THE RELATIONSHIP OF ORIBATID SOIL MITE

ABUNDANCE TO ABIOTIC AND

BIOTIC FACTORS

by

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ABSTRACT

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Oribatid soil mites primarily feed on fungi and dead organisms. They belong to the arthropod subclass, Acari, that are believed to contribute to soil processes such as plant litter breakdown and nutrient release.   In order to facilitate more accurate predictions about obscure soil processes, research has been done that has attempted to correlate soil mite abundance and diversity to more easily measured aboveground biota.

The present study examined monthly Oribatid soil mite abundance and its relationship to four different plant communities in North Texas: mowed grass monoculture, un-managed field, riparian, and woodland, during one growing season. Due to the nutritional additions of plant litter to the soil communities, the woodland and riparian sites were expected to have the highest mite abundance, followed by the field, and grass sites respectively. Also examined was the relationship between soil moisture and Oribatid abundance, with greater moisture levels expected to positively

correlate with mite abundance, as suggested in the literature. Due to the minimizing effects of the tree canopy on evapotranspiration, the woodland and riparian sites were expected to retain the most moisture, followed by the field and grass sites respectively. The effects of seasonal progression on Oribatid abundance were expected to be minimal, since the season's litter contribution to the soil is not immediately available to soil organisms.

Oribatid and total arthropod abundance were significantly greater in the grass monoculture over the course of sampling than in the other plant community types. The repeated addition of the grass clippings during peak growth and productivity provided high quality nutrients to the soil, ultimately enabling the Oribatid mite population to thrive. This finding could also have resulted from the relative success of the Bermuda grass in the unusually rainy season, the success of a few species in the empty niche caused by the absence of others, or sampling effects. These results indicate a need for further research at the site in order to illuminate its underlying cause. The effects of moisture on mite abundance were contradictory. The woodland soil did indeed contain the most moisture, but moisture did not correlate positively with mite abundance as expected. Slight time effects were present but unexplained, which indicate a need for further research on seasonal effects. Further research is thus recommended to explain the unexpectedly high Oribatid abundance in the mowed grass monoculture, as well as the lack of moisture correlation with Oribatid abundance, as predicted based upon previous literature.

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CHAPTER 1

INTRODUCTION

1.1 Soil Processes

Soil processes are an important but poorly understood phenomenon. Microscopic and unseen, there is little opportunity to directly observe the activities taking place beneath the surface, and in order to learn, one must attempt to recreate the conditions in the laboratory or remove samples for later observation. Within the soil are organisms that each contribute to some aspect of the recycling of the previous seasons' botanical production. These include but are not limited to: macro and micro-arthropods, nematodes, fungi, and bacteria. Each season the subterranean biota remove much of the flora and fauna of the previous season, releasing their constituents into the soil and atmosphere for re-use. Yet due to their obscure location and small size, few of these organisms are understood, and many are completely unknown. The majority of the breakdown is known to be the work of the decomposers: fungi and bacteria (Solomon, et al. 1999). But other soil organisms are at work, comminuting the litter and directly or indirectly spreading fungal spores, thereby enhancing the process. Examples of these are arthropods, nematodes, and springtails. The micro-arthropods, or soil mites, are thought to contribute significantly to the processes (Badejo 1990), yet due to their small size (0.2 mm-5 mm) and the estimated large number of unidentified species (Maraun et al. 2007), many remain a mystery.

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Subterranean mites are cosmopolitan, having been discovered world-wide (Maraun, et al. 2007). They can be found in a range of temperature and moisture conditions, including both upper and lower extremes, and at great numbers, with some estimates as high as 100,000 m^{-2} (Peschel, et al. 2006) or 160,000 m^{-2} in spruce forests (Renker, et al. 2005). Despite their small size, they can comprise up to 7% of the weight of the soil invertebrate fauna (Evans, 1992). Their diversity is illustrated by the fact that 30,000 species are described, and it is estimated that twenty times this number could be un-described (Evans, 1992). In the Oribatid subclass alone, there are 10,000 named species, though the actual number of species is estimated to be 100,000 (Schneider, et al. 2004). The Oribatid mites are the dominant mites numerically in mature forest soil, and are expected to be "key industry" animals due to their relative abundance as compared to other soil arthropods (Wallwork, 1983).

Soil mites are a diverse group of arachnids. It is generally accepted that the class Arachnida lies within the subphylum Chelicerata (Evans, 1992). Within Arachnida is the subclass Acari, which includes three orders (or superorders) listed below. Mites can be classified based upon cladistics, phenetics, and physical characters that reflect evolutionary relationships. The Acari classification is currently under debate, with taxonomists of differing classification approaches suggesting different taxonomies (Evans, 1992). The original taxonomic classification was based upon the identification of physical features as indicators of evolutionary relationships. In the 1960's, the phenetic system, where an attempt is made to quantify overall similarity, came about. At this time the cladistic method of taxonomy also came about, wherein all mites were considered monophyletic, with certain identified plesiomorphic physical features followed by derived features which have come about subsequently

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(Evans, 1992). Each group of researchers has named the mites, further complicating their classification. Grandjean's classification of Acari into the three groups Anactinochitinosi, Notostigmata, and Actinochitinosi has been renamed by Zachvatkin as Parasitiformes, Opilioacarina and Acariformes, respectively (Evans, 1992). This monophyletic system of classifying the Acari is supported by many acarologists, but differs from a diphyletic system offered by Van der Hammen (Evans, 1992). In this study, the monophyletic classification will be used (Figure 1).
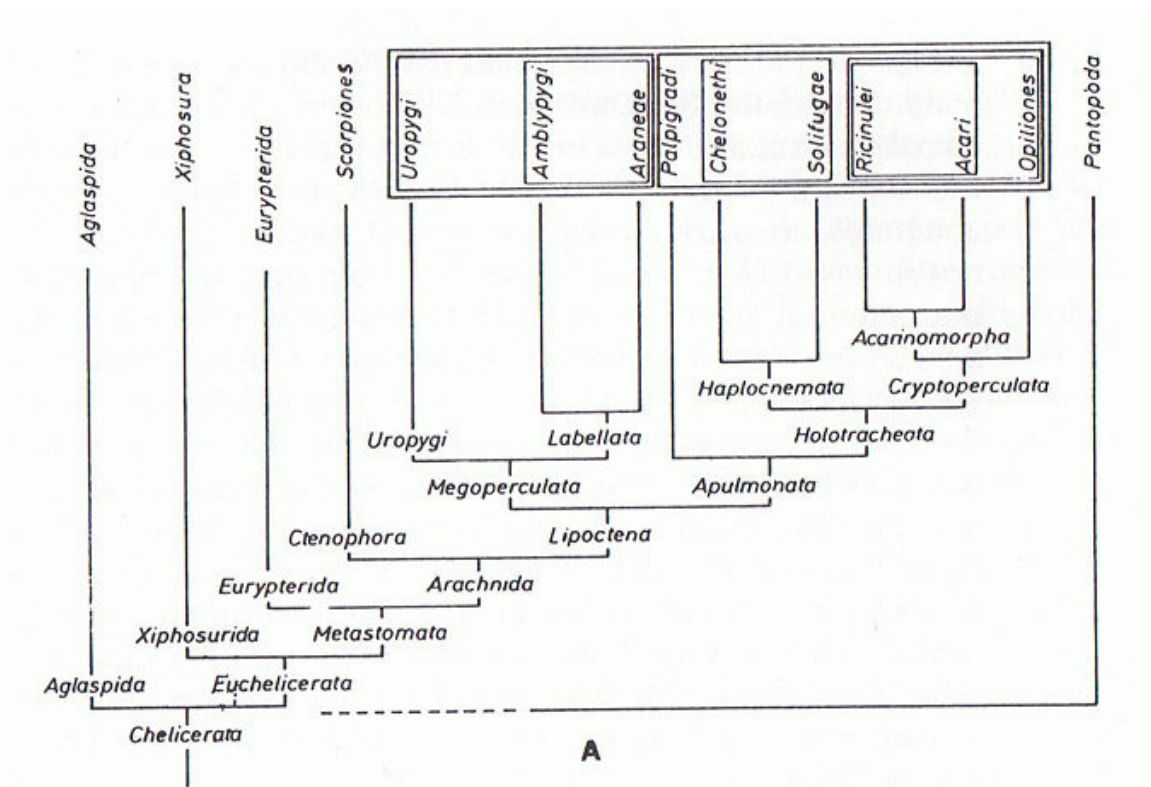

Figure 1.1 Monophyletic Taxonomy of Chelicerata
(by Weygoldt & Paulus adapted from Evans, 1992)

Within the order Acariformes, the suborders have been classified based upon the organism's respiratory characteristics. The following names are generally accepted, although they have replaced the original names put forth by Kramer (1877)

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and Canestrini (1891): Notostigmata, Holotyrida, Ixodida, Mesostigmata, Prostigmata, Astigmata and Oribatida (Evans, 1992). The focus of this paper is the Oribatida suborder.

