysis of Variance, EcMP Soil Invertebrate Total Arthropod Predators By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	19988000	14	1427710	2.35	0.006
Residual	81960100	135	607112		
Total	101948000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	316	77315.6	10	316	77315.6	87.9926
TR02	10	640	84977.8	10	640	84977.8	45.5484
TR03N	10	753.333	305233	10	753.333	305233	73.338
TR03S	10	600	328888	10	600	328888	95.5812
TR04	10	166.667	23950.6	10	166.667	23950.6	92.8558
TR05N	10	946.667	389928	10	946.667	389928	65.9622
TR05S	10	1220	2342770	10	1220	2342770	125.46
TR06	10	1230	1248510	10	1230	1248510	90.8429
TR07	10	960	1334760	10	960	1334760	120.345
TR08	10	626.667	548839	10	626.667	548839	118.219
TR09	10	846.667	770381	10	846.667	770381	103.667
TR10N	10	304	161455	10	304	161455	132.176
TR10S	10	1001.33	1409600	10	1001.33	1409600	118.568
TR11	10	131.667	17805.7	10	131.667	17805.7	101.345
TR12	10	154.667	62279.1	10	154.667	62279.1	161.352

All Arthropo... ata are in Count / m^2

Table E-33. Analysis of Variance, EcMP Soil Arthropod Herbivores By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	5238810	4	1309700	4.18	0.0031
	Depth	1490020	1	1490020	4.76	0.0309
	Community x Depth	1509140	4	377285	1.2	0.3118
Residual		43861000	140	313293		
Total		52099000	149			

Means by Community and Depth

Community	Arthropod Herbivores(#/m^2)	n
Mesic	306.111	30
Reclaimed	735.556	30
Riparian North	274.667	30
Riparian South	312.001	30
Xeric	213.555	30
Depth		
0-5 cm	468.045	75
5-10 cm	268.711	75

Table E-34. Analysis of Variance, EcMP Soil Arthropod Herbivores By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	16259000	14	1161360	4.37	0.00
Residual	35840000	135	265481		
Total	52099000	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	164	117138	0	1120	1120	208.691
TR02	10	580	215556	0	1160	1160	80.0482
TR03N	10	80	15604.8	0	400	400	156.149
TR03S	10	93.335	13036.9	0	333.33	333.33	122.333
TR04	10	256.667	103470	0	900	900	125.325
TR05N	10	520.001	863014	0	3066.67	3066.7	178.651
TR05S	10	473.333	947605	0	3200	3200	205.659
TR06	10	386.666	316838	0	1933.33	1933.3	145.574
TR07	10	1440	583111	280	2160	1880	53.029
TR08	10	336.667	115172	0	1000	1000	100.803
TR09	10	430.001	193335	0	1133.33	1133.3	102.255
TR10N	10	224	116417	0	1066.67	1066.7	152.321
TR10S	10	369.334	336635	0	1866.67	1866.7	157.094
TR11	10	81.667	8731.54	0	250	250	114.419
TR12	10	90	36555.6	0	600	600	212.439

All Arthropod Data are in Count / m^2

Table E-35. Analysis of Variance, EcMP Soil Cryptostigmatid Mite Richness By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	3.49333	4	0.873333	0.45	0.7726
	Depth	6	1	6	3.09	0.081
	Community x Depth	25.8667	4	6.46667	3.33	0.0123
Residual		272	140	1.94286		
Total		307.36	149			

Means by Community and Depth

Community	Mean Richness	n
Mesic	1.6	30
Reclaimed	1.76667	30
Riparian North	2.03333	30
Riparian South	1.76667	30
Xeric	1.63333	30
Depth		
0-5 cm	1.96	75
5-10 cm	1.56	75

Table E-36. Analysis of Variance, EcMP Soil Cryptostigmatid Mite Richness By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	77.36	14	5.52571	3.24	0.0002
Residual	230.0	135	1.7037		
Total	307.36	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	1.6	0.711111	0	3	3	52.7046
TR02	10	2.3	1.34444	0	4	4	50.4131
TR03N	10	2.7	1.34444	1	4	3	42.9445
TR03S	10	1.6	2.04444	0	4	4	89.365
TR04	10	1.1	1.65556	0	4	4	116.971
TR05N	10	1.9	2.1	0	5	5	76.2704
TR05S	10	1.9	3.21111	0	5	5	94.3135
TR06	10	2.9	3.87778	0	6	6	67.9037
TR07	10	3.1	1.65556	2	6	4	41.5059
TR08	10	1.2	0.4	0	2	2	52.7046
TR09	10	1	1.33333	0	3	3	115.47
TR10N	10	1.5	1.61111	0	4	4	84.6197
TR10S	10	1.8	1.51111	0	4	4	68.2929
TR11	10	1.4	2.26667	0	4	4	107.539
TR12	10	0.4	0.488889	0	2	2	174.801

Table E-37. Analysis of Variance, EcMP Soil Prostigmatid Mite Richness By Community and Depth

Source		Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment						
	Community	19.8	4	4.95	0.76	0.5519
	Depth	28.1667	1	28.1667	4.33	0.0392
	Community x Depth	7.66667	4	1.91667	0.29	0.8809
Residual		909.867	140	6.49905		
Total		965.5	149			

Means by Community and Depth

Community	Mean Richness	n
Mesic	8.34483	30
Reclaimed	7.8954	30
Riparian North	4.65402	30
Riparian South	4.07931	30
Xeric	7.63678	30
Depth		
0-5 cm	4.93333	75
5-10 cm	4.06667	75

Table E-38. Analysis of Variance, EcMP Soil Prostigmatid Mite Richness By Site

	Sum of Squares	df	Mean Square	F-ratio	p-value
Site	346.4	14	24.7429	5.40	0.0000
Residual	619.1	135	4.58593		
Total	965.5	149			

Means and Summary Statistics by Site

Site	n	Average	Variance	Minimum	Maximum	Range	Coefficient of Variation
TR01	10	5.4	2.48889	3	7	4	29.2152
TR02	10	6.5	9.61111	0	10	10	47.6951
TR03N	10	4.7	4.9	0	8	8	47.0978
TR03S	10	4.1	3.87778	2	8	6	48.0294
TR04	10	2.8	3.06667	0	5	5	62.5425
TR05N	10	4.1	2.76667	1	6	5	40.569
TR05S	10	4.3	4.01111	0	7	7	46.5762
TR06	10	6.9	7.43333	0	10	10	39.5132
TR07	10	7.4	8.26667	1	11	10	38.8538
TR08	10	2.5	2.72222	1	5	4	65.9966
TR09	10	5	1.11111	4	6	2	21.0819
TR10N	10	4.3	7.12222	1	9	8	62.0639
TR10S	10	4.5	5.16667	2	8	6	50.5118
TR11	10	2.7	3.78889	0	5	5	72.0928
TR12	10	2.3	2.45556	0	5	5	68.1314

Table E-39. Summary Findings and Ranked Community, Depth and Site Soil Invertebrate Means

Variable	Community Effect Significant at alpha=0.1 ?	Ranked Community Means	Depth Effect Significant at alpha=0.1 ?	Ranked Depth Means	Community x Depth Interaction Significant at alpha=0.1 ?	Site Effect Significant at alpha=0.1 ?	Ranked Site Means
Protozoa Amoebae	Yes	RipN>RipS>Xeric>Reclaimed>Mesic	No	0-5>5-10	No	Yes	TR05N>TR05S>TR03N>TR01>TR08>TR03S>TR12>TR11>TR10N>TR02>TR06>TR10S>TR04>TR09
Flagellates	Yes	RipN>RipS>Reclaimed>Xeric>Mesic	No	0-5>5-10	No	Yes	TR05N>TR05S>TR10S>TR10N>TR06>TR09>TR03N>TR03S>RE11>TR12>TR08>TR02>TR01>TR04
Ciliates	No	RipN>Xeric>RipS>Mesic>Reclaimed	No	0-5>5-10	No	No	TR05N>TR12>TR11>TR10S>TR01>TR06>TR05S>TR03N>TR03S>TR10N>TR08>TR02>TR09>TR04
Nematodes Omnivore/Predator	No	RipS>Reclaimed>RipN>Mesic>Xeric	No	0-5>5-10	No	Yes	TR10S>TR05S>TR09>TR10N>TR05N>TR07>TR11>TR04>TR06>TR08>TR02>TR12>TR01>TR03N>TR03S
Fungal Feeders	No	Mesic>RipS>RipN>Xeric>Reclaimed	No	0-5>5-10	No	Yes	TR11>TR05N>TR06>TR04>TR08>TR05S>TR10S>TR10N>TR03S>TR09>TR02>TR12>TR03N>TR07>TR01
Bacterial Feeders	No	Mesic>Xeric>Reclaimed>RipS>RipN	No	0-5>5-10	No	Yes	TR06>TR11>TR05S>TR07>TR05N>TR04>TR08>TR10S>TR02>TR09>TR12>TR03S>TR03N>TR01>TR10N
Plant Parasites	No	Mesic>RipN>Reclaimed>RipS>Xeric	No	0-5>5-10	No	Yes	TR05N>TR07>TR02>TR11>TR05S>TR10N>TR10S>TR03S>TR03N>TR01>TR06>TR04>TR08>TR12>TR09
Arthropods Fungal Feeders 1	Yes	RipS>RipN>Xeric>Reclaimed>Mesic	Yes	0-5>5-10	Yes	Yes	TR05S>TR05N>TR03S>TR06>TR03N>TR10N>TR10S>TR07>TR09>TR02>TR11=TR12=TR01=TR08
Fungal Feeders 2	No	Reclaimed>RipS>Mesic>RipN>Xeric	Yes	0-5>5-10	No	No	TR10S>TR02>TR07>TR09>TR05S>TR08>TR10N>TR06>TR11>TR03N>TR12>TR03S>TR05N>TR01>TR04
Detritivores 1	Yes	RipS>RipN>Mesic>Reclaimed>Xeric	No	0-5>5-10	No	Yes	TR10S>TR05N>TR03S>TR04>TR10N>TR06>TR08>TR03N=TR05S>TR02>TR09>TR11>TR01=TR07>TR12
Detritivores 2	Yes	RipS>RipN>Reclaimed>Xeric>Mesic	No	0-5>5-10	No	No	TR10S>TR05N>TR03S>TR10N>TR08>TR05S>TR07>TR03N>TR11>TR02>TR08>TR09>TR01>TR04>TR12
Detritivores Total	Yes	RipS>RipN>Reclaimed>Xeric>Mesic	No	0-5>5-10	No	Yes	TR10S>TR05N>TR03S>TR10N>TR06>TR05S>TR07>TR03N>TR11>TR02>TR08>TR09>TR04>TR01>TR12
Fungivores Total	Yes	RipS>Reclaimed>RipN>Xeric>Mesic	Yes	0-5>5-10	Yes	No	TR05S>TR10S>TR06>TR02>TR10N>TR07>TR03S>TR09>TR05N>TR08>TR03N>TR11>TR12>TR01>TR04
General Predators	Yes	RipS>RipN>Xeric>Reclaimed>Mesic	Yes	0-5>5-10	Yes	Yes	TR05S>TR05N>TR08>TR03S>TR03N>TR10S>TR09>TR02>TR07>TR10N>TR08>TR01>TR12>TR11>TR04
Arthropod Predators	Yes	Reclaimed>Xeric>RipS>Mesic>RipN	Yes	0-5>5-10	No	Yes	TR07>TR10S>TR06>TR08>TR09>TR02>TR03N>TR01>TR04>TR05N>TR11>TR12>TR05S>TR10N>TR03S
Total Predators	Yes	Reclaimed>Xeric>RipS>Mesic>RipN	Yes	0-5>5-10	No	Yes	TR08>TR05S>TR10S>TR07>TR05N>TR09>TR03N>TR02>TR08>TR03S>TR01>TR10N>TR04>TR12>TR11
Total Herbivores	Yes	Reclaimed>RipS>Mesic>RipN>Xeric	Yes	0-5>5-10	No	Yes	TR07>TR02>TR05N>TR05S>TR09>TR06>TR10S>TR08>TR04>TR10N>TR01>TR03S>TR12>TR11>TR03N

RipN=Riparian North, RipS= Riparian South, S Appendix B for Site and Community Descriptions

APPENDIX F) RECLAMATION MONITORING

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BACKGROUND

Human disturbance of the landscape often results in removal of the native vegetation which may leave the soil exposed to erosion. Additionally, the native vegetation is often replaced by non-native, exotic species. This has resulted in large scale alterations to the native ecosystems which were once present and often lead to the extinction of some components of localized floras. Environmental regulations and laws have become necessary to provide for revegetation of areas disturbed by mining, logging, and other activities which result in the loss of vegetation from the land. At the Rocky Flats Environmental Technology Site (Site), a variety of activities occur which require remediation for disturbance and loss of native vegetation.

OBJECTIVE

The objective of this module is to monitor the revegetation of the 881 Hillside (Hillside) since the area was disturbed by the construction of the French Drain.

HYPOTHESES

1) H_O: Species richness will not differ from similar undisturbed habitats.
   H_A: Species richness will differ from similar undisturbed habitats.

2) H_O: Vegetation cover will not differ from similar undisturbed habitats.
   H_A: Vegetation cover will differ from similar undisturbed habitats.

3) H_O: 1994 species richness will not differ from 1993.
   H_A: 1994 species richness will differ from 1993.

4) H_O: 1994 vegetation cover will not differ from 1993.
   H_A: 1994 vegetation cover will differ from 1993.

5) H_O: The percentage of native species richness on the Hillside will not differ from similar undisturbed habitats.
   H_A: The percentage of native species richness on the Hillside will differ from similar undisturbed habitats.

6) H_O: The percentage of basal cover from native species on the Hillside will not differ from similar undisturbed habitats.
   H_A: The percentage of basal cover from native species on the Hillside will differ from similar undisturbed habitats.

7) H_O: The percentage of basal cover from annual species on the Hillside will not differ from similar undisturbed habitats.
   H_A: The percentage of basal cover from annual species on the Hillside will differ from similar undisturbed habitats.

METHODS

Field Methods

The field sampling methodology used for the reclamation monitoring sampling is described in the Vegetation Sampling Standard Operating Procedures (4-H64-ENV-ECOL.10, Revision 0). In addition, more specific, detailed field instructions (though following the SOP methods) can be found in field training manuals which were written for the belt transect and point-intercept transect methods used for the terrestrial vegetation sampling in late summer 1994.

During the 1994 field season, data were collected by Ecolgical Monitoring Program (EcMP) personnel from the Hillside from November 30 through December 22, 1994. Twenty-five, 50-m long transects placed end to end were sampled across the Hillside in an east-west direction with the transects located generally perpendicular to the slope angle. Two different types of measurements were taken at the 25 transects: species richness and basal cover. A short description of the measurement methods follows, however, for more details, refer to the Terrestrial Vegetation SOP and field training manuals mentioned above.

Belt Transect

Species richness was determined in a 2-m belt centered along each 50-m transect. Each plant species observed within this 100 m^2 area was recorded. A total of 25 belt transects were sampled on the Hillside during the sampling session.

Point-intercept Transect

Twenty-five transects (the same ones used for belt transects) were sampled by the point-intercept method on the Hillside. Basal cover was determined at 50-cm increments along each transect for a total of 100 "hits" per transect. A 2-m long rod with 0.25 inch diameter, was dropped along the right side of a tape measure stretched along the 50-m length of the transect. Material at ground level was recorded for the basal hit. A basal hit could be vegetation (live plant), litter (fallen dead material), rock (greater than the diameter of the point-intercept rod), bare ground, or water in that order of importance. Importance was determined by a cover type's potential to protect the soil from erosion.

Quality Assurance/Quality Control

Data were collected onsite by EcMP personnel. Nomenclature was standardized using the Flora of the Great Plains (Great Plains Flora Association, 1991) as the primary reference, and data were recorded on field sheets in the form of unique site and species codes. If a plant species could not be identified with confidence in the field, plant species were recorded as unknowns on the field data sheets. Voucher specimens were made of unknown species and later identified by keying, comparison with known specimens in the reference collection or herbarium collection, or by trips to the University of Colorado Herbarium in Boulder. In some cases, due to lack of key characteristics, specimens were identified only to the family or genus level. If a specimen could not even be identified to that level, it was ignored. Taxa identified to the family or genus level were included in calculations only when there were no verified species from the same family or genus present at the site.

Prior to data entry, all unknown specimens were identified and corrections made to the field data sheets. Data entry and QA of the database files were done by EcMP personnel. The QA process used for data entry was as follows:

- data entry,
- printout hardcopy of electronic file for proofreading,
- initial 100% proofreading of hardcopy,
- corrections made to the database from the corrected hardcopy proofreading pages,
- second hardcopy printout after corrections made to database,
- second proofreading consisting of checking corrections made to database,
- if errors were still found another round of correcting and proofreading followed,
- if no errors were found, then a spot check of two random records from each page of the final proofreading printout were made.

Each stage of the QA process was documented by a signature on a Quality Assurance Form.

DATABASE STATUS

Data from the 1994 Hillside sampling were entered into dBase files on an IBM compatible computer. The name of the file for the belt transect data was RMBEL942.dbf, and for the point-intercept data, RMPIT942.dbf. The RMBEL942.dbf contained 623 records and the RMPIT942.dbf contained 162 records.

STATISTICAL ANALYSIS

A one-way ANOVA was used to compare 1994 Hillside basal cover data with both 1994 Hillside and 1994 EcMP mesic community basal cover data to determine if significant differences were present between years and from the Hillside to the mesic community. The ANOVA was done on an IBM compatible computer using the Statgraphics statistical program. A Tukey means separation was used and checks were made of the variances and residual distributions. In order to have a balanced analysis, 15 of the 25 transects from each of the 1993 and 1994 Hillside transects were randomly chosen to represent each year. This balanced the analysis because the mesic community data consisted of 15 total transects.

SITE DESCRIPTION

The Hillside is a south facing slope in the Woman Creek watershed on the south side of the industrial complex at the Site. During 1991-1992, much of the Hillside was disturbed during the construction of the French Drain. As a result, a revegetation program was initiated to provide ground cover to stabilize the soil on the Hillside. A brief description of the revegetation history follows (Woods, 1993).

After the completion of construction, the site was prepared by ripping the area to a depth of 12 inches, applying N and P_2O_5 at 60 pounds per acre, and then disking. After this, stockpiled topsoil was spread over the surface of the disturbed area. A commercial compost was spread over remaining areas after topsoil had run out. A rangeland drill was used to plant spring barley (*Hordeum vulgare*, Otis variety), as an initial plant cover, on May 12 and 13, 1992. On May 13, 1992 a "hydroseeder" was used to spray on mulch. This initial plant cover was to provide a starter ground cover for the spring and summer of 1992. In November of 1992, a second seeding of native grass, forb, and shrub seeds was planted to provide a native, perennial cover. This seed was planted with a no-till drill. The following species comprised the seed mix for this planting:

Agropyron smithii
Bouteloua gracilis

Bouteloua curtipendula
Stipa comata
Andropogon gerardii
Andropogon scoparium (Schyzachyrium scoparium)
Panicum virgatum
Ceratoides lanata
Chrysothamnus nauseousus
Atriplex canescens
Linum perenne var. lewisii (Linum lewisii)
Penstemon strictus
Dalea purpurea

The August-September 1993 sampling of the Hillside revealed that the success of the seeded species was low. The Hillside was reseeded in the fall of 1993 using a pure mix of *Agropyron smithii.*

The surrounding vegetation and physical characteristics of the area make it most similar to the mesic mixed grassland sites monitored by the EcMP. The mesic mixed grassland sites monitored by the EcMP are all on southfacing hillsides at the Site and the areas around the disturbed hillside area have the same type of vegetation as the EcMP sites. Data from the OU1 study area which encompasses the Hillside revegetation project area reports vegetation cover to have been 29.2% and species richness to have been 117 species prior to the disturbance (DOE, 1992). Although none of the transects used for the OU1 study were in exactly the locations of those done for this monitoring, they are on the same general Hillside area.

RESULTS

Note: Species with no native or annual status (due to identification only to genus or family) were not included in calculations concerning these categories.

Species Richness

Species richness for the Hillside was determined by combining the belt transect and point-intercept data. A complete species list of the 1994 Hillside sampling is found in Table F-1. A summary of the species richness from the 1994 Hillside and a comparison with 1994 EcMP mesic sites and community is found in Table F-2. A total of 68 species in 19 families were recorded, with only 48% of the species being native. Annual species represented 29% of the total flora.