The Acari subclass fulfills diverse life history roles as well, and can be phytophagous, saprophagous (as are the Oribatid mites), and predatory. They can be free-living, or they can live in association with other organisms, either commensally or parasitically. Many free-living mites also practice phoresy, by which they form temporary commensal attachments to larger organisms for transport and dispersal (Evans, 1992).

1.2 Oribatid Mites: Structure

The main body of the mite, or soma, is subdivided into the anterior prosoma and the posterior opisthosoma (see Appendix A: Basic Oribatid Anatomy). Though these two segments (tagmata) exist, the soil mites can tend to appear as though only one segment is present, with the only obvious characteristic of the division being the disjugal furrow between them. The number of locomotive appendages can have limited usefulness in identification, primarily in distinguishing adult mites from earlier stages. Adult Acari are octapodal, though earlier stases are hexapods (Evans, 1992).

The Oribatid mites tend to have heavily sclerotized cuticles, of uniform thickness, which can be plain or ornately ornamented with various patterns. The sclerotization process usually coincides with pigmentation giving the mite a darker, opaque coloration. It is achieved as the resistant and insoluble protein sclerotin is formed in a tanning process involving orthoquinone. Some Oribatids can achieve cuticular strengthening through the use of calcium deposition as well   (Evans 1992).

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This heavy sclerotization inhibits predation, allowing the mites to survive in "enemy-free space", with predatory mites such as Mesostigmatids choosing to avoid the Oribatids for other, easier to consume, prey (Peschel, et al. 2006). An effect of the sclerotized cuticle that has proven beneficial to this study is the longevity it affords the physical characteristics of the specimens of the suborder, delaying decomposition and enabling identification for months subsequent to the death of the organism.

1.3 Oribatid Mites: Behavior

Oribatid mites are largely saprophagous substrate-feeders. One-third of the food consumed by Oribatids is consumed by the phytophagous mites, which can be macrophytophagous, microphytophagous, or a combination of the two, termed panphytophagous mites (Luxton, 1981c as reported in Schuster and Murphy 1991). Oribatids can also be considered copraphages, and more rarely zoophages and necrophages (Wallwork, 1983). They consume plant litter in all stages of decomposition, the fungal and bacterial microbes which inhabit the litter, and the remains of other soil inhabitants.   The food preferred can vary depending upon other factors such as availability and developmental stage. Mites can be opportunistic polyphages, feeding differently when food sources change. The stases can also affect feeding choice, with larval, nymphal and adult stases feeding differently (Schuster and Murphy 1991). Mites have also been known to switch food preferences. Schneider, et al. (2004) investigated long-term trophic relationships using stable isotope ratios in Oribatids and found that niche differentiation does exist in these organisms, though they have been considered generalists. The Oribatids were found to occupy up to four

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trophic levels, which helps to explain the complexity and large populations of subterranean communities.

The Oribatids are considered K-strategists due to life history characteristics such as relatively low fecundity rates, slow ontogeny, and a lack of specific dispersal adaptations or behaviors (Lindo, 2004; St. John et al. 2006a, b). Surface and sub-surface litter provides a fairly stable environment for many Oribatids that favors these less rigorous life strategies in order to maintain population density. These K-strategies enable a "slow but steady" population maintenance in an environment with few unpredictable perturbations.   The populations of such edaphic saprophagous feeders show little variability, and there is little tendency toward aggregation, since risk is low (Lebrun, et al. 1980, as reported in Schuster and Murphy 1991). This fact allows for abundance generalizations based upon field sampling studies such as this one.

Oribatid mites can affect changes upon the soil and the related micro-ecosystem, and its processes. Soil-dwelling micro-arthropods such as Oribatids enhance decomposition both through the spreading of fungal spores and the stimulation of microbial processes. Fungal spores are spread directly through contact with the mite as it moves through the soil or indirectly via fecal material as it is deposited.   This dispersal mobilizes nutrients which stimulate microbial activity. Oribatids have been found to enhance the recovery of soil communities following disturbance by restoration of these fungal and microbial colonies. This is thought to increase the resilience of a system following anthropomorphic or naturally induced perturbations (Maraun et al. 1998).

1.4 Oribatid Mites and Soil Processes

The direct role of micro-arthropods in decomposition has been found to be minimal, with Oribatids contributing little to the sub-surface food chain and its energy flow (Wallwork 1983). They have been considered "wasteful" consumers, channeling the majority of their energy into respiration rather than production.   However, it is their indirect contribution to the energy and mineral pathways that may be of greater significance.

Soil microflora, such as fungi, are considered a nutrient and mineral "sink", due to the immobilization of the substances upon assimilation into the fungal body. They are subsequently unavailable to other ecological components of the food chain, arresting soil processes. Oribatids facilitate the release of these substances back into the soil, making them available to other organisms, through their ingestion of the fungus. The elements are then released immediately through fecal matter or more slowly after the death of the mite. Using radioisotopes to monitor mineral turnover, research in pine and hardwood stands in Coweeta Forest in Georgia yielded evidence of mineral release by two numerically dominant soil faunal species, Oribatid mites and Collembolans (Wallwork, 1983). Oribatids were specifically tied to the release and subsequent utilization of calcium in hardwoods (Wallwork, 1983). As fungi concentrate calcium oxalate in their hyphae it becomes unavailable in the surrounding soil. Upon ingestion of the fungi, the microflora in the Oribatid gut breaks down this form, incorporating much of it into the Oribatid body itself. Upon the death of the Oribatid it is released back into the soil. The suborder Enarthronota is known to utilize this fungal-derived calcium for cuticular sclerotization (Evans, 1992). Lesser amounts are released through fecal material (Wallwork 1983).

Minerals are not the only soil commodity whose dispersal is facilitated by Oribatid mites. Approximately fifty percent of the microflora ingested by the mites remain viable as they pass through the Oribatid alimentary canal and flourish upon fecal deposit (Renker, et al. 2005; Wallwork, 1983). Since fungi are the only soil organisms with the ability to degrade lignin, the effects of fungal dispersal upon soil processes will be substantial (Wallwork, 1983). The literature shows that in the absence of soil fauna, decomposition slows. Surely this dispersal mechanism is a contributing component in that response (Wallwork, 1983, Wardle, 2004).

Another potential benefit to the fungus from Oribatid association is the "culling effect" whereupon mites remove less productive hyphae from the body of the fungus, which may increase fungal efficiency (Wallwork, 1983).

Renker, et al. (2005) found an even greater contribution to fungal dispersion by adherence to the Oribatid body. Though Oribatids travel an average of only a few centimeters a day, they have been found to travel up to 42 centimeters in a day (Renker, et al. 2005). And due to the heterogeneity in soil caused by rocks, litter, and other barriers, even a distance of a few centimeters can enable a fungal spore to find hospitable conditions for invigorated growth. Renkel found that the number of fungal species associated with mites corresponded to the mite body surface area.