Basal Cover

Vegetation cover on the Hillside was only 14% based on basal cover from point-intercept sampling (Table F-3). The largest amount of ground cover was provided by litter (58.9%). Bare ground accounted for 19.4% of the hits and rock for 7.8%. Native species only accounted for 4.3% (Table F-4) of the total vegetation cover of the transects sampled. Annual species (all of which were non-native species in 1994) represented 91.6% of the total vegetation cover (Table F-4). Vegetation basal cover was dominated by *Bromus tectorum* and *Aylssum minus*, both non-native, annual species, which together made up over 77% of the vegetation cover (56% and 21.1% respectively, Table F-3).

DISCUSSION

To determine the success of the revegetation effort on the Hillside, the results from the 1994 sampling must be put into some context. In addition to examining the success of the seeded species by comparison to previous years' data, comparisons can also be made to similar, undisturbed communities.

It is important to mention some of the differences concerning the sampling exercises which may affect interpretation of 1993 to 1994 comparisons. First, different personnel conducted the sampling in 1993 and 1994. This could affect the data because some species may have been identified as different species by the different personnel. Second, sampling was conducted at different times of year. In 1993, sampling was conducted in August and September. In 1994, sampling was done in November and December. The late 1994 sampling could account for some of the differences found in species richness and basal cover species values because some of the species may have died and blown away before sampling took place and therefore would not be accounted for. For example, the lack of *Melilotus officinalis* from the 1994 basal cover could be in part due to this because it is unlikely that it would have been absent in 1994 after having been so dominant (Table F-3) in 1993. In addition, during the 1994 sampling some of the higher litter value may be due in part to snow which fell during the sampling period which by matting down some of the dead plant stems may have increased the number of litter hits. Third, the transects are not permanent, so the transects sampled were not in exactly the same location during the two years. All of these concerns must be considered for the interpretation of the results. A suggestion for future sampling of the Hillside would be to attempt to limit the effect of these factors by using the same personnel for sampling, sampling at the same time of year, and possibly setting up permanent transects to sample on a yearly basis.

A general statement concerning the success of the species which were seeded on the Hillside in 1992 and 1993 would be that it has been rather poor. Of the 13 species seeded, only six were recorded as present in the 1994 sampling (Table F-1 and the list of species seeded from the site description section). This is up from three species recorded in 1993. Only *Agropyron smithii*, *Bouteloua gracilis*, *Bouteloua curtipendula*, *Andropogon scoparius*, *Atriplex canescens*, and *Linum perenne* var.*lewisii* were recorded in 1994. Of these, the amount of cover they provide totals to only 3.5% of the total vegetation cover on the hillside (Table F-3). This is a slight improvement over the 0.9% vegetation cover the seeded species provided on the Hillside in 1993.

A comparison of the 1994 Hillside data with the 1993 data shows species richness to be nearly the same - 68 and 69 species, respectively. This supports hypothesis three, so the null hypothesis is retained that states, 1994 species richness would not differ from 1993. However, using the Sorenson similarity index (S_I),

$$S_I = \frac{2(C)}{A + B}$$

where C = the number of species in common between two sites, A = the number of species at the first site, and B = the number of species at the second site (Brower and Zar, 1977), the similarity between the 1993 and 1994 sampling is only 62%. This indicates that although the number of species is essentially the same, species composition has changed from the first year to the second year. This change in species composition is further supported by the fact that in 1993, 36% of the species recorded were natives, while in 1994, the percentage increased to 48% (Table F-2). The number of annual species recorded declined, from 30 species to 20 species from 1993 to 1994. The percentage of annuals making up the flora decreased from 45% to 29% from 1993 to 1994. An interesting change however, took place in the ratio of graminoids to forbs from 1993 to 1994. In 1993, the ratio was 0.31, while in 1994, the ratio increased to 0.52, indicating that a large increase

in the number of new graminoid species (9, Table F-2) had occurred during the year. Whether this is a real change or due to the differences mentioned in sampling methods is not known, however the new graminoid species recorded for 1994 are mostly native *Boutleoua*, *Aristida*, *Stipa*, and *Agropyron* species. (*Agropyron smithii* was one of the seeded species). This would indicate that some native species are beginning to establish.

Comparison of the Hillside data with the mesic mixed grassland community (mesic community) data from the EcMP sites shows that some characteristics of overall species richness on the Hillside seem to be approaching that of the mesic community. Although the actual values are far short of the mesic community, the increase in the percent native species and decrease in the percent annuals from 1993 to 1994 are approaching that of the mesic community (Table F-2). Other comparisons however, show that the number of families and species represented on the Hillside are just over half what is found in the mesic community (Table F-2). Data from OU1 reported 117 species for the Hillside area, which although is less than that reported from the mesic community in 1994, is still considerably higher than that found on the Hillside at present (DOE,1992). The data also show that the type of species most lacking on the hillside are perennial, herbaceous dicots. Each of the categories listed show the hillside to be less than half what is found in the mesic community (Table F-2). For hypotheses number one and five, these data show the null hypotheses to be rejected, because species richness and the percentage of native species richness differs between the Hillside and similar undisturbed habitats.

Forty-three of the 68 species present on the Hillside (63%) are listed as weeds in the books, Weeds of the West (Whitson, 1991) and Weeds of Colorado (Zimdahl,1990). Four species, *Carduus nutans*, *Centaurea diffusa*, *Cirsium arvense*, and *Convolvulus arvensis* are considered prohibited noxious weed seed producers by Colorado law (Zimdahl, 1990). Seeds of these species are defined as "the seed of a perennial, biennial, or annual weeds which are highly detrimental and especially difficult to control, and the presence of which prohibits the sale of seeds for planting purposes." Two species, *Agropyron repens* and *Rumex crispus*, are considered restricted noxious weed seed producers by Colorado law (Zimdahl, 1990). The restricted noxious weed seed category differs from the former in that these seeds are from "weeds which are very objectionable in fields, lawns, and gardens of the state, but which can be controlled by good cultural practices." In addition, 11 of the species listed on the Hillside are weeds which are controlled by spraying, biological control, or mechanical methods on the Site (Department of Energy, 1993).

A comparison of basal cover data from the Hillside in 1993 and 1994 with the mesic community shows that 1) overall vegetation cover is far less than that of the mesic community (Table F-4, Figure F-1), and 2) the species providing the dominant vegetation cover on the Hillside are non-native, annual species (Table F-3). Vegetation cover on the Hillside in 1994 (14%) although up 10% from 1993 (4.7%), is less than half that found mesic community in general (29%, Table F-5) and the 29.2% reported in the general area on the Hillside during the OU1 characterization (DOE, 1992). A one-way ANOVA (Tukey means separation) for vegetation cover between the 1993 and 1994 Hillside data and the 1994 mesic community data found significant differences (α=0.05 level) between 1993 and 1994 Hillside vegetation cover (Figure F-1). Although the variances were not equal in the analysis, the residuals were evenly distributed. In addition, significant differences (α=0.05 level) were found between both years' of Hillside vegetation cover and that of the mesic community also. A discussion follows below which examines the species composition of these differences. Based on these data the null hypotheses for both hypotheses number two and number four are rejected. These stated that vegetation cover would not differ from undisturbed habitats and last year, respectively. Although a significant increase in the amount of vegetation cover has taken place between 1993 and 1994 on the Hillside, at present, the amount on the Hillside is still far less than that of the mesic community reference area.

Although the amount of bare ground was much less in 1994 (19.4%), than in 1993 (78.4%, Table F-5), the 1994 value still remains 11 times greater than that found in the mesic community (1.7%,

Table F-4). A one-way ANOVA (Tukey means separation) for bare ground cover between the 1993 and 1994 Hillside data and the 1994 mesic community data found significant differences (α=0.05 level) between 1993 and 1994 Hillside bare ground cover (Figure F-1). Although the variances were not equal in the analysis, the residuals were evenly distributed. In addition, significant differences were found between both years' of Hillside bare ground cover and that of the mesic community. The high amount of bare ground on the Hillside is of special concern at the Site since the chief mechanism for potential plutonium movement in contaminated soils is from wind erosion (Little, 1980). So it is important to maintain a good vegetation cover on the soils to limit the amount of bare ground exposed. Most of the reduction in bare ground from 1993 to 1994 on the Hillside is due to an increase in litter and vegetation cover.

Litter cover on the Hillside increased approximately seven times from 1993 to 1994 (Table F-5). The increase in litter cover was significant between years (α=0.05 level), however, no significant differences (α=0.05 level) were found for the 1994 Hillside litter as compared with the 1994 litter cover in the mesic community. Much of the increase in litter cover is probably attributable to the increase in vegetation cover which then turned into litter.

Rock cover was found to be significant (α=0.05 level) only between the 1993 Hillside data and the 1994 mesic community data. No significant change was found between 1993 and 1994 sampling on the Hillside. A large part of the difference between the Hillside and mesic community may be due to the disturbance that took place on the Hillside during construction of the French Drain. The respreading of top soil and mulch over the surface may have buried many of the rocks which may have previously been present. Why the 1994 Hillside rock cover was not significantly different than the mesic community may have been due to the difference in transect locations from year to year.

The plant species providing the various amounts of vegetation cover on the Hillside are of special interest because although species richness can tell us what is present, it does not give any indication of amounts for each species. Based on 1994 species richness data, 48% of the species represented are native (an improvement from the 36% native species in 1993). In looking at cover however, in 1993, *Melilotus officinalis*, *Bromus tectorum*, *Cirsium arvense*, *Lactuca serriola*, and *Centaurea diffusa*, provided 65% of the vegetative cover on the Hillside (Table F-3). All of these are non-natives, with two of them, *Cirsium arvense* and *Centaurea diffusa*, considered prohibited noxious weed seed producers under Colorado law (Zimdahl, 1990). In 1994, the top five cover species were *Bromus tectorum*, *Alyssum minus*, *Erodium cicutarium*, *Bromus japonicus*, and *Agropyron smithii*. Together these five species accounted for 90.3% of the total vegetation cover on the Hillside (Table F-3). The first four listed are all non-native, annual species, and account for 87.4% of the total vegetation cover. These data show a drastic shift in the species providing the most cover from 1993 to 1994. *Bromus tectorum* showed a seven-fold increase in cover, while *Alyssum minus* increased in cover by a factor of 12. The other top three species increased by a factors of approximately three. *Bromus tectorum* was the only species present in the top five cover species for both years.

In 1993, native vegetation cover accounted for 7.9% of the total vegetation cover and annuals provided 83.3% of vegetation cover (Table F-4). In 1994, native cover decreased to only 4.3% while at the same time annuals increased their dominance to 91.6% of the vegetation cover (Table F-4). Data from the mesic community in 1994 show that native plants provide 50.5% of the vegetation cover while annuals contribute 43.8% to the vegetation cover (Table F-4). The mesic community data provide reference area values for the Hillside and show at this point how different the Hillside is in many respects and how far it has to go in order to be comparable in quality. These data comparisons show the null hypotheses for hypotheses six and seven to be rejected. They stated that the percentage of basal cover from native species and annual species, respectively would not differ between the Hillside and similar undisturbed habitats.

Using basal vegetation cover data from 1993 and 1994 Hillside sampling, separate similarity indices were determined for species richness by basal cover species and basal cover amounts by specific species. The similarity index using species richness by basal cover species was done using the Sorenson similarity index mentioned previously. The results showed a similarity of 53% for the species recorded in 1993 as compared with 1994 from the Hillside. This is not that different from the 61% similarity found for the overall species richness results from 1993 and 1994.

The similarity index used for the species specific basal cover amounts was the Motyka's version of Sorenson's similiarity index (S_{ml},Chambers and Brown, 1983). The index is as follows:

$$S_{ml} = \frac{2\,MW}{MA + MB}$$

MW = The sum of the smaller values of the species common to both areas.
MA = The sum of the values of all species from the first area.
MB = The sum of the values of all species from the second area.

The results of this index show the similarity between the 1993 and 1994 cover values by species to be 19%. This indicates that a large difference exists between the species providing cover in 1993 as compared to 1994 and agrees with what the other results have shown to be the case.

The shift in the top five cover species can be explained by a number of factors. First, the late sampling in 1994 would favor those species which have stems that remain attached to the ground after senescence. This could explain why no cover was found in 1994 for *Melilotus officinale* and the cover value for *Centaurea diffusa* was lower in 1994, than in 1993. Once these species senesce, the dead stems tend to break off and blow away. Most *Centaurea diffusa* hits in 1994 were basal rosettes which result from the fact that it is a winter annual which had already germinated and produced some basal rosettes at the time of the late fall sampling. Secondly, due to the very dry summer which occurred during 1994 (Balint, 1995), many of the late season species such as *Cirsium arvense* and *Lactuca serriola* were stunted in their growth and died. As a result, some of their stems were problably broken off and no longer attached, possibly accounting for their lower 1994 values. Thus the lack of summer precipitation has favored the spread of annuals which often germinate the previous fall and then grow rapidly with favorable spring conditions such as were present in 1994. Third, the shift to *Bromus tectorum*, *Alyssum minus*, *Erodium cicutarium*, and *Bromus japonicus*, in 1994, can be explained by the fact that these species are all winter annuals. Their seeds usually germinate under favorable fall conditions, such as existed during the fall of 1994, producing basal leaves and root systems which then overwinter until the following spring (Haferkamp et al.,1994; Monsen, 1994). Thus the high cover values for these species in 1994 may be due to the late fall sampling time when the 1994 sampling was done. Favorable conditions existed for the germination of these species in the fall and so they provided a high amount of vegetation cover at that time. Even though this may explain much of the shift in species composition, the fact however remains, that *Bromus tectorum*, *Alyssum minus*, *Erodium cicutarium*, and *Bromus japonicus*, have greatly expanded their cover values on the Hillside (providing 87% of the total vegetation cover in late 1994, Table F-3) and because of the high amount of cover present in late 1994, they will become even more dominant during the spring of 1995.

The Hillside data show that from 1993 to 1994 vegetation cover has increased, but a shift has occurred in the dominant species on the Hillside. Unfortunately that shift in species composition has increased the vegetation cover by non-native, annual species. The significance of this situation cannot be underestimated. The near total domination of the Hillside by these non-native, annuals could pose a problem to the rest of the Woman Creek drainage downstream and downwind on the Site. With no remediation of this situation, the Hillside will act as a weed seed source, spreading seed potentially downstream and downwind. Studies have shown (Monsen, 1994; Rosentreter, 1994), that left unattended, the competitive influences of weedy annuals such as are present on the Hillside will prevent the natural recovery of native species. Extensive controls and management will

be necessary to allow the establishment of other species on the Hillside . In addition, dominance by annual weeds has been shown to alter the ecosytem functions on rangeland throughout the western United States (Rosentreter, 1994). The conversion of sites to annual species results in the lowering of genetic, species, and structural diversity, lowers the quality of watersheds by increasing the potential for soil erosion, and typically increases the frequency of wildfires (Pellant, 1994; Tausch et al., 1994; Rosentreter, 1994). All of these are detrimental and were certainly not present to the the extent found presently on the Hillside prior to the distubance for the construction of the French Drain.

RECOMMENDATIONS

Reseeding of the Hillside is necessary. It should be done soon with a mix of perennial and native grass and forb species. The original seed mix would be fine. The addition of other species common to the mesic community on Site (such as *Stipa viridula*, *Artemesia frigida*, *Arnica fulgens*, and *Aster ericoides*) is also recommended. At some point further measures may be necessary to eliminate and control the non-native, adventive species which are presently dominant on the Hillside.

FUTURE STUDY AND ANALYSES

Potential future study and analyses might involve dividing the 881 Hillside area into different units and applying different remediation treatments in an attempt to determine the success of different seed mixes, seeding methods, mulches, and other variables, for reclamation work in the mesic mixed grassland type communities on the Site. Soil analyses on samples from the Hillside and other revegetated locations on Site would allow comparison to similar sites monitored by EcMP and give a better understanding as to what is occurring underground. This may help explain the poor response of the Hillside to revegetation efforts.

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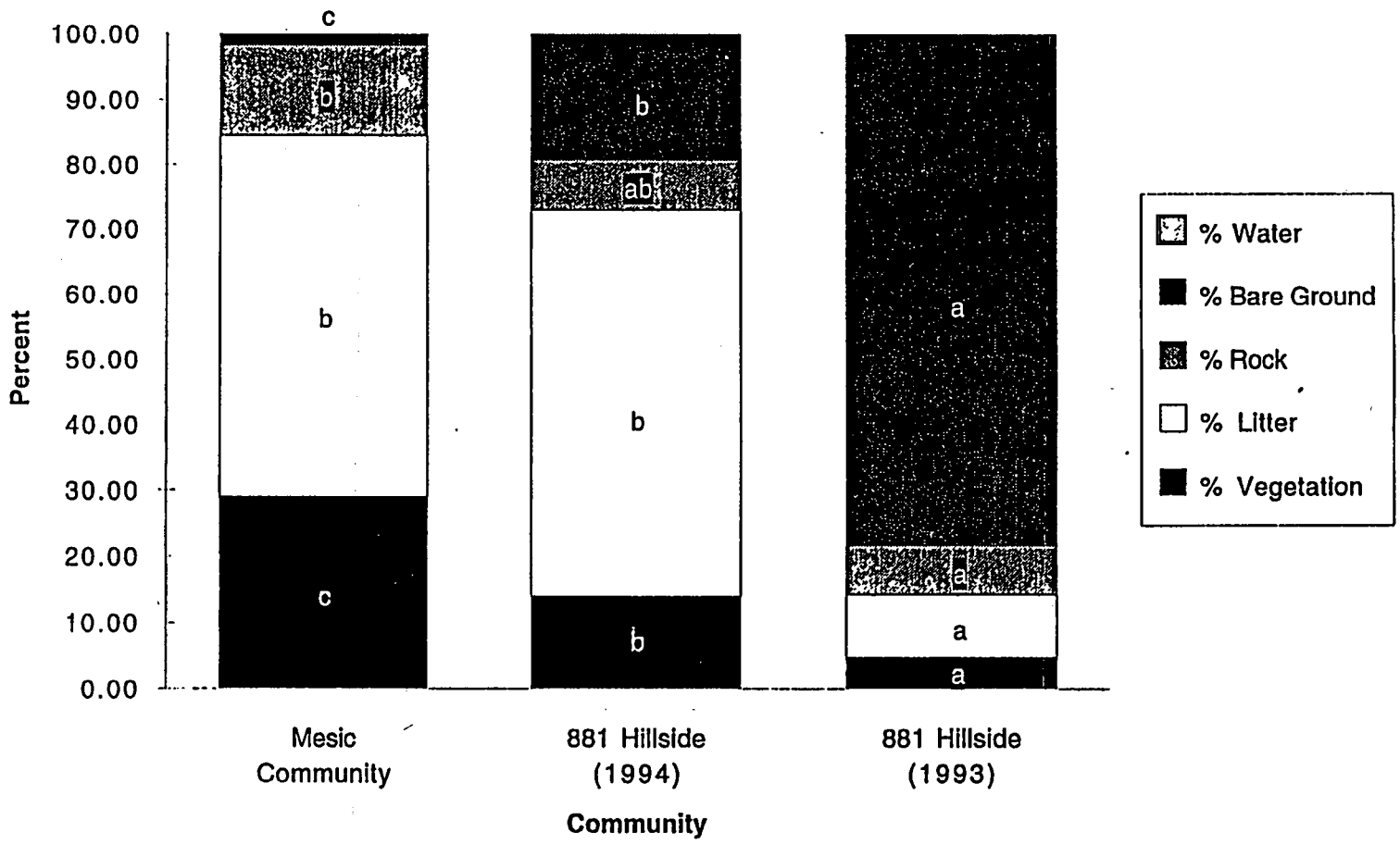

Common letters within a cover class indicate no significant difference (α =0.05 level). No water hits were recorded.

Figure F-1. Comparison of 881 Hillside Reclamation Monitoring Data (1993 & 1994) with the Mesic Community (1994).

Table F-1. 1994 Reclamation Monitoring (881 Hillside) Species Richness.

Scientific Name	Speccode	Native
AGAVACEAE		
Yucca glauca Nutt.	YUGL1	Y
ASTERACEAE		
Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	ACMI1	Y
Ambrosia artemisiifolia L.	AMAR1	Y
Ambrosia psilostachya DC.	AMPS1	Y
Arctium minus (Hill) Bernh.	ARMI1	Y
Artemisia dracunculus L.	ARDR1	Y
Aster ericoides L.	ASER1	Y
Aster porteri Gray	ASPO1	Y
Carduus nutans L.	CANU1	N
Centaurea diffusa Lam.	CEDI1	N
Cirsium arvense (L.) Scop.	CIAR1	N
Cirsium vulgare (Savi) Ten.	CIVU1	N
Grindelia squarrosa (Pursh.) Dun.	GRSQ1	Y
Gutierrezia sarothrae (Pursh.) Britt. & Rusby	GUSA1	Y
Helianthus annuus L.	HEAN1	Y
Lactuca serriola L.	LASE1	N
Scorzonera laciniata L.	SCLA1	N
Taraxacum officinale Weber	TAOF1	N
Tragopogon dubius Scop.	TRDU1	N
Xanthium strumarium L.	XAST1	Y
BRASSICACEAE		
Alyssum alyssoides L.	ALAL1	N
Alyssum minus (L.) Rothmaler	ALMI1	N
Camelina microcarpa Andrz.	CAMI1	N
Descurainia pinnata (Walt.) Britt.	DEPI1	Y
Descurainia richardsonii (Sweet) Schultz	DERI1	Y
Sisymbrium altissimum L.	SIAL1	N
CHENOPODIACEAE		
Atriplex canescens (Pursh.) Nutt.	ATCA1	Y
Kochia scoparia (L.) Schrad.	KOSC1	N
Salsola iberica Senn. & Pau.	SAIB1	N
CONVOLVULACEAE		
Convolvulus arvensis L.	COAR1	N
CYPERACEAE		
Carex sp.	CAR1	
ELAEAGNACEAE		
Elaeagnus angustifolia L.	ELAN1	N
FABACEAE		
Melilotus sp.	MEL1	
GERANIACEAE		
Erodium cicutarium (L.) L'Her.	ERCI1	N

Table F-1(cont.). 1994 Reclamation Monitoring (881 Hillside) Species Richness.

Scientific Name	Speccode	Native
JUNCACEAE		
Juncus torreyi Cov.	JUTO1	Y
LAMIACEAE		
Marrubium vulgare L.	MAVU1	N
LINACEAE		
Linum perenne L. var. lewisii (Pursh.) Eat. & Wright	LIPE1	Y
MALVACEAE		
Malva neglecta Wallr.	MANE1	N
Sphaeralcea coccinea (Pursh.) Rydb.	SPCO1	Y
ONAGRACEAE		
Oenothera biennis L.	OEBI1	Y
POACEAE		
Agropyron cristatum (L.) Gaertn.	AGCR1	N
Agropyron intermedium (Host) Beauv.	AGIN1	N
Agropyron repens (L.) Beauv.	AGRE1	N
Agropyron smithii Rydb.	AGSM1	Y
Agropyron spicatum (Pursh) Schrib. and Sm.	AGSP1	Y
Agrostis sp.	AGR2	
Andropogon scoparius Michx.	ANSC1	Y
Aristida sp.	ARI1	
Bouteloua curtipendula (Michx.) Torr.	BOCU1	Y
Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	Y
Bromus inermis Leyss.	BRIN1	N
Bromus japonicus Thunb. ex Murr.	BRJA1	N
Bromus tectorum L.	BRTE1	N
Dactylis glomerata L.	DAGL1	N
Festuca pratensis Huds.	FEPR1	Y
Hordeum jubatum L.	HOJU1	Y
Poa compressa L.	POCO1	N
Poa pratensis L.	POPR1	N
Secale cereale L.	SECE1	N
Sporobolus cryptandrus (Torr.) A. Gray	SPCR1	Y
Stipa viridula Trin.	STVI1	Y
POLYGONACEAE		
Rumex crispus L.	RUCR1	N
Rumex mexicanus Meisn.	RUME1	Y
SALICACEAE		
Salix exigua Nutt. ssp. interior (Rowlee) Cronq.	SAEX1	Y
SCROPHULARIACEAE		
Linaria dalmatica (L.) Mill.	LIDA1	N
Verbascum blattaria L.	VEBL1	N
Verbascum thapsus L.	VETH1	N
VERBENACEAE		
Verbena bracteata Lag. & Rodr.	VEBR1	Y

Table F-2. 1994 Reclamation Monitoring (881 Hillside) Species Richness - Summary and Comparison to Mesic Community and Sites.

Sample Site	# Families	# Species	% Native	# Annuals	# Biennials	# Perennials
Mesic Community	37	143	81	27	1	113
TR02	30	107	81	17	0	90
TR04	30	95	76	23	1	70
TR11	28	106	83	17	1	86
Mean	29.33	102.67	80.00	19.00	0.67	82.00
Reclamation Community 1994	19	68	48	20	4	44
Reclamation Community 1993	19	69	36	30	2	34

	Growth Form (#'s)						Type (#'s)		Form (#'s)		
Sample Site	Forb	Graminoid	Cactus	Shrub	Vine	Tree	Dicots	Monocots	Herbaceous	Succulent	Woody
Mesic Community	106	30	5	2	0	0	109	34	136	5	2
TR02	78	22	5	2	0	0	81	26	100	5	2
TR04	70	20	4	1	0	0	73	22	90	4	1
TR11	79	21	4	2	0	0	81	25	100	4	2
Mean	75.67	21.00	4.33	1.67	0.00	0.00	78.33	24.33	96.67	4.33	1.67
Reclamation Community 94	42	22	0	3	0	1	44	24	64	0	4
Reclamation Community 93	49	15	0	2	0	0	51	15	64	0	2

Community	# Families	# Species	% Native	% Annuals	Graminoids/Forbs	Monocots/Dicots
Mesic	37	143	81	19	0.28	0.31
Reclamation 1994	19	68	48	29	0.52	0.55
Reclamation 1993	19	69	36	45	0.31	0.29

Note: Graminoid/Forbs and Monocots/Dicots values are ratios.

Table F-3. 1993 & 1994 881 Hillside Reclamation Monitoring Basal Cover Data.

					93	93	93	94	94	94
Family	Scientific Name	Speccode	Native	Annual	# Hits	% Cover	Frequency	# Hits	% Cover	Frequency
	Litter	LITT			238	9.50		1472	58.90	
	Bare Ground	BARE			1959	78.40		484	19.40	
	Vegetation				117	4.70		350	14.00	
	Rock	ROCK			186	7.40		194	7.80	
Graminoids										
POACEAE	Agropyron cristatum (L.) Gaertn.	AGCR1	N	FALSE				3	0.90	8.00
POACEAE	Agropyron smithii Rydb.	AGSM1	Y	FALSE				10	2.90	36.00
POACEAE	Agropyron intermedium (Host.) Beauv.	AGIN1	N	FALSE	3	2.60	12.00			
POACEAE	Agrostis sp.	AGR2						2	0.60	4.00
POACEAE	Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	Y	FALSE				2	0.60	8.00
POACEAE	Bromus inermis Leyss.	BRIN1	N	FALSE	1	0.90	4.00	2	0.60	8.00
POACEAE	Bromus japonicus Thunb. ex Murr.	BRJA1	N	TRUE	2	1.70	8.00	13	3.70	28.00
POACEAE	Bromus tectorum L.	BRTE1	N	TRUE	9	7.70	24.00	196	56.00	76.00
POACEAE	Echinochloa crusgalili (L.) Beauv.	ECCR1	N	TRUE	2	1.70	8.00			
POACEAE	Eragrostis cilanensis (All.) E. Mosher	ERCI2	N	TRUE	1	0.90	4.00			
POACEAE	Festuca pratensis Huds.	FEPR1	Y	FALSE				1	0.30	4.00
POACEAE	Hordeum jubatum L.	HOJU1	Y	FALSE	1	0.90	4.00	1	0.30	4.00
POACEAE	Hordeum sp.	HOR1			2	1.70	8.00			
POACEAE	Poaceae	PO1						1	0.30	4.00
POACEAE	Poa compressa L.	POCO1	N	FALSE				5	1.40	16.00
Forbs										
ASTERACEAE	Ambrosia psilostachya DC.	AMPS1	Y	FALSE	4	3.40	16.00			
ASTERACEAE	Carduus nutans L.	CANU1	N	TRUE	3	2.60	12.00	1	0.30	4.00
ASTERACEAE	Centaurea diffusa Lam.	CEDI1	N	TRUE	5	4.30	20.00	6	1.70	2.00
ASTERACEAE	Cirsium arvense (L.) Scop.	CIAR1	N	FALSE	6	5.10	20.00	3	0.90	12.00
ASTERACEAE	Helianthus annuus L.	HEAN1	Y	TRUE	2	1.70	4.00			
ASTERACEAE	Lactuca serriola L.	LASE1	N	TRUE	6	5.10	20.00	1	0.30	4.00
ASTERACEAE	Scorzonera laciniata L.	SCLA1	N	TRUE	1	0.90	4.00	1	0.30	4.00
ASTERACEAE	Sonchus arvense L.	SOAR1	N	FALSE	1	0.90	4.00			
ASTERACEAE	Tragopogon dubius Scop.	TRDU1	N	FALSE	2	1.70	8.00	1	0.30	4.00
BRASSICACEAE	Alyssum minus (L.) Rothmaler	ALMI1	N	TRUE	2	1.70	8.00	74	21.10	56.00
BRASSICACEAE	Camelina microcarpa Andrz.	CAMI1	N	TRUE				1	0.30	4.00

Table F-3. 1993 & 1994 881 Hillside Reclamation Monitoring Basal Cover Data.

CHENOPODIACEAE	Chenopodium leptophyllum Nut. ex. Moq.	CHLE2	Y	TRUE	1	0.90	4.00			
CHENOPODIACEAE	Kochia scoparia (L.) Schrad.	KOSC1	N	TRUE	1	0.90	4.00	2	0.60	8.00
CHENOPODIACEAE	Salsola iberica Senn. and Pau.	SAIB1	N	TRUE	2	1.70	8.00			
FABACEAE	Melilotus officinis L.	MEOF1	N	TRUE	50	42.70	72.00			
GERANIACEAE	Erodium cicutarium (L.) L'Her.	ERCI1	N	TRUE	3	2.60	12.00	23	6.60	32.00
LINACEAE	Linum perenne L. var. lewisii (Pursh) Eat. & Wright	LIPE1	Y	FALSE	1	0.90	4.00			
POLYGONACEAE	Polygonum aviculare L.	POAV1	N	TRUE	4	3.40	8.00			
POLYGONACEAE	Rumex mexicanus Meisn.	RUME1	Y	FALSE				1	0.30	4.00
VERBENACEAE	Verbena bracteata Lag. & Rodr.	VEBR1	N	TRUE	1	0.90	4.00			
	unknown forb	?			1	0.90	4.00			
		Totals			117	100.40		350	100.30	

NOTE: % Cover value is % Relative Cover. % Cover sums are greater than 100% due to rounding.
MEOF1 is considered an annual for this exercise, although sometimes it is considered a biennial.
Frequency = Probability of getting a hit for a given species.

Table F-4. % Native and % Annual Species Comparisons Between the 881 Hillside and Mesic Community.

	1993 Hillside	1994 Hillside	Mesic Community
% Native Cover	7.9	4.3	50.5
% Annual Cover	83.3	91.6	43.8

Table F-5. Comparison of 881 Hillside Reclamation Monitoring Data with Mesic Community.

Sample Site	% Vegetation	% Litter	% Rock	% Bare Ground	% Water
Mesic Community	29.00	55.30	14.00	1.70	0.00
TR02	21.40	56.00	21.00	1.60	0.00
TR04	40.40	51.00	6.20	2.60	0.00
TR11	25.40	59.00	14.80	0.80	0.00
881 Hillside (1994)	14.00	58.90	7.80	19.40	0.00
881 Hillside (1993)	4.70	9.50	7.40	78.40	0.00

APPENDIX G). TERRESTRIAL ARTHROPODS

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INTRODUCTION

The Terrestrial Arthropod Module was established in June, 1994 with the delivery of the *Ecological Monitoring Program Final Terrestrial Arthropod Field Procedure*, DOE (deliverable #61405206-E). The first sample collections were conducted in August and September of 1994. A laboratory contract with Colorado State University was established in January, 1995 to provide expertise in identifying arthropods in an efficient manner.

The following outlines the background, study objectives, methods, results, and discussion from activities conducted during 1994. Additionally, future plans for 1995 are discussed.

BACKGROUND

Insects, and therefore arthropods, make up more that half of all living things on earth (Borror and White,1970). Their overwhelming abundance and richness merit study. Arthropods tend to be localized in nature and are closely tied to soil and vegetative communities (Gilbert,1980). Therefore, arthropods may be sensitive to changes in soils, such as contaminant pollution, physical disturbance, or changes in vegetative communities.

Arthropods are important agents of pollination; important components in the diets of fish, reptiles, mammals, and birds; or may be beneficial in the control of noxious weeds and insect pests. Arthropods are probably the primary herbivores in terrestrial ecosystems at RFP. Therefore, the absence, presence, or abundance of specific arthropod species or groups can provide an assessment of the health of that ecosystem.

The large biomass represented by terrestrial arthropods represents large nutrient pools and possibly a significant pool for environmental contaminants. This biomass therefore, represents a foundation for RFP foodchains and possibly a contaminant pathway to top carnivores.

Colorado State University (CSU) researchers, Bly and Whicker (1979), measured potential contaminants in arthropod tissue collected from grasslands on the RFP. Researchers documented the relatively large biomass represented by terrestrial arthropods and recognized the potential for contaminant transfer from soils to arthropods. The study also documented a close correlation between soil contaminants and contaminants found in arthropods.

The Baseline Biological Characterization at RFP (DOE,1992) documented arthropod diversity found in the RFP buffer zone. The dominant groups were herbivores, mainly of the order Homoptera.

The Ecological Evaluation for Operable Unit One (DOE,1993) included a comparison of arthropod richness by habitat type. Sweep netting was used to gather samples, which were identified by the CSU Entomology Laboratory. Grasshopper tissue samples were collected on OU1 to determine contaminant levels in tissue. The results of tissue analysis were used to calculate a dose to insect predators and therefore reveal the potential risk to predators from contaminants found at OU1.

OBJECTIVE

The objective of this study is to characterize the diversity and biomass of insects, spiders, and other above ground terrestrial arthropods, collectively called terrestrial arthropods. Characterization will be conducted within and among vegetation communities. Data will be used to establish the natural variation in arthropod diversity and biomass among vegetation communities, document taxon richness by community types, develop a listing of arthropod taxa present at Rocky Flats and

categorize the taxa by trophic groups.

HYPOTHESIS

$H1_o$: Arthropod taxon richness does not differ significantly among or within vegetation communities.
$H1_A$: Arthropod taxon richness differ significantly among or within vegetation communities.

Basis for hypothesis: If arthropod communities are closely tied to vegetation communities in which they live, differences in arthropod taxon richness should be detected between vegetation types. Differences noted within a terrestrial site reveal natural variation of arthropod taxon richness and document uncertainty of measurements.

$H2_o$: Arthropod biomass does not differ significantly among or within vegetation communities.
$H2_A$: Arthropod biomass measurements differ significantly among or within vegetation communities.

Basis for hypothesis: Vegetation production varies among vegetation types. Arthropod biomass may be a reflection of plant production and should vary accordingly.

$H3_o$: The ratio of primary consumers to higher consumers is approximately equal among and within vegetation types.
$H3_A$: The ratio of primary consumers to higher consumers is not equal among and within vegetation types.

Basis for hypothesis: Trophic groups within the arthropod communities should have a ratio reflecting a large number of primary consumers which are fed upon by a smaller number of insect predators. This ratio should hold true regardless of vegetation communities. Changes in the documented ratios may indicate stressed communities or communities in transition.

$H4_o$: Arthropod taxon richness and biomass does not change significantly from year to year.
$H4_A$: Arthropod taxon richness and biomass does change significantly from year to year.

Basis for hypothesis: Arthropod taxon richness and biomass should reflect the variability of annual weather conditions and the annual variability of vegetation production.

SAMPLE DESIGN

This sampling design was intended to test the four hypotheses, monitor changes through space and time, and establish the natural variability associated with the selected arthropod communities. These data can then be used to help document a picture of Buffer Zone ecological resources, and serve as reference data for comparison to Operable Units and other impacted areas.

Long-term monitoring requires the establishment of permanent sampling transects to insure repeatability of data collection year after year. During 1994 sampling, sweep nets, malaise traps, and pitfall traps were used to collect samples. Each site was sampled for biomass and taxonomy at each of the 12 terrestrial sampling locations. All the sampling was conducted along the permanent vegetation transects. Each community type, which contain three site replicates, had one site sampled simply by collecting a sample for biomass and a sample for taxonomy. A second site was sampled by replicating four times for biomass. The remaining site was sampled by replicating four times for taxonomy. The replicates were conducted along a different vegetation transect within the same site. This replicated sampling documents variation within a site. The sampling session, conducted during August and September collected 24 sweep net samples, 4

pitfall trap samples, and 4 Malaise trap samples (Table G-1).

METHODS

Many methods can be used to capture and study terrestrial arthropods. In fact, a number of methods and equipment must be used to sample all the arthropod groups that may be present in a community type. The methods employed by entomologists are semi-quantitative at best. One goal of the 1994 sampling, therefore, will be to compare methods and equipment to decide which combinations will provide the best sampling methodology for the testing of the stated hypotheses.

Grassland communities including mesic, xeric, and reclaimed grasslands, were sampled using sweep nets, pit fall traps, and malaise traps. Riparian communities were sampled using sweep nets, beating trays, pit fall traps, and malaise traps.

Sweep Net Methodology

Sweep netting was used to collect insects clinging to vegetation, such as grasshoppers, beetles, and spiders. The area that is swept is standardized between grassland sites. A sweep net sample consisted of a 50 m by 2 m transect which is located parallel to the chosen vegetation transect, offset 1 meter to the outside edge of the vegetation belt. Sweep net samples were also standardized among riparian sites, consisting of two 25 m by 2 m transects on both sides of the stream channel. Care was taken not to walk in the area to be swept prior to sampling. The Terrestrial Arthropod Sampling Standard Operating Procedure (SOP 4-K23-EVN-ECOL.09, revision 2, draft B) was followed for sweep net sampling.

Once the sweep net sample was collected, the material aggregate (plants and arthropods) was placed in a kill jar. A label with the site number, transect number, date, time, and method was placed in the kill jar.

Pitfall Trap Methodology

Pitfall traps were used to collect ground-dwelling arthropods that may have been missed during sweep netting. Pitfall traps were installed on either side of two randomly chosen vegetation transects. Traps were located 10 m in from the zero end on the left side of the transect and 40 m from the zero end on the right side of the vegetation transect. The traps were opened for one week during sweep net sampling and checked daily. The arthropods were transferred from the trap chamber to a sample jar using ethyl alcohol as a preservative. Labels with the site number, date, time, and method on the sample jar. Taxa were collected as a separate sample and included as a taxonomic sample for the site. Pitfall trap samples were not be included for biomass measurements. The Terrestrial Arthropod Sampling Standard Operating Procedure (SOP 4-K23-EVN-ECOL.09, revision 2, draft B) was followed for pitfall trap sampling. The traps were closed at the end of the sampling session.

Malaise Trap Methodology

Malaise traps were used to collect flying and or emerging arthropods, such as wasps, flies, and moths. These traps are designed to intercept arthropods flying from any direction. They are tent-like structures made of netting which funnels flying insects into a collection jar located at the top of the tent.

One of three sites for each community type were chosen at random. Once the site was chosen, the trap was placed along stream beds or ridge tops, but within the EcMP site boundaries. The trap was checked once after 24 hours. A sample was collected after 72 hours. Organisms were

collected from both the collection jar and from the netting. The sample was transferred from the trap chamber to a sample jar using ethyl alcohol as a preservative. Labels with the site number, date, time, and method on the sample jar. The Terrestrial Arthropod Sampling Standard Operating Procedure (SOP 4-K23-EVN-ECOL.09, revision 2, draft B) was followed for Malaise traps.

Beating Tray Methodology

For riparian locations, a combination of beating trays and sweep nets were employed to collect samples. Five points along the 25 m transect were established every 5 m starting at the beginning of the transect. Five trays were placed on either side of the transect line and all surrounding vegetation was "beat" with a sweep net for approximately 30 seconds. The samples from riparian locations consisted of arthropods collected from sweep nets and beating trays. The Terrestrial Arthropod Sampling Standard Operating Procedure (SOP 4-K23-EVN-ECOL.09, revision 2, draft B) was followed for beating trays.