1.5 Oribatid Mites and Plant Community

Since soil interactions are not completely understood, there have been attempts to estimate soil arthropod abundance and community composition based upon the resident plant community. Results in the literature are contentious, with some studies showing a weak, positive correlation between soil arthropod species richness and

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abundance and plant community attributes (Gormsen et al. 2006), some showing negative correlation (St. John et al. 2006a; 2006b), and some showing a strong, positive correlation (Siemann et al. 1998, Haddad, et al. 2001, Minor and Cianciolo 2007). The use of higher taxonomic groups as surrogates for mite species can affect correlation significance, with results that show a stronger relationship between mite richness and grass richness at higher taxonomic levels in Kansas prairies (St. John et al. 2006b). The trophic niche of the mite taxa will greatly impact its association with above-ground plant community composition, with stronger relationships expected with phytophagous mites, and weaker relationships with predator and saprophagous mites (Oribatida). As expected with Oribatids due to their diet of decomposing matter, an Australian study comparing Oribatid abundance in two forest sites found that mites were more abundant in the more dense forest location (Osler and Beattie, 2001).

Despite the lack of consensus in the literature, the plant community can be presumed to have subtle effects upon the mite population due to its direct role in affecting soil conditions. Soil characteristics can vary based upon plant-dependent factors in the subterranean environment that are created by the spatial qualities related to root structure, the plant's chemical exudations, the plant's affinity for local nutrients and available moisture, and other factors (Wardle, et al. 2004). The microhabitat diversity resulting from these botanical characteristics can then be expected to alter mite communities (St. John, et al. 2006a, Hansen 2000). Though no significant evidence exists that the mite community is related to grass species richness in the Konza Prairie Biological Station studies in Kansas (St. John, et al. 2006a, b), the similarity of the grasses may not have produced sufficient microhabitat variation to influence mite community structure.

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Plant characteristics such as nutrient quality and availability have also been shown to have a limited effect upon soil arthropod abundance. Though Oribatids were not found to show host-plant specificity (Osler and Beattie, 2001), a correlation exists between mites and plant photosynthetic pathways. Plants utilizing the C_4 photosynthetic pathway are of lower-quality nutrition for soil organisms, and their presence has a negative affect on arthropod abundance. In a study comparing the effects of both plant functional group richness and plant species richness on arthropod abundance, the presence of these low quality plant species caused soil arthropod abundance to decrease by 25% (Haddad et al. 2001). However, the same study found that in the absence of C_4 plants, higher plant diversity caused an increase in soil arthropod abundance and species richness. These results imply that plant functional groups may be a more important determinant of mite communities than plant species, in contrast with findings at Cedar Creek, Minnesota, in which plant species richness had a greater impact on soil arthropod community structure than plant functional group (Siemann et al. 1998). However, these findings dealt with total soil arthropods, including macroarthropods and herbivores. Since botanical functional group studies may better isolate the plant nutrient contribution to the soil than botanical species diversity studies, their results may more readily convey the effects on the saprophagous Oribatids.

1.6 Oribatid Mites and Stress or Disturbance

Plant community influences on mites can be closely related to the relative degrees of disturbance imposed on the soil by the plants or by anthropological plant management practices. Physical stressors can include moisture and temperature extremes, and food shortage. Agricultural practices may cause severe soil perturbations, imposed arable plant species dominance or monocultures, and alterations of soil chemistry.

In arable soils in central Argentina, Acari abundance has been shown to be negatively correlated with human soil management, with Oribatids and Mesostigmatids showing the greatest sensitivity to these practices (Bedano et al. 2005). Soil perturbations and resulting soil degradation were factors that the authors believe contributed to the Oribatids' poor response to agricultural practices. Along a gradient of land use types in New York, as anthropologic land management practices increased from a wild forest to arable corn pastures, Oribatid population species richness decreased (Minor and Cianciolo, 2006). In Canadian mixedwood boreal forests, Oribatid abundances were negatively correlated with severity of tree harvesting techniques, though species richness was not significantly affected (Lindo and Visser, 2004). These results are not surprising since the partial and clear-cut harvesting removed significant amounts of detritus and organic matter upon which the mites feed. The Oribatid mites' negative correlation reflects their inability to effectively re-populate following disturbance such as plowing and cultivation. Oribatids move an average of a few centimeters a day, causing them to be unable to escape severe disturbance (Minor and Cianciolo, 2006, Renker, et al. 2005). Oribatid communities structurally similar to those found in agricultural settings were found twenty years after the farm had been

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abandoned. This indicates that the Oribatids' poor re-colonization abilities prevent significant colony changes following disturbance (Seipel 1996). This slow Oribatid re-colonization has also been found in the case of pesticide application, with negative effects on diversity remaining ten years after application (Lindberg et al. 2002.

Mesostigmatid mites, being more mobile r-strategists, tend to show less negative response to disturbance than Oribatids (Gormsen et al. 2006; Minor et al. 2007). Their mobility may enable them to leave a disturbed area before its negative effects can be realized, and it may enable them to return when favorable conditions reappear. Their reproductive characteristics enable them to repopulate faster than Oribatid upon the return of these favorable conditions.

1.6.1 Effects of Precipitation Events

There have been numerous studies which have attempted to correlate Oribatid abundance and species richness with moisture. Water is considered to be a primary factor influencing soil arthropod abundances, and moisture has been positively related to Oribatids and soil fauna in the related literature (Badejo 1990). This may be due to water's high heat capacity acting to moderate temperature extremes.   Badejo (1990) found an inverse relationship between moisture and soil temperature, with the increased moisture positively influencing mite abundance, due to the lower soil temperatures following precipitation events in a Nigerian tropical climate. This study actually found that the temperature exerts greater influence over the mites than the moisture, with up to 76% of the mite abundance variation accounted for by the temperature variations, as compared to a maximum of 42% by moisture (Badejo, 1990). On the contrary, pilot studies have determined that mites do not drown, and it is suggested that water may actually serve as a dispersal method (Siepel, 1996). Since

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drought has been found to negatively impact Oribatid community structure in Norwegian spruce stands, with decreases in abundance and diversity, sufficient moisture appears to be a key component of normal mite life cycle success (Lindberg et al., 2002).

The severity of the event, however, combined with the K-strategies of Oribatid mites will obviously determine the extent of the effects on the mite community. Due to the Oribatid mites' slow re-colonization and dispersal tendencies, severe precipitation events or droughts may negatively affect Oribatid mites more significantly than other soil organisms. In other studies, negative correlations between moisture and species richness remained throughout a three-year recovery period, but abundance effects were not significant (Lindberg and Bengtsson, 2006). These results may be related to the unique tolerance thresholds of the different Oribatid species (Siepel 1996). Species intolerant of the excessive moisture will die, enabling the remaining species to fill the open niche. This may cause overall abundances to remain constant.

This is similar to the "vacant niche" theory by Lawton (Siepel 1996). When the frequency or severity of disturbance exceeds the period of recovery, a completely unpopulated environment is created (Siepel, 1996). Siepel (1996) discusses the relationship between these two effects, the disturbance verses the recovery (or recolonization), as strongly affecting the metapopulation dynamics of mites. This hypothesis presents three distinct possibilities for the mite community. When disturbance is frequent enough to warrant a struggle for survival, but not frequent enough to cause extinction, conditions exist for interspecific competition to actually decrease, preventing any one species from dominating over the others. The second potential dynamic exists when the frequency of disturbance is less then the

recovery/recolonization. In this condition Siepel terms the community a saturated biotope, with maximum species richness and abundance. The third condition is the vacant niche created by the frequency of disturbance in excess of the recovery/recolonization (Siepel 1996).

1.7 Hypotheses

Here I present the overall questions guiding this research as well as the related hypotheses I tested in a field site located in north Texas that contained four different plant communities: woodland, riparian, field and grass.

1. What effect does seasonal progression have upon Oribatid abundance?

The present study's sampling took place during the growing season, from May to August, in 2007. Since decomposition is not immediate, any accumulation of plant litter from the current season's growth is not expected to directly affect Oribatid soil mites. However, climatic conditions may have an effect on abiotic soil characteristics such as soil moisture. The changes in mite abundances that result from these conditions will more likely follow precipitation events, rather than months. Correlations with moisture will be addressed in the next hypothesis. Therefore, my first hypothesis was that Oribatid abundance would not be correlated with the time over which collection took place.