Sorting and Finalizing Taxonomic Samples

Once samples were collected for the day (probably two sites), field personnel returned to the lab and sorted all samples (sweep net and beating tray) when necessary. For the sweep net samples, arthropods were sorted from plant material in a plastic or metal tray. The sample was then transferred to a 1/2 pint sample jar containing a 70% solution of ethyl alcohol for taxonomic samples. Sample jars were labeled with the sample number, chain-of-custody number, and type of preservative. A chain-of-custody (COC) form for the sample was completed. Samples were secured until shipment to the Colorado State University Entomology lab.

Biomass Sampling Methodology

Biomass sampling was achieved by sweep netting a 50 m by 2 m area adjacent to a permanent vegetation transect. Sample materials were placed in a kill jar with a label containing information on sample number, site id, transect, date, and time. Once at the laboratory, the arthropod biomass sample was sorted from the vegetative material and placed in a labeled plastic bag and frozen.

Once sufficient numbers of biomass samples were collected, an initial weighing trial was conducted. The results of this trial are discussed in the Future Needs and the Planning sections.

1994 FIELD EFFORT

Schedule

Field trials for testing methodologies were conducted during the last week of July to experiment with methods from a logistical view point. A training session was held 1 August after trial methods were determined. Sampling methods were explained and all EcMP staff present had the opportunity to practice methods prior to sampling. Arthropod sampling was conducted during a four week period from August 1 to September 1, 1994.

Sample Collection

Table G-1 summarizes taxonomic and biomass samples collected. These numbers may change annually, depending on new methods and past results. The general trend was to take one taxonomic and one biomass sample from one of the three terrestrial site in each community type. The remaining sites were replicated sites, where either four taxonomic samples or four biomass samples were taken. Biomass samples and taxonomic samples were not replicated at the same site.

1994 DATA MANAGEMENT AND ADMINISTRATIVE EFFORTS

The field sampling plan and the technical field guide have been updated. Changes included removal of the beating tray method and addition of instructions for determining personnel's individual sweep net sample area. Refined sample design for pitfall traps was incorporated based on sampling one watershed per sample session. Additionally, biomass sampling will be limited to the last sampling session to match activities last year. The results of this effort will be used to determine if the biomass study should continue.

The results of the initial weighing trials revealed biomass samples with insufficient mass to register on the scales provided. At this time, further efforts for determining biomass for 1994 samples were discontinued. Three samples from the Baseline Biological Characterization (DOE,1992) study were air dried and weighed for comparison. These samples contained a greater number of arthropods and weighed between 0.10 and 0.02 grams.

Database

The design of the arthropod database was completed. It consists of a sample tracking file, a dictionary of scientific names, a raw data file that will be uploaded from the laboratory, and a summary file that will contain ecological endpoint information including biomass and taxon richness.

Chain-of-custody forms were designed and used in the sample shipment. Information from these forms was entered into the tracking database. A quality assurance plan was adopted for data entry and a location for a QA file was determined.

Laboratory Contract

A laboratory subcontract was awarded on January 5, 1995 for taxonomic analysis of terrestrial arthropods with the Colorado State University Entomology Department. The contract covers four sampling sessions, one in 1994 and three in 1995. One sampling session equates to 32 samples.

The taxonomic analysis will list all taxa present and the abundance of each taxon identified. The identification will be to the lowest taxonomic level possible; probably to family for both insects and spiders.

The subcontractor is obligated to provide taxonomic data within 6 months of sample receipt. The current sample batch is due to the CRT on June 16, 1995. Results have been received for some sites, and are undergoing data entry and quality assurance requirements.

1995 FUTURE IMPROVEMENTS AND PLANNING

The biomass study has been postponed until late summer due to the insufficient mass obtained via the sweep net method. The scales available cannot weigh these small samples. Hopefully, more sensitive scales from one of the RFETS analytic laboratories can be used in the future. Due to the dryness of the 1994 field season, another sampling session should be conducted to determine if biomass is a viable measurement for arthropods under more normal moisture conditions.

The D-vac method will be explored to supplement or replace sweep netting for the biomass sampling and possibly the taxonomic sampling. It is considered a superior method to sweep netting in that it samples a well-defined area, is easily replicated, and captures arthropods more completely when used properly. The deterring factor may be cost, however. Sweep netting is considerably less expensive and may be a sufficient method for monitoring purposes, especially for taxonomic sampling.

RESULTS

As mentioned above, only partial information on taxonomic data has been provided to date. This includes thirteen samples that represent 5 of the 12 EcMP sample sites for sweep netting, one malaise trap sample, and 3 out of four pitfall sites. Partial results under going quality assurance do not provide data for hypothesis testing. Analysis must be delayed until all results are received and undergo quality assurance requirements. •

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Table G-1. Terrestrial Arthropod Sampling Summary, 1994

	Taxonomic Sampling			Biomass Sampling
Site	Sweep Net Samples	Malaise Trap Samples	Pitfall Trap Samples	Sweep Net Samples
TR01	1	0	0	1
TR02	4	0	0	1
TR03	1	0	0	4
TR04	1	0	0	1
TR05	4	0	0	1
TR06	4	0	0	1
TR07	1	0	0	1
TR08	4	0	0	1
TR09	1	1	1	4
TR10	1	1	1	1
TR11	1	1	1	4
TR12	1	1	1	4
Seasonal Totals	24	4	4	24

Samples were collected between August 1 and September 6, 1994

Table G-2. Proposed Schedule for Terrestrial Arthropod Sampling, 1995.

Sweep Netting Schedule

Site	Session 1	Session 2	Session 3	Total
TR01	4	1	1	6
TR02	1	4	1	6
TR03	1	1	4	6
TR04	4	1	1	6
TR05	1	4	1	6
TR06	1	4	1	6
TR07	4	1	1	6
TR08	1	4	1	6
TR09	1	1	4	6
TR10	4	1	1	6
TR11	1	1	4	6
TR12	1	1	4	6
Sitewide			1	1
Seasonal Totals	24	24	25	73

Malaise Trapping

Site	Session 1	Session 2	Session 3	Total
TR01	0	0	1	1
TR02	1	0	0	1
TR03	0	0	1	1
TR04	0	0	1	1
TR05	1	0	0	1
TR06	1	0	0	1
TR07	0	0	1	1
TR08	1	0	0	1
TR09	0	1	0	1
TR10	0	1	0	1
TR11	0	1	0	1
TR12	0	1	0	1
Seasonal Totals	4	4	4	12

*Sessions defined: Session 1 - May/June, Session 2 - July/August, Session 3 - September

Notes: Samples will be collected during one week during each session.

Pitfall Traps will be checked daily during each session and added to the sweep net samples.

Table G-2. Proposed Schedule for Terrestrial Arthropod Sampling, 1995.

Pitfall Trapping

Site	Session 1	Session 2	Session 3	Total
TR01	0	0	1	1
TR02	1	0	0	1
TR03	0	0	1	1
TR04	0	0	1	1
TR05	1	0	0	1
TR06	1	0	0	1
TR07	0	0	1	1
TR08	1	0	0	1
TR09	0	1	0	1
TR10	0	1	0	1
TR11	0	1	0	1
TR12	0	1	0	1
Seasonal Totals	4	4	4	12

Biomass Sampling

Site	Session 3
TR01	1
TR02	1
TR03	4
TR04	1
TR05	1
TR06	1
TR07	1
TR08	1
TR09	4
TR10	1
TR11	4
TR12	4
Sitewide	
Seasonal Totals	24

*Sessions defined: Session 1 - May/June, Session 2 - July/August, Session 3 - September

Notes: Samples will be collected during one week during each session.

Pitfall Traps will be checked daily during each session and added to the sweep net samples.

H. EcMP DATABASE

This section was summarized in the Technical Summary.

I) OPERABLE UNIT 11 ECOLOGICAL EFFECTS

Authors: M.E. Bakeman and L.E. Woods

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INTRODUCTION

Between April 1982 and October 1985, three areas in the Rocky Flats Buffer Zone were sprayed with water from the Solar Ponds. This was done to remove excess water when the ponds became full. Because the water was contaminated, the site was identified as a hazardous waste management unit under the Resource Conservation and Recovery Act (RCRA) in 1986. Through a series of regulatory actions, the three areas were combined to create Operable Unit (OU) 11 of the Rocky Flats Interagency Agreement (IAG). Designation as an OU under the IAG required a RCRA Facility Investigation/Remedial Investigation (RFI/RI) to be carried out. an ecological Risk Assessment (ERA) is part of that investigation.

Ungrazed unplowed virgin native grassland comprises OU 11. Relict tallgrass species grow in association with shortgrass species that are common farther east. The Flatirons very cobbly sandy loam soil series covers the entire area. This soil is classified as a clayey-skeletal, montmorillonitic, mesic Aridic Paleustoll. Rock fragments make up 35 to 80% of its volume.

The sprayed area, originally reported to cover 14.1 acres (5.7 ha) (EG&G, 1992), is now known to be somewhat larger. One location received 190 inches (4.8 m) of irrigation water. Exact amounts of N applied in irrigation water are not known, but amounts were large. In a single spraying, on April 17 and 18, 1982, 89,445 gallons per acre containing 55.8 mg per liter of nitrate as N added about 7.6 kg/ha (6.8 lbs/ac). Setlock (1985) estimated that 40,638 pounds of N were applied in total. If added evenly to 14 acres, 4,838 lbs/ac (3251 kg/ha) were added in four years. Even if added to a somewhat larger area, this is more N than would be added to any agricultural crop. If any nitrate addition would alter N cycling in an ecosystem, this one should.

Most organic N in an ecosystem is in soil organic matter. The next largest amount is in plant tissue and litter. Another large and important amount of N is dinitrogen (or N_2) in the atmosphere. All other ecosystem functions depend on the transfers between these constituents. These transfers are biologically-mediated processes of decomposition, plant uptake, denitrification and nitrogen fixation.

Measures of microbial biomass and potential microbial activity reflect basic ecosystem processes. If ecosystem functions changed when large excesses of water and N were applied, measurements of the amount of microbial biomass and its potential activity ought to reflect the changes, even if other aspects of the ecosystem do not. If they do not, other changes may not be important.

In late summer of 1993, staff from the Ecological Monitoring Program were asked by the OU 11 manager to investigate the possibility of conducting the ERA for this site. Ecology staff had contracts with several laboratories at that time whose analytical work might contribute to the assessment of ecological effects. Staff then devised a sampling program to determine ecological effects of several potential receptors.

OBJECTIVES/APPROACH

The approach taken was to conduct a quantitative effects assessment on several potential ecological receptors, and to provide evidence from population, community, and ecosystem levels of organization as to whether an effect(s) was present eight years following the treatment application. If differences did persist, which ones demonstrated the clearest differences? A related purpose was to determine if these relatively inexpensive and quick tests could provide a sensitive measurement of contaminant effects. If similar trends were to emerge from this wide array of receptors, it might be possible to draw conclusions regarding the presence or absence of significant effects.

The receptors measured include:

A) Soil Physical and Chemical Properties

1) Total soil organic carbon
2) Total soil nitrogen
3) Soil exchangeable potassium
4) Soil extractable phosphorus
5) Soil calcium concentration
6) Soil particle size (texture)
7) Soil cation exchange capacity

Some of these properties (C and N) and other soil properties (particle size) were also measured under the ecosystem function section of this report.

B) Vegetation and Litter

1) Vegetation biomass.
2) Vegetation carbon, nitrogen, potassium and phosphorus concentrations (mg element kg^{-1} vegetation) and element contents (mg element m^{-2}).
3) Litter mass.
4) Litter carbon, nitrogen, potassium and phosphorus concentrations (mg element kg^{-1} vegetation) and element contents (mg element m^{-2}).

C) Soil Invertebrates

1) Soil invertebrate nematodes from the 0-5 and the 5-10 cm depths, classified into several functional groups.
2) Soil invertebrate arthropods from the 0-5 and the 5-10 cm depth, analyzed both taxonomically and by functional groups.

D) Ecosystem Functions

1) Extractable soil nitrate (NO_3)
2) Extractable soil ammonium (NH_4)
3) Total soil nitrogen
4) Total soil carbon
5) Fine Particulate Soil Organic Carbon
6) Fine Particulate Soil Organic Nitrogen
7) Microbial carbon concentration (direct extraction)
8) Potentially mineralizable nitrogen (10 day incubation at field capacity water content at 25° C followed by NO_3 and NH_4 analysis)
9) Potentially respirable carbon (CO_2 analysis during a 10 day incubation at field capacity water content and 25° C)
10) Nitrogen fixation rate (ethylene production)
11) Denitrification rate (nitrous oxide production under 10% acetylene)

All hypotheses tested were related to significant differences between treatment means. The null hypothesis was that the treatment means of the variable in question were equal, and the alternative hypothesis was that at least two of the treatment means were significantly different at the stated alpha level.

SAMPLE DESIGN

Twelve sites from Operable Unit (OU) 11 were sampled: three treatments (Sprayed, Nonsprayed and Reference), four replicate sites within each treatment, and five plots per site. Sprayed plots

were exposed to high levels of nitrate. Non-sprayed plots were not initially thought to have been exposed to nitrates; but were subsequently found to have received some spray. Reference sites were outside the spray area, just north of the McKay ditch, but were in the same soil series and vegetation community (Xeric mixed grassland).

METHODS

Field Methods

A) Field Methods, Soil Physical and Chemical Properties:
Soil samples for invertebrate, ecosystem function, and physical chemical analyses were collocated in space and time for comparability. Five plots (P1-P5), in each of the four sites (MG1-MG4), in each of the three treatments (Sprayed, Nonsprayed, and Reference) were sampled, for a total of 60 sample units. Samples were not composited. Twelve additional quality assurance samples were taken. Soil invertebrate samples were taken from 0-5 and 5-10 cm depths, but physical/chemical and ecosystem function samples were taken from 1 depth, 0-10 cm. Larger rock and cobbles were removed from samples by hand. All samples were taken with hand tools (shovels, trowels, knives) and transferred to pre-labeled ziplock plastic bags, which also had labels inside the bags. Samples were then placed on blue ice in coolers, sealed, and transferred to a locked room in T891 G at the end of the day. Samples were logged onto chain-of custody sheets within 24 hours of collection by M. Bakeman. Samples were delivered to laboratories within 48 hours, because of the relatively short holding time of the soil functional and invertebrate samples. These methods became the basis for the biological portion of the EMAD Operating Procedures, 4-E07-ECOL.12 Soil Sampling. Figure 1 illustrates the field sampling scheme.

B) Field Methods, Vegetation and litter mass:
Vegetation was collected, dried and weighed by species by 0.25 m^2 plot. Litter was dried and weighed by plot. All vegetation rooted within the plot was clipped by species, placed in labeled paper bags, and then transported to T891G. Samples were collected at the rate of 5 samples per site x 4 sites per treatment x 3 treatments = 60 samples total.

C) Plant and litter tissue nutrient analysis:
Subsets of plant tissue were composited after drying (all species within the same quadrat) for nutrient analysis; it was felt that species nutrient data would be less useful information than average above-ground nutrient data on an area basis. Analyses was apportioned as follows: 3 (of 5) plots x 2 (of 4) sites x 3 treatments = 18 sample units. Subsets of litter (corresponding to plant tissue) were analyzed for the same nutrient elements as plant tissue, with the exception that lignin analysis was performed on all litter samples.

D) Field Methods, Soil Invertebrates:
See Field methods, Soil Physical Chemical Properties above. Above-ground vegetation was not removed from soil inveretbrate samples.

E) Field Methods, Ecosystem Functions:
Detailed descriptions of the soil sampling procedures have been provided in "Procedures for Sampling Soil Invertebrates and Ecosystem Function Measurements, Appendix 11 of the Ecological Monitoring Program Management/Technical Performance Report-GHS-462-93 (93-RF-11615)." These procedures are also found in the Ecology Procedures: Volume V of EG&G Rocky Flats EMAD Operating Procedures, 4-E07-ECOL.12 Soil Sampling. Samples were collected by excavating a 10 x 10 x 10 cm cube of soil from the selected location. All samples represented the surface 10 cm. Samples were collected adjacent to each vegetation production plot for ecosystem function measurements. Sample collection was complicated by the presence of cobbles and stones. Large rocks were removed and weighed separately. Samples were immediately

transferred to coolers containing ice (Blue Ice or its equivalent). They were maintained in coolers until they were transported to the laboratory. In the laboratory they were maintained in a 4°C cold room until analysis.

Laboratory Methods

A) Laboratory Methods, Soil Physical and Chemical Properties:
Soil samples were shipped to the University of Idaho Analytical Laboratory in plastic lined sample bags provided by the laboratory. Each sample consisted of approximately 1 kg of soil, fresh weight. Soil samples were passed through a 2 mm sieve and moisture content determined. Microelements, such as Zn, Mn, Cu, Fe, Pb, and Cd were extracted by DTPA at pH 7.3, and then analyzed on an ICP-AES. Exchangeable elements such as Ca, Mg, Na, and K were extracted with 1.0 N ammonium acetate and analyzed on the ICP. Phosphorus was extracted with 0.5 M sodium bicarbonate and then analyzed on a spectrophotometer. Soil sulfate was determined by shaking the sample with deionized water with 1 drop of concentrated HCL, filtered, and $BaCl_2$ was added to form Ba SO_4, which was then measured on a Turbidometer. Cation exchange capacity was determined by extraction with ammonium acetate at pH 7, followed by measurement of extractable cations by ICP. Total carbon and nitrogen concentrations were determined using an automated CHN Analyzer (McGeehan and Naylor, 1988). Quality control was ensured by the use of laboratory blanks, spikes, and certified standard materials. All laboratory procedures are on file with EcMP staff.

B) Laboratory Methods, Vegetation and Litter:
All vegetation samples were dried at 65°C in a forced air drying oven until they had reached constant weight, and then weighed on a top loading balance to the nearest 0.1 g. Samples were then shipped to the University of Idaho Analytical Laboratory in paper bags for elemental analysis. Dried samples were first ground in a Wiley mill, weighed (0.25 - 0.50 g of tissue), and digested in 3.0 ml of reagent grade nitric acid. Samples were centrifuged and the resulting solutions were analyzed on a Perkin Elmer P-40 ICP for cation elements, phosphorus, and sulfur. Total carbon and nitrogen concentrations were determined using an automated CHN Analyzer (McGeehan and Naylor, 1988). Quality control was ensured by the use of laboratory blanks, spikes, and certified standard materials. All laboratory procedures are on file with EcMP staff.

C) Laboratory Methods, Soil Invertebrates:
After soil samples were delivered to the laboratory, they were immediately extracted. Dynamic extraction is used for nematodes and arthropods, where the sample is slowly dried out and the living organisms are forced to migrate either freely or via water films into an extraction vial. Organisms were then viewed under a binocular microscope, where they were counted and identified. Quality assurance was provided by the collection of duplicate samples and the use of a reference collection for the arthropods.

D) Laboratory Methods, Ecosystem Functions:
Detailed procedures for the analyses performed by the Natural Resource Ecology Laboratory are on file with EWM personnel. For initial processing at the laboratory, samples were sorted and laboratory identification numbers assigned. A separate field bag held each sample. The contents of these bags were mixed and coarse mineral and organic matter fragments were removed. These coarse fragments were later weighed. The soil was then sieved through a 2 mm sieve. Water content of the sieved soil at field capacity was measured.

Incubations were then initiated using sieved soil. Field nitrate and ammonium concentrations were measured. Three subsamples were prepared for each sample date. All extractions and incubations were carried out for each soil sample and for selected duplicates and three blanks. Fifty grams of soil was weighed into appropriate containers. Water was added to bring the soil to the water content at field capacity. The cups were placed into respiration chambers with several ml

of water to prevent desiccation of the soil. A vial containing a known volume of 3 M NaOH (usually 1.275 ml) was place in each chamber. The chambers were sealed and incubated at 25°C. On the third, sixth and tenth days, the vials of NaOH were titrated with 1 M HCl in the presence of $BaCl_2$. The vials were replaced on the third and sixth days. On the tenth day, the soil was removed and subsampled for water content, mineralized N, and microbial biomass C and N.

Water content was measured gravimetrically. Mineralized N was measured by analyzing for ammonium and nitrate+nitrite on an auto-analyzer. Microbial biomass C and N were estimated by measuring the differences in soluble C and N between a control and a chloroform fumigated subsample of each sample. In this report, microbial biomass is presented as the difference between these subsamples. No correction was made for the efficiency of extraction. It is more common in scientific reporting to divided the difference in extractable carbon between chloroformed and unchloroformed soil by 0.41 or some other factor. That is to say, exposure to chloroform renders 41% of the microbial carbon extractable. Nitrogen is calculated by various formulae, because the extractability of nitrogen is not straightforward. Details of these corrections are not explored for this report.