2. What is the relationship between moisture and Oribatid abundance?

Moisture has been shown to positively affect mite community abundance and species richness (see 1.6.1 above). Therefore, my second hypothesis was that the sites with the greatest amount of soil moisture would have the greatest mite abundance. The woodland and riparian sites have the greatest litter input due to the

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greater plant productivity at these locations. This litter accumulation is expected to result in a water-retaining humus component of the soil. This fact, combined with the reduced evapotranspiration that results from the tree canopy at both sites, allowed me to predict that the woodland and riparian sites would contain the greatest moisure, and therefore the greatest Oribatid mite abundance, followed by the field and grass sites, respectively.

3. What is the relationship between plant community type and Oribatid abundance?

Decomposing plant litter is the primary nutrient source in a soil ecosystem, and the mites feed upon the litter itself and the fungal and bacterial microbes which inhabit it (see discussion 1.3, 1.4, and 1.5). For these reasons, Oribatid mite abundance is expected to positively correlate with more productive plant communities. My third hypothesis was that the mite abundances would be highest at the woodland site, followed by the riparian, field and grass sites, respectively, because of the relative productivity of the vegetation.

CHAPTER 2

METHODS

2.1 Collection Sites

The collection sites were located at Samuell Farms, a 340-acre non-profit farm that is open to the general public in Sunnyvale, Texas at 32° 46'59.55 N 96° 35'12.91 W. The park is ecologically diverse, encompassing varied plant communities due to a flood-prone stream running centrally in a southeast direction through the park (Appendix A).   This variation allowed for comparisons among different plant communities, ranging from mowed monoculture (grassy lawn), to stream-bank riparian, to un-mowed wild-growth field, to woodlands. The stream, North Mesquite Creek, is a derivative of the East Fork Trinity River which draws its water from the Trinity Aquifer (National Resources Conservation Service).

The soil is Houston Black-Heiden, a dark clay soil which originated under prairies and thus has a high organic content (ANHCNT; A natural History of Central North Texas). The soil is a vertisol which has a high shrink/swell capability (Natural Resources Conservation Service 2003). This can cause large cracks during the dry season, but due to its slow permeability flash floods are common with heavy rains. Houston Black is the Texas state soil, and can only be found in this state. The soil can be sticky when moist and hard when dry, making it difficult to handle. Due to these characteristics, some of the samples taken had to be pried loose from the coring tool or scraped off, causing the cores to break apart.

Four sites were selected to represent different plant communities, including a grassy, mowed lawn, an un-mowed, unmanaged field, a riparian site that directly abuts

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the stream, and a woodland. Each site contained five randomly placed 1 m^2 plots from which one core was extracted each month from May through August. Sampling took place on May 12, June 14, July 15, and August 15, 2007 between 7:00 and 11:00 AM.

Figure 2.1. Samuell Farms Site Map
Site F: Field site. Site G: Grass site. Site R: Riparian site. Site W: Woodland site
Googleearth.com

2.1.1. Site G

The first site was a grassy mowed area near the public entrance to the park of approximately 4-5 acres, hereafter named site G. The lawn was dominated by the genus *Cynodon* with approximately ten percent *Lolium*. This site was chosen to represent an area of low plant diversity, being dominated by the Bermuda (*Cynodon*) grass. The lawn was mowed bi-monthly during the growing season with the clippings allowed to remain on the ground. No fertilizer or pesticide treatments have been applied in the four years for which maintenance records were available preceding collection. The mowing could be a source of potential disturbance for phytophagous mites, but since all mites were extracted directly from the soil, the disturbance effects were expected to be minimal in the subterranean habitat. Any disturbance effects may be presumed to be due to soil compaction.

2.1.2. Site R

The second collection site, site R, is a riparian woodland with a sparse tree canopy and an undergrowth of shrubs, vines and low-growth ground plants. The understory was dominated by members of the genera *Ligustrum* (Privet) and *Toxicodendron* (poison ivy). The five replicates were located at varying elevations ranging from creek level to approximately 1.5m above creek level. At this site, the banks were flooded approximately six times a year, with water levels fluctuating up to 3.6m higher than normal in June of 2007 due to unusually high rain levels (see Figure 1.6.1). Due to the different elevation among replicates, soil characteristics showed high variability at this site. Collection replicate R5, at creek level, consisted of moist, muddy soil at collections following rain events, while R4, the highest elevated, was

spongy and loose at the same collection date, presumably due to the soil loss during flooding episodes.

2.1.3.   Site F

The third site, designated site F, was a large field previously planted with hay. It has been unplanted and unmanaged for the past 4 years. It consists of varied grasses and forbs, with some areas showing clusters of the same plants, and others showing an even dispersal of varied species. Plants were sparsely distributed, with visible patches of bare soil. This lack of water-retaining biota may help to explain why the field was among the driest of the sites.

2.1.4   Site W

The final site is a woodland, designated site W, which consists of an understory dominated by *Ligustrum* (Privet) shrubs 2-4m in height beneath a sparse tree canopy comprised of *Ulmus* (elm) and *Maclura* (Bois d'arc). The Privet shrubs grew quickly throughout the duration of the collections, with maximum productivity in May and June. The floor contains a thick layer of leaf litter, which caused the soil consistency to differ from the other sites visibly, and lightened its density. Soils were moist, perhaps explained by the effects of the woodland biota, which by preventing sunlight and wind, may have reduced evapotranspiration.

2.2   Collection

For collection, soil was extracted for the May sampling using a long-handled bulb-planter. The total core length was 15 cm, and diameter was 5.5 cm. Therefore, the maximum size of each sample was approximately 302.5 cm^3. Due to breakage, another coring tool was used for the remainder of the collections. This was also long-handled, and extracted a 512 cm^3 soil core. Samples were extracted from the surface

to a depth of 8 cm, which may influence the results, since sub-surface sampling at different levels of strata has been shown to reveal greater species richness and abundance (St. John, et al. 2006b). Upon sampling, the cores were temporarily stored in individual plastic containers and placed in a cooler to prevent overheating. They were transported immediately upon the completion of the collections to the extractor (details in next section) where the samples were weighed, removed from the containers, inverted, and carefully placed in netting within a funnel. The inversion allows surface organisms a shorter distance to travel as they move away from high temperature and arid soil conditions, and gives deeper-dwelling organisms, more adept at sub-surface movement, the longer distance to travel (MacFayden, 1953).

During the May collection soil conditions were moderate, with moisture present at all four sites. Precipitation in May 2007 exceeded previous averages by 62%, with 211.8 mm in 2007 as compared to the average 130.81 mm (Figure 3.1). Site R was spongy and moist, and sites G and F were the most visibly dry. Data collection took place on a sunny day of 31 degrees with 6 mph SE winds.

The June collection took place after the second wettest June on record, with 281.94 mm in 2007, which exceeds previous averages of 82.04 mm by 343% (Figure 3.1). Site R showed evidence of recent flooding, and the plant growth at site W was so pronounced that the site was almost unrecognizable. Site F was nearing peak productivity, with some plants reaching 1.8 meters. June sample collection took place on a partly cloudy day of 32 degrees with 8.4 mph SW winds.

July soil conditions remained moist due to light rains combined with the previous month's heavy precipitation. July precipitation totaled 140.72 mm, 261% above the average of 54.86 mm (Figure 3.1). Many field plants were post-

senescence, but the sunflowers towered at 2.1 meters, and the privets were still at full productivity. Site R soil still held easily detectable moisture. Site G showed no visible changes throughout the monthly collections. Collection took place on July 15 from 7:30-10:00 AM at 33 degrees on a sunny day with a light breeze of 3.2 mph NE.

The August collection showed evidence in each site of drying. The total monthly rainfall was below average for the first time during the collections, with 8.89 mm total, only 17% of the average of 51.56 mm (Figure 3.1). Most of the species of plants had undergone senescence at site F, and most shrubs and trees no longer bore reproductive organs. The privet at site R showed evidence of stress, possibly from severity of floods earlier in the season. Site W showed beginnings of senescence of the privet shrubs. Site G soil was hard and dry. Collection took place on August 15 from 7:50-9:20AM at 35 degrees with SE winds of 5.4 mph during sampling.