Texture and Particulate Organic Carbon and Nitrogen were measured by suspending soil samples in 5% sodium hexametaphosphate. Sand sized particles are collected on a 53 µm sieve. The remaining sample is placed in 1 l sedimentation cylinders and measured by hydrometer. Particulate organic carbon and nitrogen are then measured on the sand fraction collected on the sieve.

Statistical analyses were by nested Analysis of Variance. Three treatments were sampled: Sprayed, Non-sprayed and Reference Areas. Replicates were nested within treatments and plots were nested within replicates within treatments. Treatment mean squares were tested against replicate within treatment mean squares. Replicate mean squares were tested against plot within replicate within treatment, or residual, mean squares. Where the F statistic was significant at the 0.05 level, Honestly Significant Differences (HSDs) were calculated.

RESULTS

A) Statistical Approach

A nested Analysis of Variance (ANOVA) model was used to determine the significance of the treatment and replicate within treatment effects. If a treatment effect was significant, it indicated that at least two of the three treatment means (sprayed, nonsprayed, and reference) were significantly different. If the replicate within treatment effect was significant, it indicated that there was a significant difference in the sites within treatments. This approach tends to be more conservative than a simple one-way analysis of variance (there are fewer significant treatment effects). However, after analyzing data with both models and often finding significant replicate within treatment effects, it was decided that the nested model was the most appropriate for these data. In cases where the replicate within treatment effect was not significant in the nested model, some of the data were reanalyzed with the one-way ANOVA model to test for treatment effects. Variables analyzed in this model included vegetation and litter mass, soil invertebrate functional group and mite taxa counts, soil physical/chemical data, and ecosystem function analyses. Soil invertebrate data were analyzed separately for 0-5 cm and 5-10 cm depths. Vegetation and litter nutrient analyses were analyzed with a simple one-way ANOVA model because the reduced level of replication did not allow for use of the nested design.

The assumptions of an ANOVA model do not always hold for soil invertebrate count data; this is often due to the large variability in these data sets. Variances among group means are often not equal, and this was encountered in some of the data, although this does not in itself disqualify the

robust ANOVA model. Most of the residuals that were examined in the analyses were normally distributed, lending credence to this model. Also, most treatment means had sample sizes of 20 observations, and the model is more robust at moderate (>10 observations) to large sample sizes.

An alpha level of 0.10 was generally used to consider if an effect was statistically significant; this is applicable for such variable data.

B) Soil Physical/Chemical Properties

Soil carbon, nitrogen, potassium, phosphorus, and calcium concentrations, texture, and cation exchange capacity were measured and analyzed for significant treatment effects using the nested ANOVA model. Carbon, nitrogen, texture, and cation exchange capacity results are presented in the next section because of their particular relevance to ecosystem function properties.

Mean soil potassium concentrations were ranked in the order Sprayed > Nonsprayed > Reference (306.15, 298.3, 235.25 mg kg^{-1} respectively, Table I-1). The overall treatment effect was not significant (p=0.1774), but the replicate within treatment effect was highly significant (p=0.0003). This illustrates the considerable variability within the replicate sites used for each treatment.

Phosphorus soil concentration means ranged from 6.935 mg kg^{-1} (Reference) to 9.485 (Nonsprayed). The treatment effect was not statistically significant (p=0.1626), but the replicate within treatment effect was (p=0.0002, Table I-2).

Mean soil calcium concentrations were very similar, and again the treatment effect was not statistically significant (p=0.4684), but the replicate within treatment effect was (p=0.0017, Table I-3).

C) Vegetation and Litter

Results of vegetation biomass were reported previously, but are repeated again for completeness. Total vegetation production was greatest on the Sprayed treatment area (mean 166 g m^{-2}), followed by Nonsprayed (146.8 g m^{-2}), and Reference (142.9 g m^{-2}, Table I-4). None of these differences were significant (p=.2311) at the 0.10 level.

Litter values followed a similar trend , with the exception that the Reference treatment mean was greater than the Nonsprayed mean (Sprayed, 233.3 g m^{-2} > Reference, 205.3 g m^{-2} > Nonsprayed, 195.2 g m^{-2}, Table I-5). Again, these differences were not significant (p=.4265).

All plant and litter nutrient concentrations and contents were corrected for ash content.

Plant carbon concentrations were significantly different (p=0.0375) despite the extremely tight range of values encountered (47.7 to 46.6 %, Table I-6). The reference treatment had significantly lower plant tissue carbon values than the nonsprayed treatment.

Litter carbon concentration could not be analyzed using this model, because of inequality of variances among the treatment means.

Both plant and litter total carbon (g C m^{-2}) were not significant (p-values were 0.1613 and 0.3718 respectively, Tables I-7 and I-8).

Plant and litter nitrogen concentrations and contents also did not show statistically significant differences among treatments (Tables I-9 through I-12). There was also no consistent ranking of the treatment means, with plant nitrogen concentration highest in the nonsprayed treatment, but nitrogen content highest in the sprayed treatment. Litter nitrogen concentrations and contents were

highest in the sprayed treatment, but again, none of the nitrogen differences were statistically significant.

Plant potassium concentrations and contents showed unusual significant effects. Concentrations and contents were ranked Nonsprayed>Reference>Sprayed (P-values = 0.0189 and 0.0551 respectively, Tables I-13 and I-15). Litter potassium concentrations and contents showed no statistically significant differences among treatments (Tables I-14 and I-16).

Plant phosphorus concentration showed a significant treatment effect (p=0.0129, Table I-17), being highest in the Nonsprayed treatment. Litter P concentration was also highest in the Nonsprayed treatment, but was not statistically significant (p=0.2242, Table I-18). Plant and litter P contents also showed higher contents in the Nonsprayed treatment, but neither were statistically significant (Tables I-19 and I-20).

D) Soil Invertebrates

Data are presented on the basis of the two gross taxonomic groups: nematodes, and arthropods. Brief descriptions of each group follow, including comments on life history, classification, units of analysis, and data variables.

Nematodes

Nematodes, also called roundworms, are a group of ubiquitous soil organisms that move throughout the profile via soil water films. Soil moisture is a critical factor affecting their distribution. The taxonomy of free-living nematodes is not well documented (Freckman and Baldwin, 1990), primarily because much of the available work has been targeted at crop pests. Nematodes occupy a great variety of niches in the soil, acting as predators of soil arthropods, bacteria and other nematodes, fungal feeders, plant root feeders, and parasites of invertebrate and vertebrate hosts.

For this study, nematodes were classified into four functional groups:

Bacterial Feeders;
Fungal Feeders;
Ominivore/Predator; and
Plant Feeders.

Functional group determination is based on body morphology and mouth part.

All nematode functional groups were expressed as counts of organisms g^{-1} dry soil.

Nematodes functional groups were dominated by fungal and bacterial feeders (93% of total nematodes in both the 0-5 and 5-10 cm depths), followed by omnivore/predators (4% surface, 3% subsurface) and plant parasites (2% surface, 3% subsurface). Surface soils (0-5 cm depth) had higher functional group counts than subsurface soil (5-10 cm), with the exception of omnivore/predators which showed the opposite relationship. Surface soil had an average of 12,410 nematodes g^{-1} soil (all functional groups, all sites), and subsurface soil had an average of 11,858 nematodes g^{-1} soil (all functional groups, all sites).

In the 0-5 cm depth, most of the functional groups (omnivore/predator, plant feeders, and bacterial feeders) displayed the trend of treatment means being ranked in the order Sprayed>Reference>Nonsprayed Tables I-21 through I-24). In these cases, the Sprayed treatment often had an average number of nematodes that was 1.5 to 2 times greater than the next highest mean. However, the treatment effect was only statistically significant for the omnivore/predator functional group (p=0.0853, Tables I-24). The fungal feeder functional group

had the highest mean number of nematodes in the Nonsprayed treatment, followed by Reference and Sprayed treatments, but none of these differences were significantly different. Only one of the four functional groups had a significant replicate within treatment effect (plant feeders). The two remaining functional groups that did not show a significant treatment effect (fungal and bacterial feeders) were reanalyzed with the one-way ANOVA model; differences were not statistically significant.

In the 5-10 cm depth, functional group treatment means were often ranked in the same order as the surface horizon, with Sprayed means > either Reference or Nonsprayed means (Tables I-25 through I-28). Mean plant feeders nematode counts in the Sprayed treatment were significantly greater than in the Nonsprayed, with Reference treatment intermediate (p=.0753, Table I-27). Again, the fungal feeder functional group had higher mean counts in the Nonsprayed treatment than Sprayed or Reference treatments. None of the functional groups had a significant replicate within treatment effect, so the three groups that had nonsignificant treatment effects were reanalyzed with the with the one-way ANOVA model; none had significant treatment effects.

Soil Arthropods

Soil arthropods are comprised of a vast array of invertebrate groups and species. Some of the representative taxa in this study are insects, crustaceans, arachnids (soil mites and spiders), and myriopods (centipedes, millipedes). Arthropods were analyzed both taxonomically and by functional groups for this study. Taxonomy resolution depended on class of organisms analyzed, from family/genus for most of the collembola and mites, to order for many of the remaining groups.

All organisms were classified into the following functional groups:

Fungivore 1 - this was a count of all the Collembola in the sample - this insect class was determined separately from other fungivores because of their predominance in this functional group;

Fungivore 2 - all other fungivores;

Total Fungivores - Count of fungivore 1 + fungivore 2;

Detritivore 1 - small detritivores;

Detritivore 2 - large detritivores;

Arthropod predators;

General Predators;

Total Predators - Arthropod predators + general predators; and

Herbivores - Root Feeders.

Total counts were also made of the various mite genera because of the finer taxonomic resolution for these groups.

Arthropod counts were expressed as # organisms m^{-2}. However, these counts on an area basis are rough approximations, because defining a sample area in the rocky soils of the Site is extremely difficult.

Soil arthropod functional and mite groups were analyzed in the same manner as nematodes

except that arthropods had more functional groups (10) and 3 to 4 mite taxa groups, all from surface (0-5 cm) and subsurface (5-10 cm) horizons.

For surface functional groups, total fungivores had the highest mean organism count (2102 total fungivores m^{-2}) of all functional groups, all treatments, and arthropod predators the lowest mean count (255 m^{-2}). Mite families were dominated by the Mesostigmata (281 m^{-2}), and the Astigmata were relatively scarce (7 m^{-2}).

Statistical analyses and treatment means for functional group counts and mite taxa counts from the surface horizon are summarized in Tables I-29 through I-42. Two major patterns emerged in ranking functional group treatment means: Sprayed treatments had either the highest of the three treatment means (all 3 predator functional groups, total and detritivore 2 groups), or the lowest mean counts (all 3 fungivore groups, detritivore 1, and herbivores). However, none of the 10 surface horizon functional groups showed a significant treatment effect at an alpha level of 0.10, and most were highly nonsignificant. Seven of the ten functional groups showed significant replicate within treatment effects, indicating a high degree of variability within sites in a treatment. Sites that did not show a significant replicate within treatment effect were reanalyzed with the one-way ANOVA model, and none showed a statistically significant treatment effect.

Mite counts from the four taxa groups in surface horizons showed both increases in the Sprayed treatment (mesostigmata and cryptostgmata) and decreases (prostgmata). Mesostigmatid mite counts from the surface horizon showed a significant treatment effect (p=.0939), with the Sprayed treatment having the highest count (505 mites m^{-2}) and the Nonsprayed treatment the lowest count (150). However, the conservative Tukey means separation procedure did not find the difference in these means statistically significant.

Subsurface arthropod functional groups were once again dominated by the total fungivore group (mean 1211 fungivores m^{-2}, all samples), and the detritivore 1 functional group having the lowest average count (14 m^{-2}). The cryptostigmatid mites dominated the mite taxa (mean 622 mites m^{-2}), and the astigmata were again fewest (2 m^{-2}).

Statistical analyses of functional group data found that 3 of the 10 functional groups showed a significant treatment effect (Tables I-43 through I- 52).This included the functional groups herbivores (p=0.0623), detritivores 2 (p=0.0798), and total detritivores (p=0.082). For these 3 functional groups, the Sprayed treatment had the highest organism counts and was significantly greater than the nonsprayed treatment, but not the reference treatment. As with the surface horizon, a majority of the functional groups (6/10) had significant replicate within treatment effects, indicating considerable variation with sites within a treatment. Six functional groups had highest mean organism counts in the Reference treatment, and the Sprayed treatment was the lowest in those cases, but none of those differences were statistically significant.

Analyses of mite subsurface taxa counts were also conducted (Tables I-53 through I-55), except for astigmatid mites because of failures in the assumptions of the model. Cryptostigmatid mites showed the only statistically significant treatment effect, with the Sprayed treatment having a significantly greater mean count (906 mites m^{-2}) than the Nonsprayed treatment (mean = 257 mites m^{-2}).

E) Ecosystem Functions

The particle size distributions of particles that passed through a two-mm sieve from the surface 10 cm in all treatments were identical: 61.6% sand (standard deviation = 3.4), 14.5% silt (standard deviation = 4.3) and 23.9% clay (standard deviation = 4.0). The soil texture is sandy clay loam. This soil has been classified as very cobbly or very stony sandy loams. Surface horizons are 20% cobbles, 40% gravel. The large fraction of coarse fragments precluded reliable estimates of bulk

density.

Mean soil cation exchange capacity varied little among the treatments, from 18.09 cmol kg^{-1} in the Nonsprayed treatment, to 20.49 in the Sprayed treatment. These differences were not statistically significant (p=0.1694).

Total soil organic C concentrations were highest in the Sprayed plots; differences were statistically significant at 0.072 (F=3.57). Sprayed plots averaged 39 g/kg, reference plots averaged 32 and non-sprayed plots averaged 33 g/kg (Fig. 2). If a significance level of 0.072 is accepted, apparently the difference between sprayed and the other two treatments is the only difference.

Soil Organic N concentrations were also greatest in sprayed plots. Differences were statistically significant at the 0.039 confidence level (F=4.75). Sprayed plots averaged 3.08 g/kg (Fig. 3). Non-sprayed plots averaged 2.67 g/kg. Reference plots averaged 2.60 g/kg. Means can be separated by an HSD of 0.47. Thus the sprayed treatment had significantly more total N than non-sprayed or reference areas.

Field nitrate concentrations were significantly higher in sprayed than in reference or non-sprayed plots (F=9.21; Significance of F=0.007). Figure 4 shows this relationship. Nitrate concentrations, expressed as N, were more than twice as high in the sprayed plots.

Field ammonium concentrations were less than 5 mg/kg ammonium-N. A treatment effect significant at 0.076 (F=3.48) existed. Ammonium-N concentrations were 1.7 mg/kg in sprayed plots, 4.7 in reference plots and 4.9 in non-sprayed plot.

Potentially respirable C and mineralizable N concentrations exhibited no statistically significant differences.

Microbial biomass C concentrations were not statistically significantly different between treatments, but Microbial biomass N revealed a treatment effect significant at 0.014 (F=7.21). Mean concentrations of biomass N were 68 mg/kg in sprayed plots, 45 mg/kg in reference plots and 53 mg/kg in non-sprayed plots. Honestly Significant Differences were at least 15 mg/kg. Therefore, Sprayed plots had significantly higher concentrations of microbial biomass N than reference, but not than non-sprayed plots.

Fine particulate organic C and N concentrations were higher in sprayed than in reference or non-sprayed plots. Sprayed plots averaged 12 g/kg of fine particulate organic C compared to 9.4 g/kg in reference and 9.5 g/kg in non-sprayed plots. Sprayed plots averaged 0.752 g/kg of fine particulate organic N compared to 0.567 g/kg in reference and 0.576 g/kg in non-sprayed plots. However, the significance level for fine particulate organic C was 0.080 (F=3.38) and for fine particulate organic N was 0.054 (F=4.10).

The fraction of total organic C that was microbial biomass C had no significant treatment effects (F=0.29). Similarly, the fraction of total soil N that was microbial biomass N had not significant treatment effects (F=1.99). On average, 1.13 percent of the C and 1.95 percent of the N occurs in the fraction made soluble by chloroform fumigation. This fraction is called microbial biomass in this report. The trends of the means in these two variables, however, suggest that sprayed plots have a higher average fraction of their organic C and N in microbial biomass.

The fraction of the soil organic C that was respirable in 10 days did not show any statistically significant treatment effects (F=2.58). The fraction of the total soil N that was mineralizable was, however, significant (F=6.01; significance of F=0.022). The HSD for separating treatments is 0.177 percent. Figure 5 indicates that the sprayed treatment has the lowest fraction of N in mineralizable forms. Reference and Non-sprayed treatments were not different from each other.

The fractions of organic C and N in fine particulate organic matter had no significant treatment effects. For C, the treatment was 0.24 and for N, the treatment F was 1.38.

DISCUSSION

A) Soil Physical Chemical Properties

Some of the physico-chemical soil variables measured, such as texture, and to a lesser extent soil cation exchange capacity, are basic ecosystem properties that affect many of the subsequent measurements. They are also much less sensitive to changes induced by the spray treatment than are many of the subsequent variables, and significant changes due to the treatment would not be expected. If significant differences are found, this could indicate that there were inherent, measurable differences in the three treatment sites before the application of the spray.

Soil sand, silt and clay mean contents were remarkably similar among the three treatments, as were mean cation exchange capacity values. Thus, it appears that there are not inherent treatment site differences as measured by these variables.

Soil chemical properties were considerably more variable, and most had a statistically significant replicate within treatment effect. Soil carbon and nitrogen concentrations at 0-10 cm were the only elements that showed a significant elevated response to the Spray treatment. The implications of these increases are further discussed below under ecosystem functions. All other soil element concentrations measured did not show a significant treatment effect. This is not unusual, given that the physical soil properties of this area are similar among treatments, and that the vegetation community type is the same for all treatments (xeric mixed grassland).

B) Vegetation and Litter Biomass and Nutrient Concentrations and Contents

These results include information on biomass (g dry tissue m^{-2}), nutrient concentrations (g element g^{-1} biomass), and nutrient contents (g element m^{-2}). Biomass production is a fundamental property of all ecosystems, and if differences were found among the treatments, several other effects might be expected. Plant and litter nutrient concentration and content data are related to soil available nutrient pools, vegetation production, species composition, and decomposition rate, to name a few.

If a nutrient is added to a site and a growth effect is anticipated, then the effect can often be measured in both increased biomass production, and increased tissue concentration and content of the added element. Tissue concentration, content, and biomass data are often all related to one another, because of potential element dilution effects as biomass increases. A real biological effect often finds increases in all three of these variables.

For vegetation carbon, the Spray treatment had greater biomass, intermediate carbon concentration, and a moderate increase in total vegetation C over the Reference treatment (but not the Nonsprayed). Only the increase in carbon concentration was statistically significant. It is clear that although there was a slight (statistically nonsignificant) increase in vegetation biomass production, carbon concentrations and contents were unaffected.

Sprayed mean litter mass also was higher than the other 2 treatments, but litter C concentration was lower (a possible dilution effect), and litter C content was higher. None of these differences were statistically significant (concentration was not analyzed), and there is no clear effect of the Spray treatment on litter carbon pools.

Vegetation and litter nitrogen data showed varied effects. Vegetation N concentration was lowest in the Sprayed treatment (again, a possible dilution effect since biomass was greater), but N content was highest; these differences were not statistically significant. Litter biomass, N concentration and

was highest; these differences were not statistically significant. Litter biomass, N concentration and content means were all highest in the Sprayed treatment, although none were statistically significant. However, the trend of all 3 variables greater than the other 2 treatment means may indicate that a real biological effect occurred, and that the sampling intensity (6 observations/treatment for element data) was not adequate to detect statistical significance.

Both plant potassium concentration and content analyses showed a statistically significant treatment effect, although differences among treatments are not consistent. Nonsprayed treatment mean K concentrations were significantly greater than Sprayed, and Nonsprayed K contents were significantly greater than the Reference treatment. Mean Nonsprayed and Sprayed soil K concentrations were not different (298.3 and 306.15 mg kg^{-1} respectively). Litter potassium concentrations and contents showed this same trend (although statistically insignificant); it is not known why Nonsprayed treatments were higher than other treatments for this element. Plant and litter phosphorus concentrations and contents also displayed the trend of being highest in the Nonsprayed treatment.