2.3 Extraction

The extractor was a modified Burlese variety. The Burlese funnel uses a temperature and moisture gradient to drive soil organisms downward in a funnel, where they fall into a trap filled with fixative (Macfadyen 1953a, 1961b). This extractor consisted of plywood with 20 holes, each 10 cm in diameter. Each hole held an aluminum funnel, with upper and lower openings of 13 cm and 2 cm respectively. A sheet of screen landscaping netting lined each funnel, to trap the soil but allow the soil organisms to pass through. Beneath each funnel, glass vials were suspended and affixed to the funnels with tape, and partially filled with denatured alcohol. The heat gradient was established by the application of 7 watt light bulbs suspended directly above each sample.   This resulted in a slight temperature gradient between the soil

closest to the heat source and the soil at the base of each funnel, with specific gradient temperatures being dependent upon varying room temperature in the extraction building, which was not climate-controlled. Being contiguous, all other climactic conditions among samples were similar.

2.4 Identification

Structurally, the mites are varied in appearance, making identification a daunting task at best. Frequently, identification in research is limited to higher taxonomic levels such as suborder. This is due to the fact that not only is the number of possible Oribatid species large (up to 1,100,000 species may exist by some estimates), but each species can undergo as many as six physical phases, or stases, which can differ morphologically from the adult (Maraun et al. 2007). The stases which follow the egg are the prelarva, larva, protonymph, deuteronymph, tritonymph, and adult. This fact can be confounded by the presence of instars, another set of phases based upon moulting and integumentary characteristics which also can appear structurally different from one another (Evans, 1992). Using higher taxa instead of species-level is cost effective, minimizing the field and laboratory hours required to complete difficult and tedious identifications. It has been shown to effectively estimate species diversity in local and regional settings, without significantly compromising the data (Osler, 1999, Balmford, et al. 1996a, b). In this study, abundance was determined using the level of suborder.

Subjects extracted from the soil samples as described above were identified and placed into one of the following groups: Oribatid Mite, Non-Oribatid Mite, and Other. In the stereomicroscope, the Oribatids uniqueness from their Acarine relatives

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is both subtle and obvious. Oribatids range in size from two hundred to four hundred micrometers, a size which is not unique to them but which can assist in eliminating other contenders (Evan, 1992). Oribatid mites were identified based on very general features such as brown coloration, which results from heavy sclerotization common among the sub-order, teardrop body shape, absence of posterior features, and obscure or reduced mouthparts (University of British Columbia online). The Non-Oribatid group consists of Acarine members which tended to consist largely of the sub-order Mesostigmata, a group of predators recognized by lighter coloration due to reduced levels of sclerotization and more pronounced mouthparts due to feeding habits (UBC). The group, "other", included all soil organisms except those in the Acari. These included macroarthropods such as Insects, Chilopods, and Arachnids as well as microarthropods such as Collembolans. Also counted in this category were members of Nematoda. The Springtails (Collembola) and Nematodes were difficult to recognize at times due to the effects of dessication resulting from a delay between collection and identification. Lacking a heavy exoskeleton, these organisms were not clearly recognizable after several months without preservative.

Identification was facilitated by the use of a combination of descriptions and keys in Principles of Acarology (Evans, 1992) and the online keys of the University of British Columbia (http://www.zoology.ubc.ca/~srivast/mites/gloss.html). Eggs and early stases were not included in the counts, unless they clearly displayed Oribatid morphological traits and lacked traits which would place them among one of the other groups. When the effects of decomposition, desiccation, or lack of certainty hindered classification into one of the three broad groups, organisms were not counted, therefore these counts represent conservative abundance estimates for each date.

CHAPTER 3

RESULTS

3.1 Temperature and Precipitation

The temperature and precipitation for the months of May through June 2007 are shown in figures 3.1 and 3.2, respectively. The average temperature from May to August differed little from normal area temperatures for the season, with an average monthly departure of 0.55 °C (Figure 3.1). Rainfall data from May through July 2007 indicates an average monthly departure of 12.26 cm in excess of normal precipitation (Figure 3.1). In August, precipitation fell 4.2 cm below normal. No significant effects are presumed to be a result of temperature conditions as deviation from normal values was minimal (NOAA). However, the buffering effects of soil moisture against air temperature may have been a factor which positively affected the mite abundances (see "Effects of Precipitation Events"). Data from other years with more typical precipitation levels would be necessary to explore this possibility. The effects of this abnormally wet season must be considered in evaluation of the data.
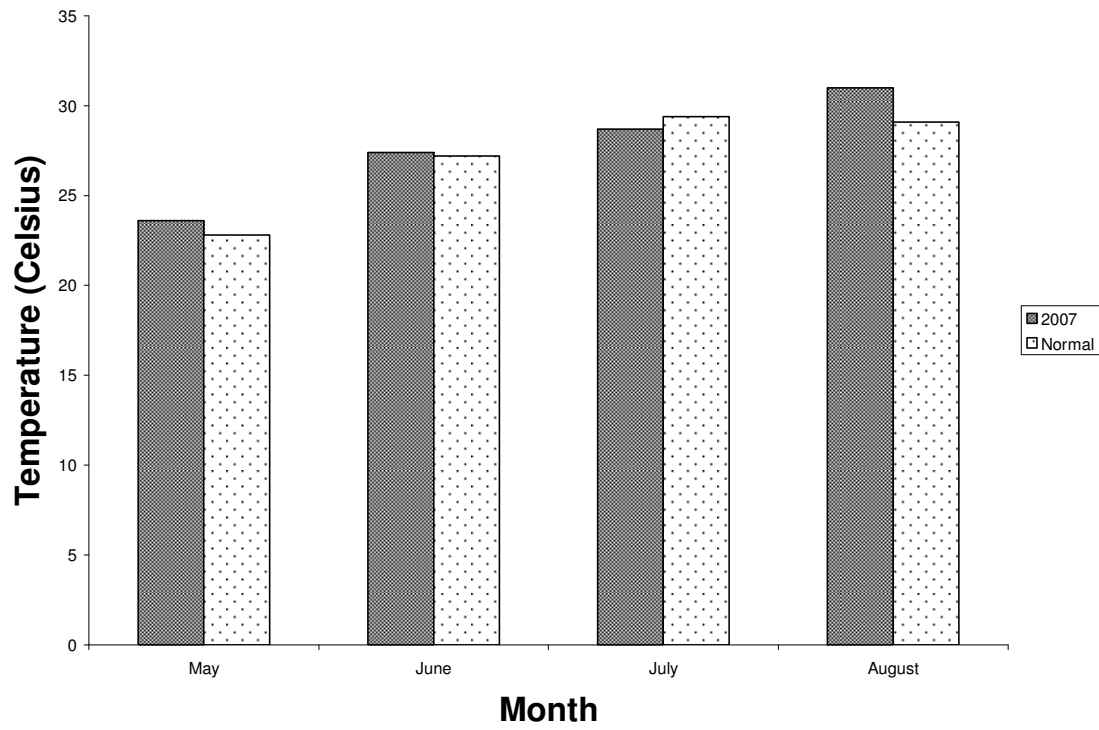
Figure 3.1 Mean Monthly Temperature for DFW
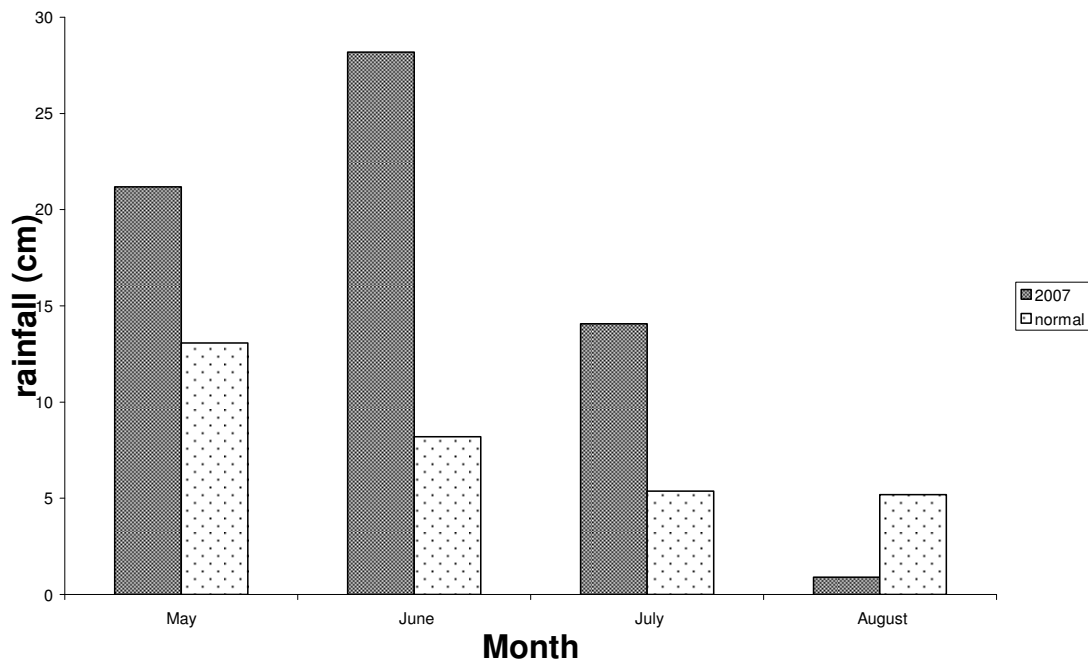(data adapted from http://www.srh.noaa.gov/fwd/CLIMO/dfw/lcd/dfwjul07.html)

Figure 3.2 Mean Monthly Precipitation for DFW
(data adapted from http://www.srh.noaa.gov/fwd/CLIMO/dfw/lcd/dfwjul07.html)

3.2   Soil Moisture

Moisture data at the sites were determined using percent water loss for each soil sample by comparison of soil mass before and after the seven-to-ten day extraction period. Due to the high temperatures in the extractor's location and the added heat of the 7-watt bulbs, the samples had sufficiently air-dried upon the time of second weighing.   Soil moisture gradually increased throughout the rainy months of May, June and July, with a decrease in August (Figure 3.3), but this pattern varied significantly among sites (time*site: $F_{9,34}=68.06$, P=0.001; time: $F_{3,14}=4.13$, P<0.0001). The overall drop in moisture at the August collection may reflect dryer conditions due to both a decrease in precipitation, and the evaporation resulting from warmer seasonal

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temperatures. Site W contained the most soil moisture for each sampling date, significantly more than the grass and field sites on three out of four dates, and significantly more than the riparian site on two dates (main effect of site $F_{3,16}=10.36$, P=0.0005). The riparian site contained the second highest moisture value in May and June, and never was the driest site. The Field and Grass sites did not significantly differ from one another on any of the sampling dates, and contained the lowest soil moisture levels.

The higher moisture content of the riparian and woodland soil may have resulted from the tree canopy, and the subsequent reduction of evaporation. The higher levels of ground litter in these sites due to the greater plant biomass may have increased the moisture-holding capacity of the soil through increased organic content. This is reflected in the soil bulk density data which indicates that the woodland soil was consistently less dense than the other sites (Figure 3.4; main effect of site: $F_{3,16}=4.42$, P=0.02). The grass site, and to a lesser degree the field site, lacking the protective tree canopy, may have lost moisture through evapotranspiration. A slight grade at the field site may have facilitated run-off following heavy precipitation events.
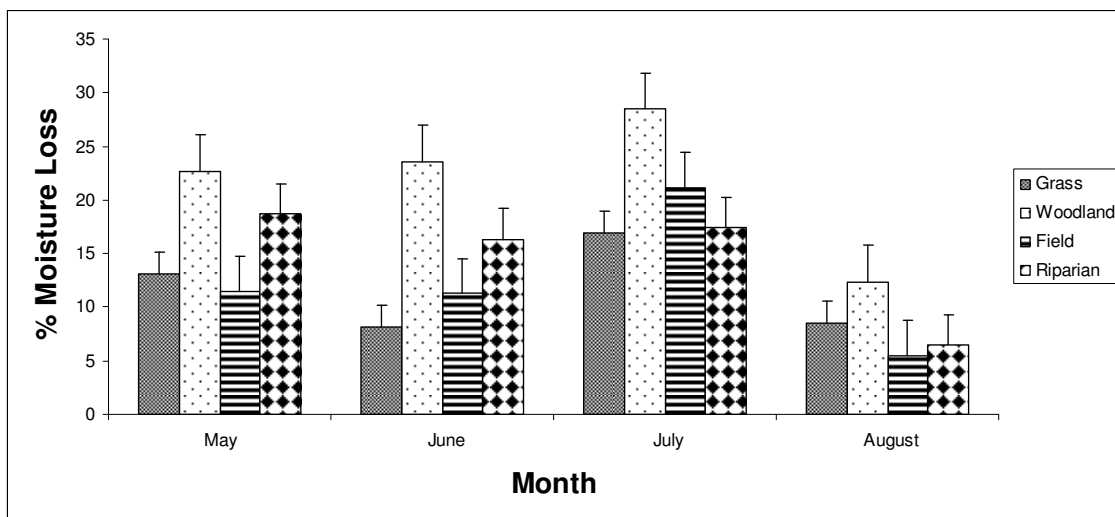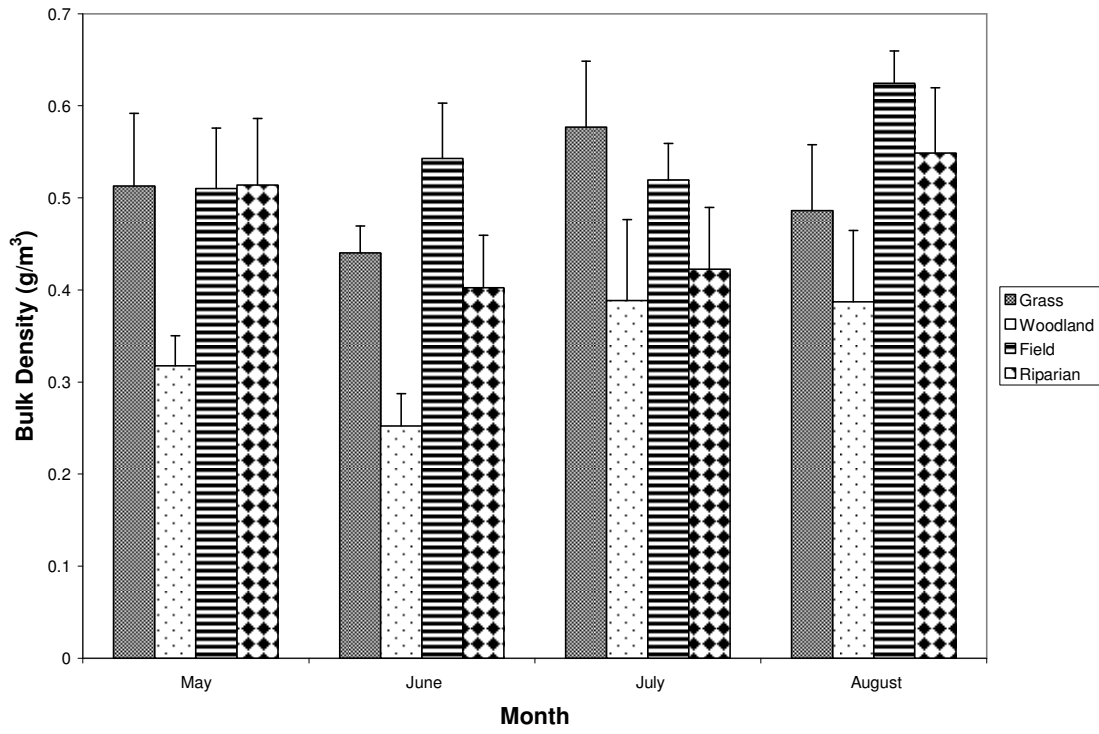