Nutrient and biomass data show two general trends: 1) Sprayed plots increased in litter mass, nitrogen concentration, and nitrogen content, and 2) Nonsprayed plots had greater plant and litter K and P concentrations and contents. It appears that litter nitrogen may be the most biologically sensitive receptor (of those evaluated for biomass and nutrients) to the N-spray treatment, although effects were not statistically significant. The elevated levels of K and P in plant tissue in the Nonsprayed treatment are not easily explained. This trend was also observed in the analysis of other receptors and will be further discussed.

C) Soil Invertebrates

Nematodes

Nematode functional group mean counts were greatest in the Sprayed treatment for omnivore/predator, plant feeders, and bacterial feeder functional groups at both depths. Mean counts were often at least 1.5 to two times greater than the next highest treatment mean. However, the effect was only statistically significant for two functional groups at an alpha of 0.10: omnivore/predators increased at 0-5 cm, and plant feeders increased at 5-10 cm. It does appear that Sprayed plots have more total nematodes (Sprayed mean all functional groups 13,822 ; Nonsprayed 11,417, and Reference 11,087), but again, these differences are not statistically significant. This may be a response to increased total substrates or increase in available substrates. The Sprayed treatment was also higher in litter mass and litter nitrogen concentrations and content than the other treatments, although many of these comparisons were not statistically significant. There were also substantial differences in ratios of functional groups: mean (fungal feeders+1)/(bacterial feeders+1) was substantially lower in the Sprayed treatment than the two other treatments, (Sprayed = 1.10, Nonsprayed = 1.73, Reference = 4.59), and the mean ratios of (omnivore-predator+1/plant feeders +1) were: Sprayed, 24.61, Reference, 69.32, and Nonsprayed, 104.60) {When ratios were determined, the value 1 was added to all functional group counts to eliminate all count values of 0}. However, none of these differences were statistically significant.

It appears that total numbers of nematodes in three functional groups increased in the spray plots, and the selected ratios of functional groups also changed in the Sprayed treatment. A few of these changes were statistically significant, but most were not. When OU 11 nematode means were compared to nematode Xeric mixed grassland community means from non-impacted (reference) sites at RFETS, counts in OU 11 usually exceeded reference sites, especially Sprayed treatment means (see Appendix E. Soil Invertebrates). It is possible that differences in Sprayed treatment areas are biologically relevant to changes in invertebrate biomass distribution and nutrient cycling pathways; the bacterial feeder functional group has increased at the expense of fungal feeders and omnivore/predators have decreased relative to plant feeders. The consequences of such changes

statistically significant or perhaps biologically relevant, most soil nematode functional group populations (and total numbers) increased on Sprayed areas (with the exception of fungal feeders), and it is highly unlikely that this would have a deleterious effect on this ecosystem.

Arthropods

As with the nematode data, arthropod data were statistically analyzed for a significant treatment effect, but data were also scrutinized for trends that might emerge from ranking of treatment means. None of the organism counts in surface functional groups showed a statistically significant treatment effect, and only 3 of 10 subsurface functional groups were significant (herbivores, detritivores 2, and total detritivores). In the cases of the significant functional groups, Sprayed treatment means were higher than Nonsprayed means, but not Reference means. Analysis of mite taxa found that one surface mite taxum (Mesostigmata) and one subsurface taxum (Cryptosigmata) were also significantly greater in the Sprayed treatment. Thus, the only statistically significant effects were an increase in a few functional group or mite taxa counts due to the Spray treatment.

The reverse trend, where Sprayed treatment means were lower than the other two treatments, was also evident, but none of the differences were significantly different. Ratios of predators to herbivores were also not significantly different by treatment at either depth.

It appears that although the Spray treatment may have caused both increases and decreases in soil arthropod functional group and mite taxa counts, most of the changes were not statistically significant, and significant effects were ususually found where there were organism increases on Sprayed treatment areas. The effect of these increases on other ecosystem properties is unknown, but the influence of the Spray treatment on most soil arthropods has been to increase their numbers.

General soil invertebrate discussion

Changes in both arthropod and nematode functional groups were generally not evident as a result of the Sprayed treatment. Detectable changes were only found where organisms in the Sprayed treatment were significantly greater than either Nonsprayed or Reference treatments. It was stated earlier that Nonsprayed treatment areas were found to have received treatment spray, although it was believed to have been at a lesser rate than the Sprayed treatment. However, there was not a consistent ranking of treatment means in the expected order (Sprayed > Nonsprayed > Reference, or the reverse). Many of the analyses showed a significant replicate within treatment effect in the nested ANOVA model used, indicating considerable variation within treatment areas, which made it difficult to detect treatment differences. This variation could be due to inconsistent spray application to different areas, or the inability to designate accurate treatment boundaries on the ground ten years later. Many additional analyses can be conducted on these data, including analyses of transformed data and multivariate classification and ordination techniques. The latter analyses may show better groupings of sample units than the current scheme, and data can be reanalyzed using new treatment designations. However, it can be stated that preliminary analyses have not shown any statistically significant or dramatic (more than 10x) nematode or arthropod functional group declines in areas where the Spray treatment was though to be heaviest.

D) Ecosystem Functions

Eight years after spraying ceased, soil C and N concentrations are greater in Sprayed than in unsprayed treatments (Figures. 2 and 3). Assuming that an acre of soil six inches deep has a mass of two million pounds, and that 0-10 cm has two-thirds of the mass found from 0-15 cm (0-6 in), we can calculate, even if crudely, that sprayed soil contains 650 pounds more N per acre than unsprayed soil in the top ten cm (four in). This amount is 13% of the total N applied, as estimated by Setlock (1985, unpublished internal letter, Rockwell International). Because assumptions and

estimates are so crude, we do not emphasize specific values here. The salient point is that a substantial amount of applied N remains in the soil organic matter. Soil organic C concentrations probably increased because increased N caused greater plant growth, litter production, and greater microbial biomass and microbial metabolic products.

Nitrate-N concentrations were also greater eight years after spraying (14.0 µg/g) than in reference soil (6.4 µg/g). Concentrations of nitrate-N greater than ten µg/g are unusually high for grassland soils, although they are common in agricultural soils.

Although potentially mineralizable N concentrations were not different at p=0.05, they were significantly different at p=0.10. Sprayed soils mineralized the least N (8.9 µg/g) and reference soils the most N (13.7 ug/g). There are 7.6 ug/g more nitrate and 4.8 ug/g less mineralizable N. Possibly N that was mineralizable N in reference soil was already mineralized in sprayed soil. The sum of mineral and mineralizable N is 23 ug/g for sprayed and 17 ug/g for reference soil. Together these fractions represent the most active part of the soil organic N. The rapidity of nitrogen transformations suggests that the combination of mineral and mineralizable N can be conceived as a unique part of the soil organic N. The concentration of this pool does not reflect the spraying treatment (p=0.40). The fraction of the total N represented by this active part, 0.9% on average, also does not reflect the spraying treatment (p=0.28).

Microbial biomass C and N concentrations presented in this paper are simply the additional C and N made soluble by chloroform vapors. More commonly in the scientific literature, these values will be corrected for the extractability of the C and N. Typically, microbial C is assumed to be between 41% and 45% extractable. Microbial N is corrected by various factors. It is beyond our scope to evaluate the differences in this manuscript. Comparisons should not be made to corrected microbial biomass from other sources. Essentially, the true microbial biomass concentration is a little more than double the values presented here. Comparisons between treatments in this report are not affected, however.

Microbial biomass C was not significantly different in sprayed soils, but microbial biomass N was significantly greater. At first, this suggested that microbial populations changed, changing the microbial C:N ratio. For example, fungi have wider C:N ratios than bacteria and as fungi become relatively more abundant, microbial C:N ratios increase. There were, however, no statistical differences between treatments in microbial C:N ratio.

Another part of the total soil organic matter that might be expected to change with large additions of N is fine particulate soil organic matter. This is the organic matter retained on a 54-µm sieve after dispersion in sodium hexametaphosphate (as standard soil particle size measurement method). This fraction is thought to be a very active part of the soil organic matter. Because soil organic matter is the largest reservoir of organic matter in any ecosystem and because the main function of ecosystem functions is to move organic matter into and out of this reservoir, the active portion should be the first to reflect changes brought on by large additions of N. Concentrations of fine particulate organic C and N were greater in Sprayed than in Reference treatment soils.

In contrast to the concentrations, the fractions of the total soil organic C and N represented by fine particulate organic matter had no significant treatment effects. It is possible that changes were so small that they were lost in measurement error. It is also possible that the eight years between the application of N and the sample collection were long enough to convert the active to inactive organic matter and to reestablish the original ratio. It is also possible that this fraction of the soil organic matter was not changed by the spraying. In any case, fine particulate soil organic matter was not affected differently than total soil organic matter.

The only fraction of soil organic matter that showed a significant treatment effect was the fraction of the total N mineralized. Surprisingly, sprayed soil had less of its organic matter in mineralizable

forms than the unsprayed soil. The meaning of this difference is not clear.

What is clear is that total organic C and N can be increased by a heavy addition of water and N. Furthermore, it appears that a substantial fraction of the added N can be retained as soil organic matter. None of the measurements reported here show significant risks to the ecosystem from spraying, although some responses are measurable. It is not surprising that concentrations of substances (nitrate-N) did not "impede soil microbial respiration to an extent that plant and microbial growth have been inhibited, or inhibit carbon mineralization resulting from a reduction in soil microbial populations," as stated in the Natural Resource Damage Assessments - Final Rule (43 CFR Part 11). Nitrogen additions normally increase microbial activity. Other contaminants can either increase or decrease respiration, N mineralization or other microbial activity.

CONCLUSIONS

The effects of a nitrogen spray treatment on a xeric mixed grassland community were evaluated on several potential ecological receptors. Receptors measured included several soil physical and chemical variables, plant and litter biomass and nutrient analysis, soil invertebrate functional groups, and ecosystem functions. These measurements represent a variety of ecological variables at population, community, and ecosystem level s of organization,with varying levels of sensativity. Sprayed, Nonsprayed, and Reference treatment levels were evaluated for effects; Nonsprayed treatments were found to have received some spray, and treatment means were not always ranked in the expected order of Spray > Nonspray > Reference (or the reverse). A total of 74 variables were analyzed (Table I-56), and 18 variables showed statistically significant differences at the $\alpha = 0.10$ level of significance. The most biologically significant effects were the increase in soil C and N in the Sprayed treatment. This effect was also seen in elevated amounts of nitrate in the Sprayed treatment. Of seven soil invertebrate variables that were found to have a significant treatment effect, six functional or taxa groups showed increases in the Sprayed treatment areas. Variables that showed statistically significant decreases in the Sprayed treatment were not thought to have deleterious ecological effects. Although the spray treatment has altered some of the nutrient pools and cycling processes, the result has not caused any ecosystem damage.

FUTURE ANALYSES

The number of data variables analyzed for this report were considerable, and many other analyses are possible. Analysis of transformed invertebrate and gaseous functional data are not complete, as previously mentioned. Consideration will also be given to ordinating and classifying the sample units by several variables to see if patterns emerge among groups of sample units. Reclassifying the sample units may reduce some of the considerable variation that was often encountered when the replicate within treatment effect was evaluated, and make it easier to detect treatment effects.

REFERENCES

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Figure I-1.

Soil Sampling Scheme, OU 11

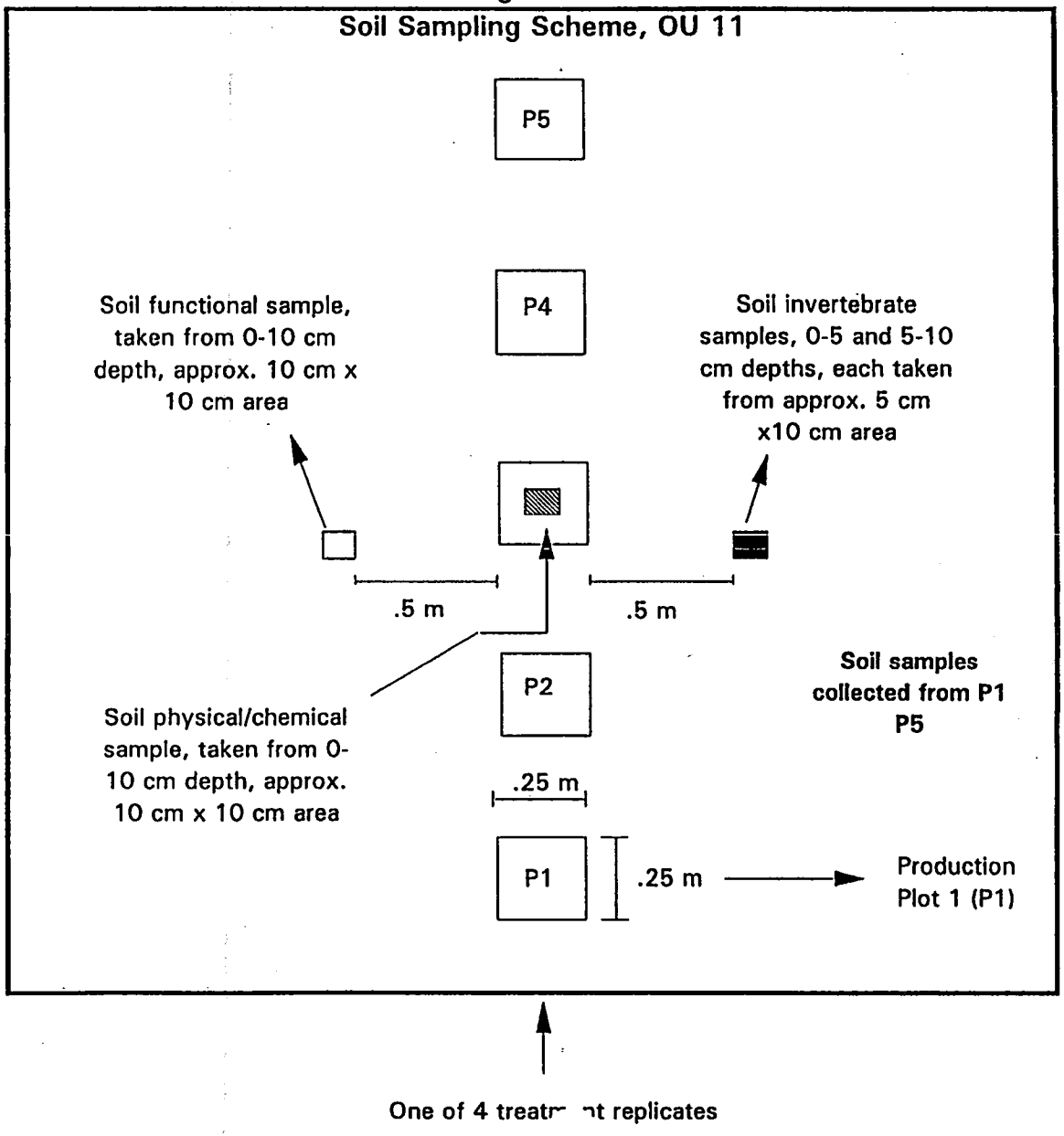
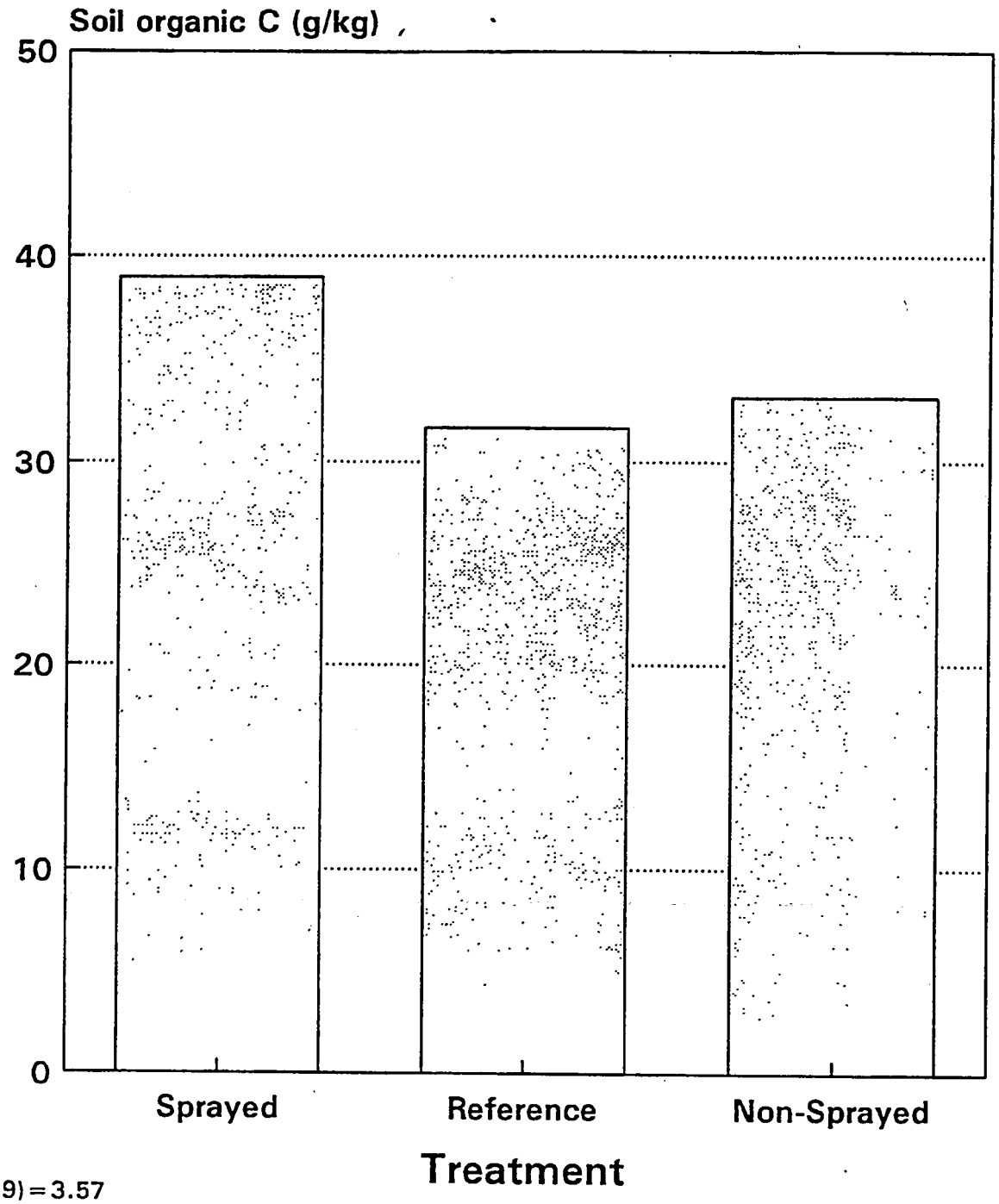
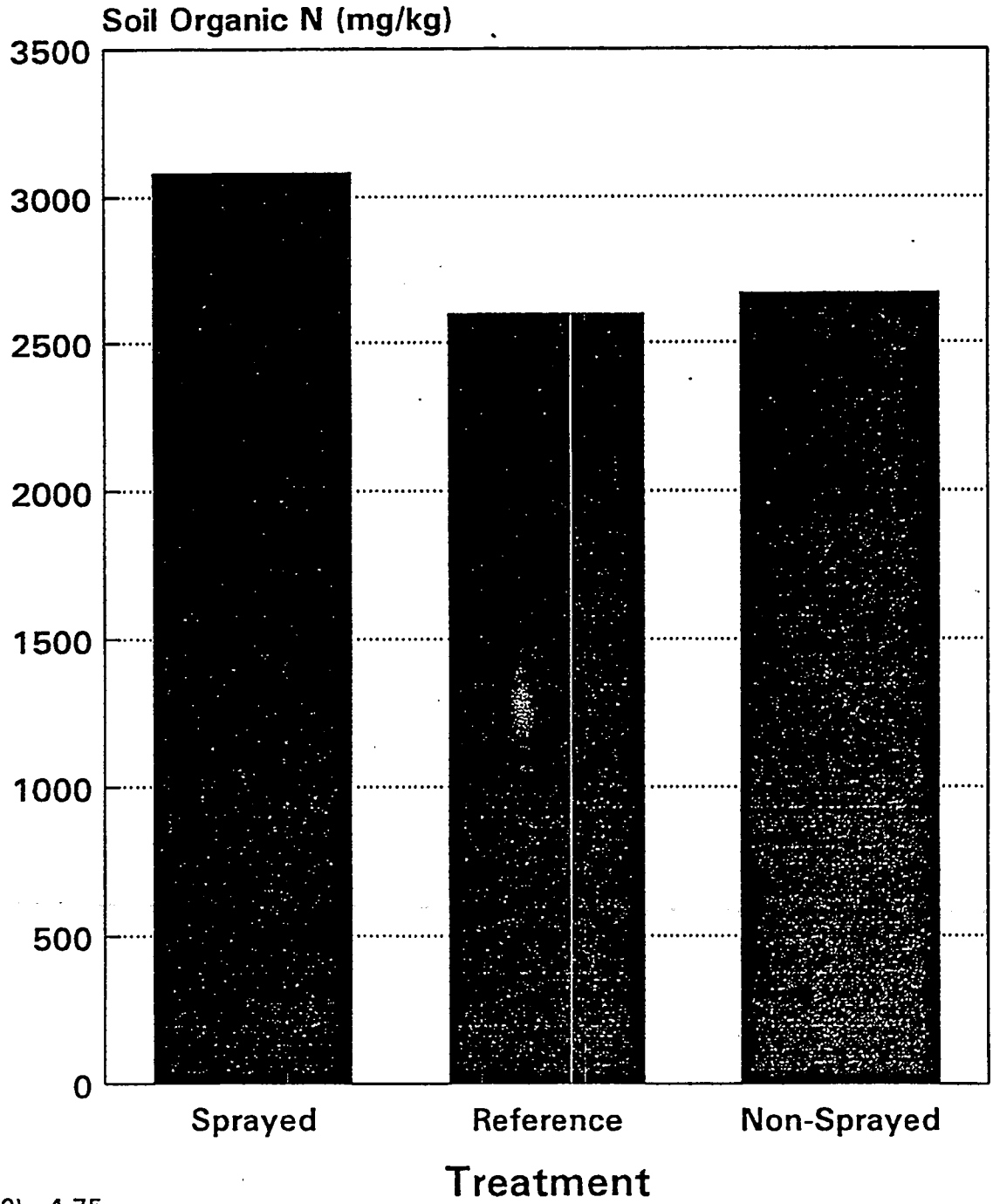


Figure I-2. Soil organic C.



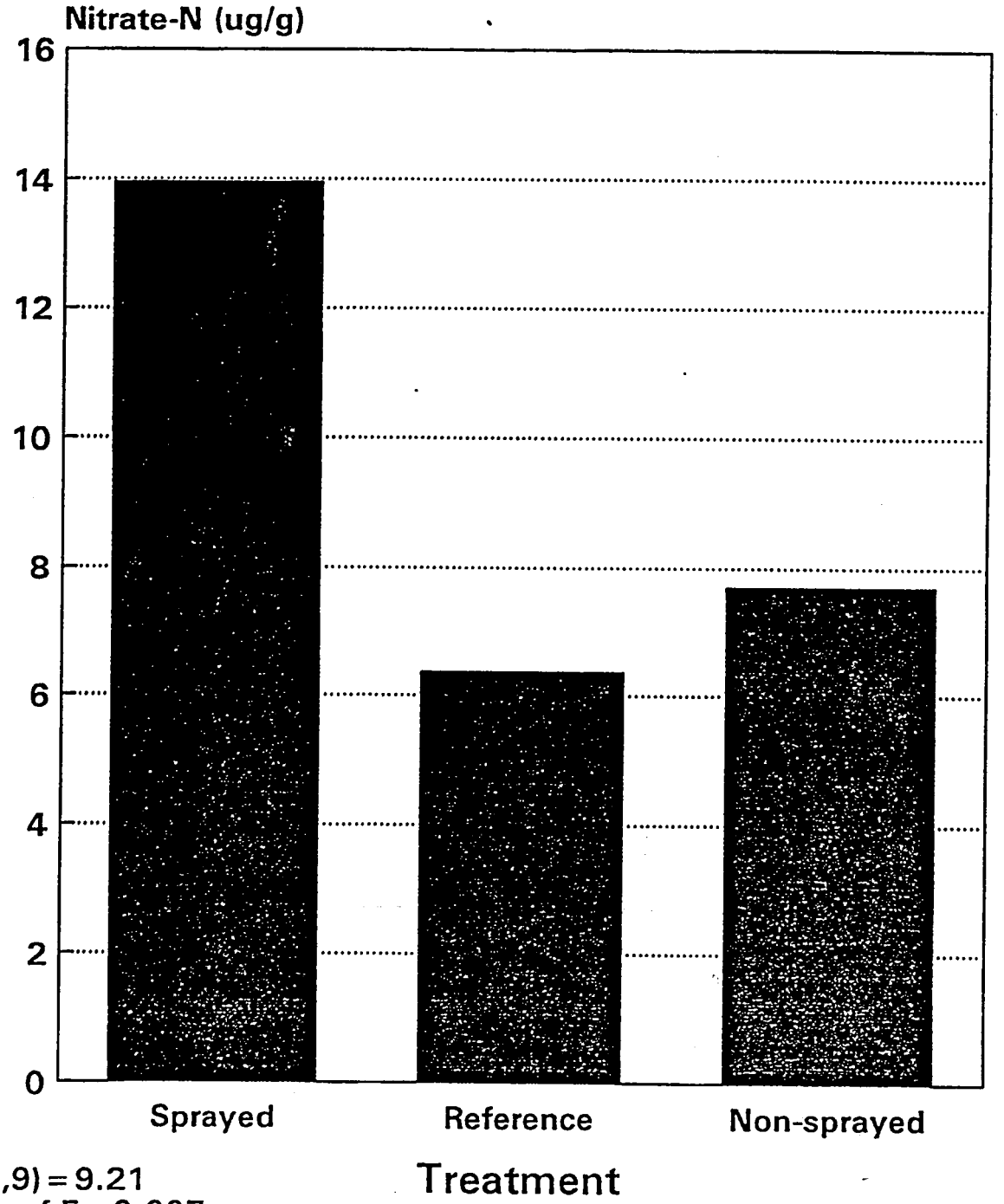
F(2,9) = 3.57
Sig. of F = 0.07

Figure I-3. Soil Organic N



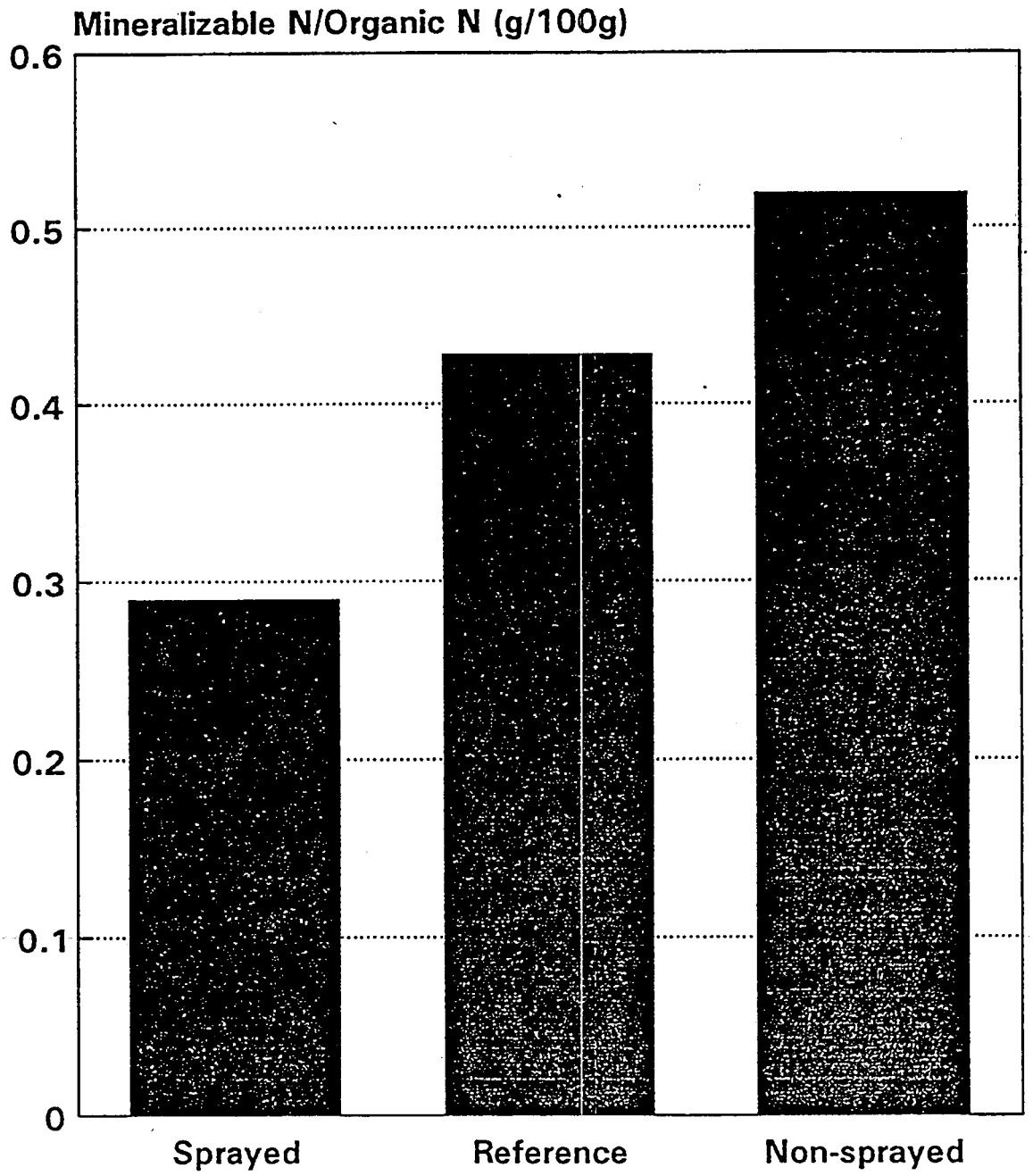
F(2,9) = 4.75
Sig. of F = 0.04
HSD(3,9) = 473

Figure I-4. Nitrate-N concentrations



F(2,9) = 9.21
Sig. of F = 0.007
HSD(3,9) = 5.3

Figure I-5. Percent Mineralizable N



F(2,9) = 6.01
Sig. of F = 0.022
HSD(3,9) = 0.177

Table I-1. Summary Statistics and ANOVA, Soil Potassium Concentrations, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	20	298.3	12358.0	37.2667	0.0	483.0	483.0
Reference	20	235.25	2722.93	22.1814	162.0	385.0	223.0
Sprayed	20	306.15	3945.29	20.5166	194.0	466.0	272.0

Analysis of Variance

	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment		2			
Replicates within Treatments		9			
Residual		48			
Total		59			

Table I-2. Summary Statistics and ANOVA, Soil Phosphorus Concentrations, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	20	9.485	10.8624	34.7477	6.7	21.3	14.6
Reference	20	6.935	1.05818	14.8332	5.5	8.8	3.3
Sprayed	20	8.34	2.93305	20.535	6.6	12.2	5.6

Analysis of Variance

	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment		2			
Replicates within Treatments		9			
Residual		48			
Total		59			

Mean Concentrations are expressed as mg element/ kg soil, 0-10 cm

Table I-3. Summary Statistics and ANOVA, Soil Calcium Concentrations, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	20	7.737	0.556369	9.64071	6.31	8.84	2.53
Reference	20	7.7695	0.853973	11.894	5.16	8.95	3.79
Sprayed	20	8.1955	0.446879	8.15679	7.13	9.88	2.75

Analysis of Variance

	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment		2			
Replicates within Treatments		9			
Residual		48			
Total		59			

Mean Concentrations are expressed as mg Ca/ kg soil, 0-10 cm

Table I-4. Analysis of Variance, OU 11 Total Vegetation Production

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	6106.117	2	3053.0587	1.73	0.2311
Replicates within Treatments	15867.352	9	1763.0391	1.41	0.2084
Residual	59811.84	48	1246.08		
Total	81785.309	59			

Treatment Means	g/m^2	n
Nonsprayed	146.8	20
Reference	142.9	20
Sprayed	166	20

Table I-5. Analysis of Variance, OU 11 Total Litter Mass

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	15513.712	2	7756.856	0.93	0.4265
Replicates within Treatments	74406.032	9	8267.3369	1.43	0.2009
Residual	276905.15	48	5768.8573		
Total	366824.9	59			

Treatment Means	g/m^2	n
Nonsprayed	195.2	20
Reference	205.3	20
Sprayed	233.3	20

Table I-6. Summary Statistics and ANOVA, Plant Carbon Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	47.7002	0.794278	1.86839	45.938	48.405	2.467
Reference	6	46.561	0.184264	0.921929	45.968	47.216	1.248
Sprayed	6	47.1548	0.440374	1.40729	46.453	48.152	1.699

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	3.89545	2	1.94773	4.12	0.0375
Within Groups	7.09458	15	.472972		
Total (corr.)	10.99	17			

Mean Concentrations are expressed as g C / 100 g plant tissue

Table I-7. Summary Statistics and ANOVA, Plant Total Carbon, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	71.4783	373.931	27.0534	50.89	108.55	57.66
Reference	6	58.65	136.994	19.9564	41.21	73.97	32.76
Sprayed	6	77.1883	274.585	21.4677	57.04	103.17	46.13

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	1081.68	2	540.84	2.07	0.1613
Within Groups	3927.55	15	261.837		
Total (corr.)	5009.23	17			

Table I-8. Summary Statistics and ANOVA, Total Litter Carbon, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	91.3917	273.035	18.0802	65.88	113.68	47.8
Reference	6	73.41	1851.77	58.619	23.46	141.25	117.79
Sprayed	6	103.227	1711.41	40.0761	56.7	154.05	97.35

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	2704.88	2	1352.44	1.06	0.3718
Within Groups	19181.1	15	1278.74		
Total (corr.)	21886.0	17			

Means are expressed as g carbon/m^2

Table I-9. Summary Statistics and ANOVA, Plant Nitrogen Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	0.9673	0.0256142	16.5455	0.8085	1.239	0.4305
Reference	6	0.901717	0.0330658	20.166	0.624	1.1025	0.4785
Sprayed	6	0.89735	0.0270516	18.3288	0.6695	1.1124	0.4429

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	0.0184265	2	0.00921324	0.32	0.7293
Within Groups	0.428658	15	0.0285772		
Total (corr.)	0.447084	17			

Table I-10. Summary Statistics and ANOVA, Litter Nitrogen Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	0.87185	0.0139176	13.5313	0.7208	1.012	0.2912
Reference	6	0.7938	0.0201475	17.8813	0.6825	1.0509	0.3684
Sprayed	6	0.9098	0.0462542	23.639	0.6848	1.1978	0.513

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	0.041976	2	0.020988	0.78	0.4744
Within Groups	0.401596	15	0.0267731		
Total (corr.)	0.443572	17			

Means are expressed as g nitrogen / 100 g plant tissue

Table I-11. Summary Statistics and ANOVA, Plant Nitrogen Content, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	1.435	0.15439	27.3815	1.12	2.1	0.98
Reference	6	1.105	0.02243	13.5535	0.9	1.26	0.36
Sprayed	6	1.49167	0.232377	32.3165	0.82	1.99	1.17

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	0.523244	2	0.261622	1.92	0.1812
Within Groups	2.04598	15	0.136399		
Total (corr.)	2.56923	17			

Table I-12. Summary Statistics and ANOVA, Litter Nitrogen Content, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	1.66667	0.177467	25.2761	1.23	2.32	1.09
Reference	6	1.25	0.62056	63.0205	0.41	2.33	1.92
Sprayed	6	2.00333	0.316387	28.0773	1.35	2.86	1.51

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	1.70893	2	0.854467	2.3	0.1345
Within Groups	5.57207	15	0.371471		
Total (corr.)	7.281	17			

Means are expressed as g nitrogen / m^2

Table I-13 . Summary Statistics and ANOVA, Plant Potassium Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	6596.67	1329350	17.4781	4532	8085	3553
Reference	6	5362.17	894979	17.6427	4200	6552	2352
Sprayed	6	4635.33	1160240	23.2377	2987	5562	2575

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	11798200	2	5899110	5.23	0.0189
Within Groups	16922900	15	1128190		
Total (corr.)	28721100	17			

Table I-14. Summary Statistics and ANOVA, Litter Potassium Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	1582.83	112159	21.1584	1166	2091	925
Reference	6	1366.5	75149.5	20.061	1050	1695	645
Sprayed	6	1316.6	147553	29.1756	939.6	1808	868.4

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	240341	2	120170	1.08	0.3657
Within Groups	1674310	15	111620		
Total (corr.)	1914650	17			

Means are expressed as mg potassium/ kg plant or litter ti

Table I-15. Summary Statistics and ANOVA, Plant Potassium Content, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	983.847	87816.9	30.1205	659.86	1483.37	823.51
Reference	6	681.897	39727.8	29.23	369.6	969.89	600.29
Sprayed	6	729.32	6551.45	11.0982	647.58	850.14	202.56

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	316413	2	158207	3.54	0.0551
Within Groups	670481	15	44698.7		
Total (corr.)	986894	17			

Table I-16. Summary Statistics and ANOVA, Litter Potassium Content, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	298.248	5072.81	23.8807	215.48	425.96	210.48
Reference	6	210.19	15321.9	58.8904	72.38	377.5	305.12
Sprayed	6	281.333	2727.85	18.5648	209.57	352.51	142.94

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	26203.5	2	13101.8	1.70	0.2161
Within Groups	115613.0	15	7707.53		
Total (corr.)	141816.0	17			

Means are expressed as mg potassium/ m^2

Table I- 17. Summary Statistics and ANOVA, Plant Phosphorus Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	728.983	16620.3	17.6848	613.6	976.5	362.9
Reference	6	668.65	7732.27	13.1509	509.6	745.5	235.9
Sprayed	6	537.483	4928.62	17.6848	453.2	618	164.8

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	115034	2	57517.1	5.89	0.0129
Within Groups	146406	15	9760.38		
Total (corr.)	261440	17			

Table I-18. Summary Statistics and ANOVA, Litter Phosphorus Concentration, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	596.583	7195.18	14.2184	449.4	676.5	227.1
Reference	6	519.417	13128.5	22.0593	357	700.6	343.6
Sprayed	6	481	17364	27.3955	378	700.6	322.6

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	41580.1	2	20790	1.65	0.2242
Within Groups	188438	15	12562.6		
Total (corr.)	230018	17			

Means are expressed as mg potassium/ kg plant or litter

Table I-19. Summary Statistics and ANOVA, Plant Phosphorus Content, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	107.942	765.68	25.6351	78.72	148.34	69.62
Reference	6	83.005	175.292	15.9506	63.76	100.28	36.52
Sprayed	6	87.5333	346.668	21.2708	56.92	110.74	53.82

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	2117.69	2	1058.84	2.47	0.1185
Within Groups	6438.2	15	429.213		
Total (corr.)	8555.88	17			

Table I-20. Summary Statistics and ANOVA, Litter Phosphorus Content, OU 11

Summary Statistics

Treatment	Count	Average	Variance	Coefficient of Variation	Minimum	Maximum	Range
Nonsprayed	6	113.155	597.793	21.6074	82.33	151.75	69.42
Reference	6	81.9033	3034.53	67.2581	26.84	163.58	136.74
Sprayed	6	103.618	444.318	20.3428	78.14	125.55	47.41

Analysis of Variance

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Between Groups	3078.31	2	1539.16	1.13	0.3482
Within Groups	20383.2	15	1358.88		
Total (corr.)	23461.5	17			

Means are expressed as mg phosphorus / m^2

Table I-21. Analysis of Variance, OU 11 Soil Nematode Fungal Feeders, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	26451000	2	13225353	0.5	0.6173
Replicates within Treatments	233750000	9	26368311	0.47	0.884
Residual	2516200000	46	52537590		
Total	2777600000	57			

Treatment Means	#/g soil	n
Sprayed	5280.33	20
Reference	6293.64	18
Nonsprayed	6890.63	20

Table I-22. Analysis of Variance, OU 11 Soil Nematode Bacterial Feeders, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	163920000	2	81960732	2.06	0.1832
Replicates within Treatments	357760000	9	39751054	1.01	0.443
Residual	1763000000	45	39177211		
Total	2285000000	56			

Treatment Means	#/g soil	n
Sprayed	7502.88	20
Reference	4400.13	18
Nonsprayed	3658.37	20

Table I-23. Analysis of Variance, OU 11 Soil Nematode Plant Feeders, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	2232200.2	2	1116100.1	2.55	0.132
Replicates within Treatments	3927985.8	9	436442.9	2.26	0.034
Residual	8858920	46	192585.22		
Total	14972218	57			

Treatment Means	#/g soil	n
Sprayed	494.39	20
Reference	324.83	18
Nonsprayed	27.16	20