Figure 3.3: Moisture Loss Data
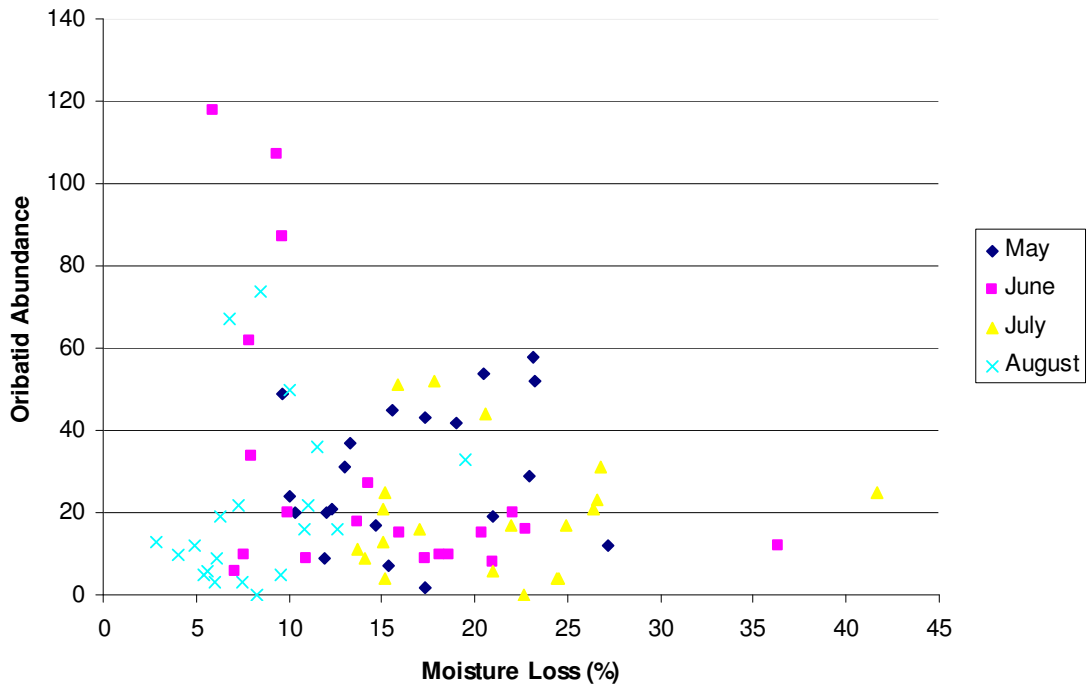
Figure 3.4: Soil Sample Bulk Density

Figure 3.5: Oribatid Abundance & Percent Moisture Loss per sample

3.3 Arthropod Abundance

Oribatid mites, non-oribatid mites and other soil arthropod counts were taken on each sampling date for all replicates at each of the four sites. Using repeated measures analysis, grass site Oribatid abundance was found to be significantly higher across all sampling dates (site: $F_{3,16}=10.80$, $P=0.0004$), particularly in June and July when abundance in the grass site was significantly greater than in the other three sites (Figure 3.5). In August, abundance in the grass site significantly exceeded the field and riparian abundance. Abundance at each site showed a slightly different pattern across time (site*time: $F_{9,34}=2.6$, $P=0.02$) primarily because the pattern of the grass site differed from the other three which rather consistently had greatest numbers in May

with fewer consistently across the other three months, and time was significant overall because of the greater overall abundance in June (time: $F_{3,14}$=6.81, P=0.005)

Total arthropod abundances included the Oribatids, non-oribatid mites, and other arthropods. I did not include the non-oribatid mites or other arthropods separately because there were no significant effects of time or site for these groups, but I do present the results for total arthropods (Figure 3.6). The four sites showed slightly different patterns of abundance over time (time*site: $F_{9,34}$=2.07, P=0.06), with a significant decrease overall as the season progressed (time: $F_{3,14}$=8.77, P=0.002). Site was significant overall because of the greater abundance at the grass site compared with the others, particularly in June and July (site: $F_{3,16}$=7.51, P=0.002).
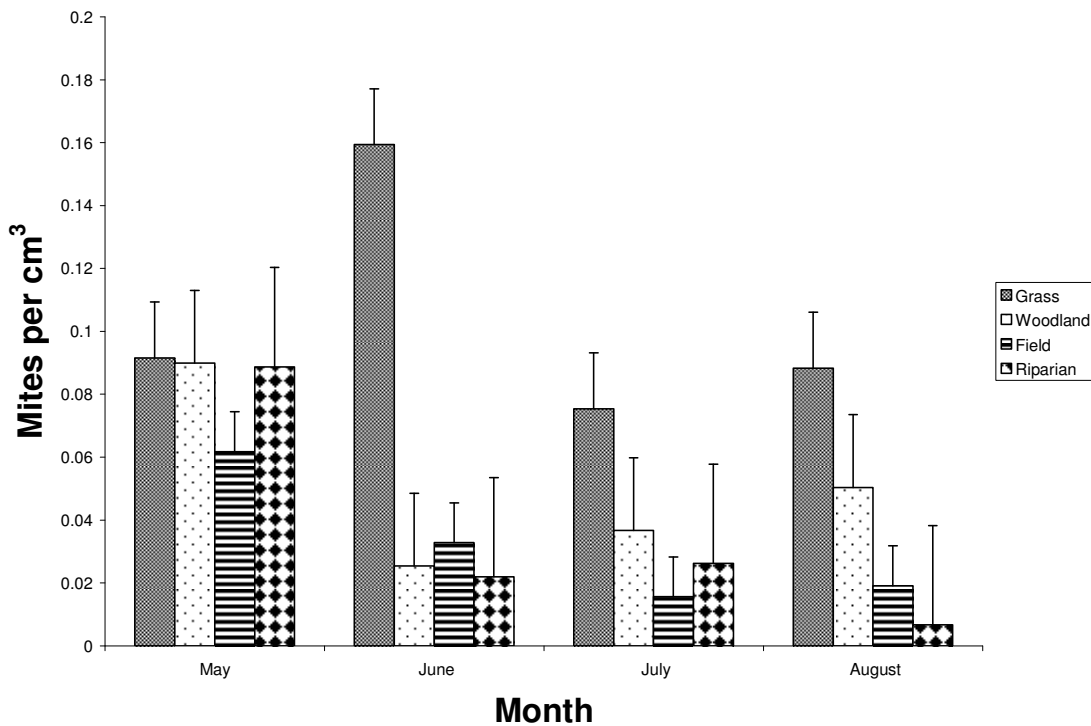

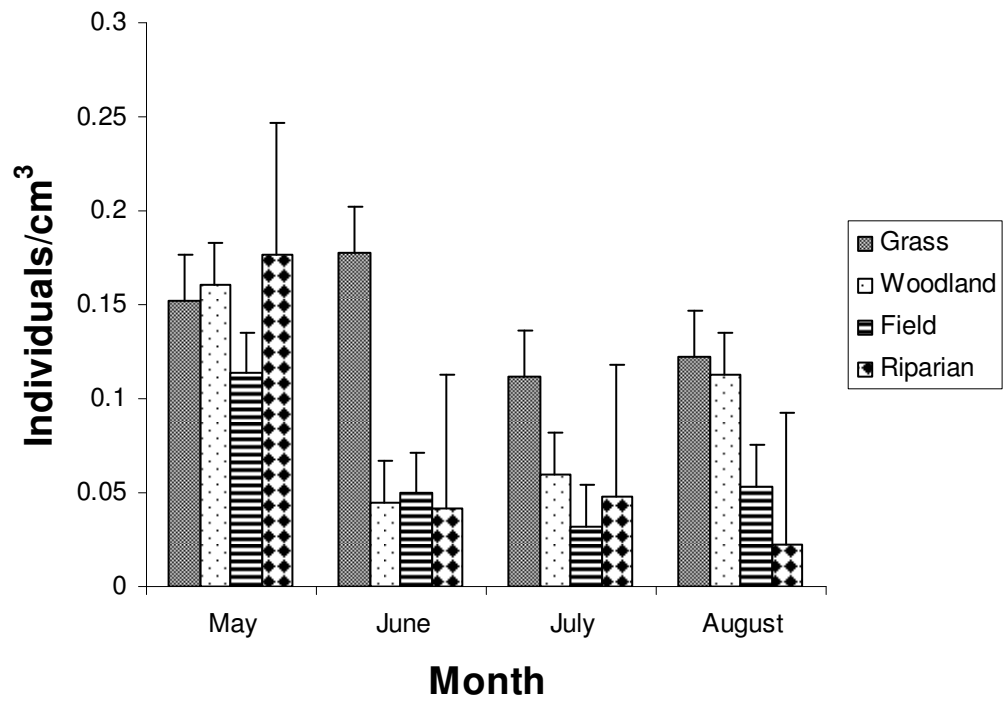Figure 3.6: Oribatid Abundance

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Figure 3.7: Total Arthropod Abundance

CHAPTER 4

DISCUSSION

4.1   Hypotheses

1. What effect does seasonal progression have upon Oribatid abundance?

Time had a significant effect on Oribatid abundance, but this varied among

communities, with the Grass site supporting the most mites in June, while abundance

was greatest in May for the other three sites. The more similar May abundances

among sites may indicate the presence of an annual pattern higher overall abundance

earlier in the season. This can only be verified by additional years of seasonal data. I

expected the data to be responsive to precipitation events, not seasonal progression.