Table I-24. Analysis of Variance, OU 11 Soil Nematode Omnivore/Predators, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	3419043.8	2	1709521.9	3.27	0.0853
Replicates within Treatments	4695908.8	9	521767.6	1.09	0.3827
Residual	21848714	46	474972.04		
Total	29902271	57			

Treatment Means	#/g soil	n
Sprayed	874.78	20
Reference	465.11	18
Nonsprayed	306.44	20

Table I-25. Analysis of Variance, OU 11 Soil Nematode Fungal Feeders, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	44125000	2	22062495	0.34	0.7166
Replicates within Treatments	573970000	9	63774067	1.65	0.127
Residual	1768800000	46	38452284		
Total	2395100000	57			

Treatment Means	#/g soil	n
Sprayed	6304.15	20
Reference	5084.61	19
Nonsprayed	7243.56	19

Table I-26. Analysis of Variance, OU 11 Soil Nematode Bacterial Feeders, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	59824000	2	29912247	1.27	0.3246
Replicates within Treatments	210630000	9	23403227	1.61	0.1395
Residual	667070000	46	14501498		
Total	937150000	57			

Treatment Means	#/g soil	n
Sprayed	6213.56	20
Reference	3986.96	19
Nonsprayed	4171.27	19

Table I-27. Analysis of Variance, OU 11 Soil Nematode Plant Feeders, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	1742836.6	2	871418.3	3.56	0.0726
Replicates within Treatments	2202337.9	9	244704.21	0.78	0.6297
Residual	143.07755	46	311038.16		
Total	18331192	57			

Treatment Means	#/g soil	n
Sprayed	606.47	20
Reference	404.38	19
Nonsprayed	182.54	19

Table I-28. Analysis of Variance, OU 11 Soil Nematode Omnivore/Predators, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	694867.3	2	347433.65	1.81	0.218
Replicates within Treatments	1724754.6	9	191639.4	0.88	0.5422
Residual	9915705	46	215558.8		
Total	12349496	57			

Treatment Means	#/g soil	n
Sprayed	546.96	20
Reference	333.49	19
Nonsprayed	302.18	19

Table I-29. Analysis of Variance, OU 11 Soil Invertebrate Arthropod General Predators, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	1395102.1	2	697551.05	2.35	0.1501
Replicates within Treatments	2661732.9	9	295748.1	2.47	0.0208
Residual	5738106.4	48	119543.88		
Total	9794941.4	59			

Treatment Means	#/m^2	n
Nonsprayed	163.334	20
Reference	263.334	20
Sprayed	525	20

Table I-30. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Predators, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	80219.1	2	40109.55	0.11	0.8973
Replicates within Treatments	3290215.8	9	365579.53	4.9	0.0001
Residual	3581208.4	48	74608.508		
Total	6951643.3	59			

Treatment Means	#/m^2	n
Nonsprayed	280	20
Reference	203.334	20
Sprayed	281.666	20

Table I-31. Analysis of Variance, OU 11 Soil Invertebrate Total Arthropod Predators, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	1654373.8	2	827186.9	0.79	0.4819
Replicates within Treatments	9391785.1	9	1043531.7	4.84	0.0001
Residual	10334232	48	215296.5		
Total	21380391	59			

Treatment Means	#/m^2	n
Nonsprayed	443.334	20
Reference	466.668	20
Sprayed	806.668	20

Table I-32. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Herbivores, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	6035815	2	3017907.6	0.91	0.4344
Replicates within Treatments	29652383	9	3294709.3	1.05	0.4137
Residual	1.50E+08	48	3128555.5		
Total	1.86E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	273.334	20
Reference	883.334	20
Sprayed	161.666	20

Table I-33. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Detritivores 1, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	2252453	2	1126226.4	0.59	0.5742
Replicates within Treatments	17166428	9	1907380.9	5.23	0.0001
Residual	17495135	48	364481.99		
Total	36914016	59			

Treatment Means	#/m^2	n
Nonsprayed	190	20
Reference	583.334	20
Sprayed	156.666	20

Table I-34. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Detritivores 2, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	26189585	2	13094792	1.38	0.2998
Replicates within Treatments	85324786	9	9480532	9.63	0
Residual	47212440	48	983592.5		
Total	1.59E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	346.668	20
Reference	649.999	20
Sprayed	1875	20

Table I-35. Analysis of Variance, OU 11 Total Soil Invertebrate Arthropod Detritivores, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	2.24E+07	2	11192344	0.85	0.4557
Replicates within Treatments	1.17E+08	9	13034120	10.22	0
Residual	61207139	48	1275148.7		
Total	2.01E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	536.667	20
Reference	1233.33	20
Sprayed	2031.67	20

Table I-36. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Fungal Feeders 1, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	916324.6	2	458162.28	0.47	0.637
Replicates within Treatments	8691282.5	9	965698.06	1.87	0.0789
Residual	24727137	48	515148.69		
Total	34334744	59			

Treatment Means	#/m^2	n
Nonsprayed	253.335	20
Reference	553.333	20
Sprayed	368.334	20

Table I-37. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Fungal Feeders 2, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	4496452	2	2248226.1	0.6	0.5672
Replicates within Treatments	33484258	9	3720473.1	1.4	0.2141
Residual	1.27E+08	48	2654628.5		
Total	1.65E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	1350	20
Reference	2013.33	20
Sprayed	1766.67	20

Table I-38. Analysis of Variance, OU 11 Total Soil Invertebrate Arthropod Fungal Feeder 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	9313428	2	4656714	0.81	0.4723
Replicates within Treatments	51345737	9	5705081.9	1.42	0.2056
Residual	1.93E+08	48	4012628		
Total	2.53E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	1603.33	20
Reference	2566.67	20
Sprayed	2135	20

Table I-39. Analysis of Variance, OU 11 Total Soil Invertebrate Mesostigmata, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	1524704.3	2	762352.16	3.11	0.0939
Replicates within Treatments	2204396.5	9	244932.95	2.57	0.0166
Residual	4567097.4	48	95147.863		
Total	8296198.3	59			

Treatment Means	#/m^2	n
Nonsprayed	150.001	20
Reference	186.667	20
Sprayed	505	20

Table I-40. Analysis of Variance, OU 11 Total Soil Invertebrate Prostigmata, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	4358378	2	2179188.9	0.35	0.71
Replicates within Treatments	55119878	9	6124430.9	2.02	0.0561
Residual	1.45E+08	48	3017778.2		
Total	2.04E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	1630	20
Reference	2273.33	20
Sprayed	2080	20

Table I-41. Analysis of Variance, OU 11 Total Soil Invertebrate Cryptostigmata, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	25945442	2	12972721	1.36	0.3029
Replicates within Treatments	85345675	9	9482853	9.56	0
Residual	47566209	48	990962.69		
Total	1.59E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	346.667	20
Reference	649.99	20
Sprayed	1868.334	20

Table I-42. Analysis of Variance, OU 11 Total Soil Invertebrate Astigmata, 0-5 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	444.4222	2	222.21111	0.34	0.7164
Replicates within Treatments	5777.6222	9	641.95803	0.86	0.5607
Residual	35554.844	48	740.72593		
Total	41776.889	59			

Treatment Means	#/m^2	n
Nonsprayed	10	20
Reference	3.33	20
Sprayed	6.67	20

Table I-43. Analysis of Variance, OU 11 Soil Invertebrate Arthropod General Predators, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	168996.4	2	84498.2	2.72	0.1187
Replicates within Treatments	279054.08	9	31006.009	1.32	0.2485
Residual	1121767.6	48	23370.157		
Total	1569818	59			

Treatment Means	#/m^2	n
Nonsprayed	96.67	20
Reference	206.67	20
Sprayed	91.66	20

Table I-44. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Predators, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	28735.07	2	14367.533	0.98	0.4108
Replicates within Treatments	131440.04	9	14604.449	3.34	0.003
Residual	209638.84	48	4367.4759		
Total	369813.95	59			

Treatment Means	#/m^2	n
Nonsprayed	63.33	20
Reference	66.67	20
Sprayed	18.67	20

Table I-45. Analysis of Variance, OU 11 Soil Invertebrate Total Arthropod Predators, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	279200.21	2	139600.1	2.72	0.119
Replicates within Treatments	461604.55	9	51289.39	1.99	0.0605
Residual	1233628.4	48	25700.593		
Total	1974433.2	59			

Treatment Means	#/m^2	n
Nonsprayed	160	20
Reference	273.33	20
Sprayed	110.33	20

Table I-46. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Herbivores, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	77457.249	2	38728.624	3.83	0.0623
Replicates within Treatments	90825.693	9	10091.744	0.81	0.6019
Residual	591781.87	48	12328.789		
Total	760064.81	59			

Treatment Means	#/m^2	n
Nonsprayed	96.67	20
Reference	90	20
Sprayed	17.33	20

Table I-47. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Detritivores 1, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	4764.596	2	2382.2978	0.75	0.4958
Replicates within Treatments	28240.533	9	3137.837	3.29	0.0034
Residual	45725.422	48	952.61296		
Total	78730.551	59			

Treatment Means	#/m^2	n
Nonsprayed	23.33	20
Reference	16.67	20
Sprayed	2	20

Table I-48. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Detritivores 2, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	4400295.3	2	2200147.7	3.39	0.0798
Replicates within Treatments	5837079.9	9	648564.4	0.9	0.5301
Residual	34467690	48	718076.87		
Total	44705065	59			

Treatment Means	#/m^2	n
Nonsprayed	260	20
Reference	703.33	20
Sprayed	909	20

Table I-49. Analysis of Variance, OU 11 Total Soil Invertebrate Arthropod Detritivores, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	4140825.8	2	2070412.9	3.34	0.082
Replicates within Treatments	5570149.3	9	618905.5	0.85	0.5695
Residual	34693808	48	722787.67		
Total	44404783	59			

Treatment Means	#/m^2	n
Nonsprayed	283.33	20
Reference	720	20
Sprayed	911	20

Table I-50. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Fungal Feeders 1, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	186816.96	2	93408.481	2.13	0.1741
Replicates within Treatments	393556.38	9	43728.486	2.41	0.0238
Residual	869330.67	48	18111.056		
Total	1449704	59			

Treatment Means	#/m^2	n
Nonsprayed	73.33	20
Reference	193.33	20
Sprayed	76.67	20

Table I-51. Analysis of Variance, OU 11 Soil Invertebrate Arthropod Fungal Feeders 2, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	1862135	2	931067.5	0.16	0.8481
Replicates within Treatments	49918293	9	5546477	2.62	0.0148
Residual	1.01E+08	48	2111160		
Total	1.53E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	1047	20
Reference	1333.33	20
Sprayed	910.67	20

Table I-52. Analysis of Variance, OU 11 Total Soil Invertebrate Arthropod Fungal Feeder 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	3159048	2	1579523.9	0.25	0.7796
Replicates within Treatments	55529695	9	6169966.1	2.8	0.01
Residual	1.06E+08	48	2202676.2		
Total	1.64E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	1120	20
Reference	1526.67	20
Sprayed	987.33	20

Table I-53. Analysis of Variance, OU 11 Total Soil Invertebrate Mesostigmata, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	118772.96	2	59386.478	2.65	0.1245
Replicates within Treatments	201721.38	9	22413.486	1.35	0.2355
Residual	794667.2	48	16555.567		
Total	1115161.5	59			

Treatment Means	#/m^2	n
Nonsprayed	70	20
Reference	173.33	20
Sprayed	91.67	20

Table I-54. Analysis of Variance, OU 11 Total Soil Invertebrate Prostigmata, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	1980461	2	990230.7	0.17	0.8413
Replicates within Treatments	50584765	9	5620529.4	2.65	0.0138
Residual	1.01E+08	48	2113815.7		
Total	1.54E+08	59			

Treatment Means	#/m^2	n
Nonsprayed	1113.33	20
Reference	1403.33	20
Sprayed	966	20

Table I-55. Analysis of Variance, OU 11 Total Soil Invertebrate Cryptostigmata, 5-10 cm Depth

Source	Sum of Squares	df	Mean Squares	F-Ratio	P-Value
Treatment	4410999.7	2	2205499.9	3.37	0.0808
Replicates within Treatments	5889393.8	9	654377.1	0.91	0.5167
Residual	34161905	48	711706.36		
Total	44462299	59			

Treatment Means	#/m^2	n
Nonsprayed	256.67	20
Reference	703.33	20
Sprayed	905.67	20

Table I-56. Summary of All Analyses, OU 11

	Treatment Effect Significant at alpha = 0.1	Treatment Mean Rank
Soil		
Total C	Yes	S>N>R
Total N	Yes	S>N>R
Exchangeable K	No	S>N>R
Exchangeable Ca	No	S>N>R
Extractable P	No	N>S>R
Particle Size	No	S=N=R
Cation Exchange Capacity	No	S=N=R
Biomass		
Vegetation	No	S>N>R
Litter	No	S>R>N
Nutrient Analyses		
Vegetation C Concentration	Yes	N>S>R
Vegetation C Content	No	S>N>R
Vegetation N Concentration	No	N>R>S
Vegetation N Content	No	S>N>R
Vegetation K Concentration	Yes	N>R>S
Vegetation K Content	Yes	N>S>R
Vegetation P Concentration	Yes	N>R>S
Vegetation P Content	No	N>S>R
Litter C Concentration	Not analyzed	
Litter C Content	No	S>N>R
Litter N Concentration	No	S>N>R
Litter N Content	No	S>N>R
Litter K Concentration	No	N>R>S
Litter K Content	No	N>S>R
Litter P Concentration	No	N>R>S
Litter P Content	No	N>S>R
Soil Invertebrates		
Nematode Functional Groups		
Bacterial Feeders, 0-5 cm	No	S>R>N
Fungal Feeders, 0-5 cm	No	N>R>S
Omnivore/Predators, 0-5 cm	Yes	S>R>N
Plant Parasites, 0-5 cm	No	S>R>N
Bacterial Feeders, 5-10 cm	No	S>N>R
Fungal Feeders, 5-10 cm	No	N>S>R
Omnivore/Predators, 5-10 cm	No	S>R>N
Plant Parasites, 5-10 cm	Yes	S>R>N

Table I-56. Summary of All Analyses, OU 11

	Treatment Effect Significant at alpha = 0.1	Treatment Mean Rank
Arthropods		
General Predators, 0-5 cm	No	S>R>N
Arthropod Predators, 0-5 cm	No	S=N>R
Total Predators, 0-5 cm	No	S>R>N
Herbivores, 0-5 cm	No	R>N>S
Detritivores 1, 0-5 cm	No	R>N>S
Detritivores 2, 0-5 cm	No	S>R>N
Total Detritivores, 0-5 cm	No	S>R>N
Fungal Feeders 1, 0-5 cm	No	R>S>N
Fungal Feeders 2, 0-5 cm	No	R>S>N
Total Fungal Feeders, 0-5 cm	No	R>S>N
Mesostigmata, 0-5 cm	Yes	S>R>N
Prostigmata, 0-5 cm	No	R>S>N
Cryptostigmata, 0-5 cm	No	S>R>N
Astigmata, 0-5 cm	No	N>S>R
General Predators, 5-10 cm	No	R>N>S
Arthropod Predators, 5-10 cm	No	R>N>S
Total Predators, 5-10 cm	No	R>N>S
Herbivores, 5-10 cm	Yes	N>R>S
Detritivores 1, 5-10 cm	No	N>R>S
Detritivores 2, 5-10 cm	Yes	S>R>N
Total Detritivores, 5-10 cm	Yes	S>R>N
Fungal Feeders 1, 5-10 cm	No	R>S>N
Fungal Feeders 2, 5-10 cm	No	R>N>S
Total Fungal Feeders, 5-10 cm	No	R>N>S
Mesostigmata, 5-10 cm	No	R>S>N
Prostigmata, 5-10 cm	No	R>N>S
Cryptostigmata, 5-10 cm	Yes	S>R>N
Ecosystem Functions		
Soil Nitrate Concentration	Yes	S>N>R
Soil Ammonium Concentration	Yes	N>R>S
Potentially Respirable C	No	S>R=N
Potentially Mineralizable N	No	N>R>S
Microbial Biomass C	No	S>R>N
Microbial Biomass N	Yes	S>N>R
Fine Particulate Organic C	Yes	S>R=N
Fine Particulate Organic N	Yes	S>N>R
Microbial Biomass C / Total Soil C	No	S>R>N
Microbial Biomass N / Total Soil N	No	S>N>R
Respirable Soil C / Total Soil Organic C	No	R>N>S
Mineralizable Soil N / Total Soil N	Yes	N>R>S
Fine Particular Organic C / Total Organic C	No	S=R>N
Fine Particulate Organic N / Total Organic N	No	S>R=N

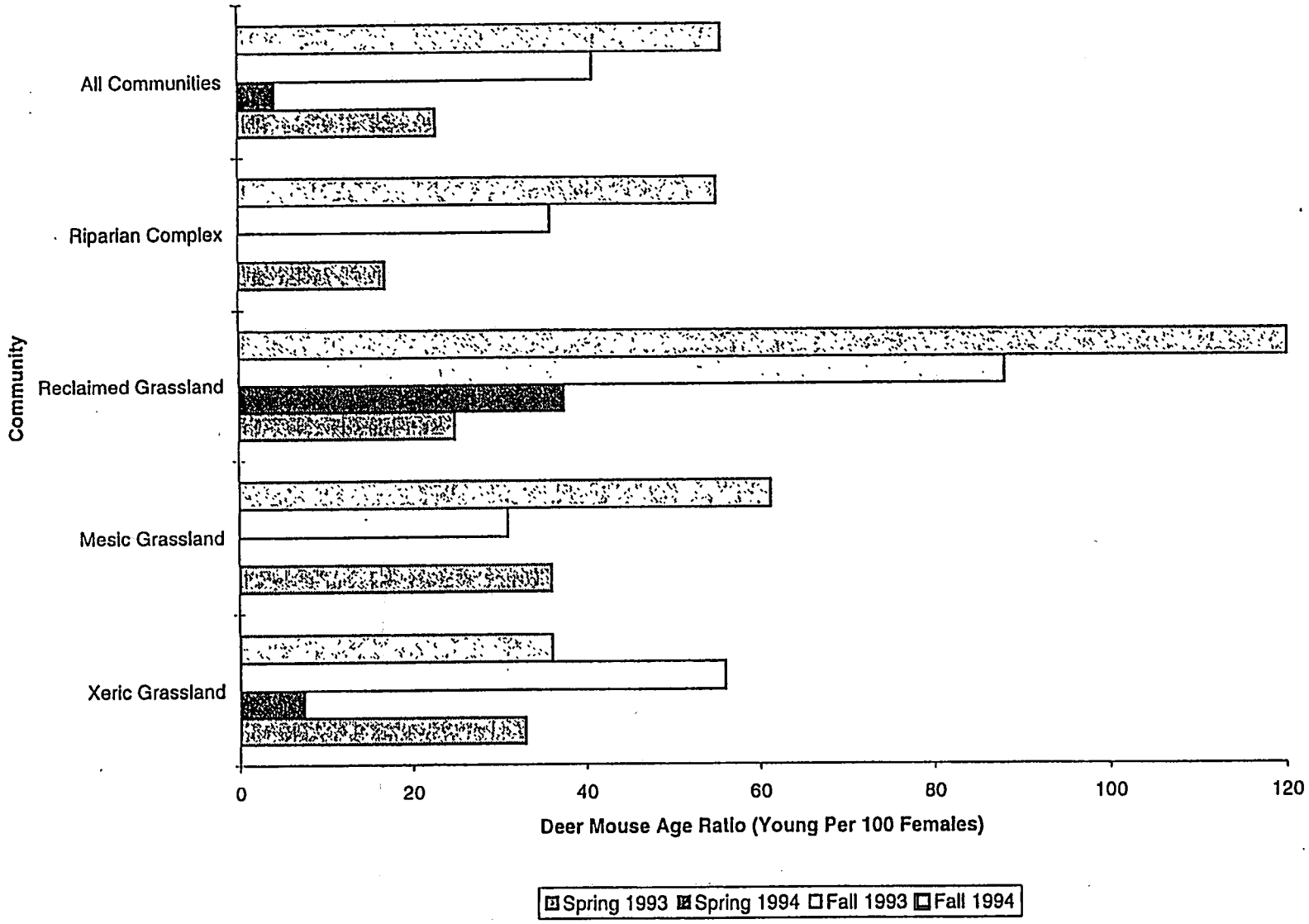


Figure C-22. Deer Mouse Age Ratio Comparison, Spring and Fall, 1993 and 1994.