That does not seem to be the case with the present results. May showed the greatest

abundances for total arthropods and Oribatids, but the present data gives no clear

explanation for this. The incongruence in the plant community responses to time

indicates that other variables may have influenced the Oribatid abundance. These can

only be elucidated through further, more extensive research into seasonal factors such

as soil chemistry.

2. What is the relationship between moisture and Oribatid abundance?

The riparian abundances seem to be most closely associated with moisture

since they showed an overall decrease throughout the sampling period as conditions

became dryer.   Riparian soils are typically poor and coarse, having lost particulate

constituents to flooding events (Mitsch & Gosselink, 2000). The resulting soil porosity

may contribute to the negative effects of flooding upon the mites, which may be literally

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washed away during times of heavy sub-surface flow. This may explain the overall low numbers of Oribatids at Site R. Riparian sites exhibit another challenging characteristic, which is the rapidly changing soil composition due to removal and deposit of alluvial soil constituents during flooding events. Further research at the riparian site that takes into account both the biotic and abiotic soil components at each collection time would help elucidate the connections between these soil influences and mite abundances.

The heavy rains may have acted as a stressor at some locations, such as the woodland site. This site contained the most moisture in the soil but fewer mites than expected. Likewise, the grass site contained less moisture and had greater mite abundance than expected. The stressful effects of flooding are factors that could account for these results. However, the lack of comparative data in years with more typical rainfall prevents conclusive analysis.

3. What is the relationship between plant community type and Oribatid abundance?

The most interesting finding in the present study was the consistently greater Oribatid abundance in site G, when this site appears to contain the simplest and least diverse plant community. There is a lack of literature comparing soil arthropod communities of the more anthropogenic "lawn" plant community to more naturally occurring plant communities such as woodlands and grasslands. More study is required to determine whether the present results are typical.

Several possible explanations exist for the present results. Among the first is the effects of the mowing, which were initially expected to be a potential disturbance factor. It is possible that the mowing not only provided a consistent addition of

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nutrients to the soil, but it also contributed to the comminution of the plant material, thereby hastening the breakdown so that the materials could be more readily available to the soil fungus. The grass was mowed at peak growth and productivity, allowing the high quality plant material to directly enter the soil ecosystem. This contrasts with the other sites where litter is added to the soil seasonally after senescence, when nutrient quality has already diminished.

The extensive roots and runners of the Bermuda grass may have been functional in supporting the soil structure during heavy precipitation events of May, June and July. This support would be essential in preventing the loss of mites due to surface and sub-surface water flow. The deep Bermuda roots also may be of the appropriate size to provide microhabitats within which Oribatids can thrive.

The uncharacteristic levels of precipitation during the sampling season may have improved conditions that existed beneath the Bermuda-dominated community. *Cynodon* is a genus that can thrive under varied conditions including both drought and floods. The increased rains may have actually increased Bermuda biomass, whereas the effects of the abnormally high precipitation on the other plant communities may have been negative, inhibiting normal seasonal growth rates. This potential increase in productivity would then increase the nutrient supply to the soil community below.

Another factor to consider is that I was not able to identify the mites to species, though species richness may help to explain abundance at each site. The high abundance at site G may exist at the expense of high species richness, with the grass monoculture conditions fostering success among a small number of species which are well-adapted to the sub-surface microhabitat created by the *Cynodon* community above. These species will then take advantage of the lack of inter-specific competition

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and thrive. Conversely, greater species richness may exist at the remaining sites, which may inhibit population growth due to the competition among species. A study which includes greater taxonomic specificity could explore these possible explanations.

The field site Oribatid abundance did not significantly differ from the other sites. The site's plant community exhibited patchy, uneven growth that could have resulted in uneven litter and nutrient deposition to the soil. This, in turn, may have resulted in an island effect on the mites and soil arthropods which would help to explain the inconsistency among the field replicates. The field moisture fell within general trends for the collection dates. A slight grade decline towards the southwest may have prevented excessive moisture retention, but a lack of significant elevation or grade allowed some moisture to stand during the uncharacteristically wet season. A more thorough analysis of the types of plant biota at this site and the mite communities beneath them could reveal more intimate relationships between Oribatids and the surface flora, but such studies have produced little consensus, especially with respect to arthropod abundance (Haddad, et al. 2001; Minor, et al. 2007, Siemann, et al. 1998).

The woodland site was expected to have the greatest Oribatid abundance due to the obvious litter accumulation on the ground surface. Instead, it fell significantly below the grass site in three of the four collections. Since much of the litter was comprised of Privet, further exploration into the decomposition of Privet and Bermuda is needed. Perhaps analysis of the different decompositional stages of the previous season's litter would reveal a very different picture, as Oribatid mites tend to display differing food preferences (Schneider, et al. 2004). An increase of collection times to

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weekly or daily, coupled with soil nutrient analysis might elucidate a clearer picture of these unexpected results.

4.2   Further Discussion

The earlier mentioned three conditions by Siepel (1996) regarding recovery from disturbance may have each existed in the present study at inter-site sampling locations.   The moisture variation due to site topography combined with frequent, extreme Spring precipitation events may have caused the disturbance at one site to exceed recovery, whereas at other, less-affected sites the recovery/recolonization exceeded the disturbance.   The woodland community showed the highest moisture levels, and did not have the highest mite abundances.   There may have been a lack of inter-specific competition due to the stressful moisture levels which limited population growth, much like Siepel's first dynamic community.   The saturated biotope may have existed at the mowed grass site, where moisture levels were not the highest nor the lowest of any of the sites, and where regular mowing created a continuous nutrient source addition to the soil, allowing for consistent fungal growth.   The vacant niche, or at least an unsaturated biotope, may have been created at the riparian site during August due to the previous months' stressful water levels and the subsequent removal of mites from the area.

Another previously unmentioned potential influence upon the soil processes are the presence of ecosystem engineers, defined as organisms that have a dramatic and important effect on an ecosystem (Mitsch & Gosselink 2000).   Such fauna as earthworms and moles could play integral roles such as the facilitation or inhibition of nutrient release, and the compaction or aeration of soil particulates.   An extension

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involving counts of these and other similar organisms could reveal their importance (or unimportance) to the Oribatid mite community.

Oribatids, due to their small size and limited dispersal abilities, tend to occupy microenvironments that can be said to behave in accordance with the expectations of island biogeography. Physical obstructions such as roots and rocks, or chemical obstructions such as moisture gradients or mineral deposits may present barriers that isolate groups of Oribatids from the greater population. It is possible that an inadequate number of replicates in the present study present a skewed picture of the Samuell Farms Oribatid population due to the effects of these acarine "islands".

Wallwork (1983) discusses the vagility of these micropopulations. Some Oribatids, especially those with a more indiscriminate diet that is not tied to a specific state of plant litter, may move vertically through the substrate according to diurnal or seasonal patterns (Wallwork, 1983). This vertical movement does not take into account disturbance or heavy precipitation events, which can also serve to re-distribute mite micropopulations. Sampling several times a day, throughout the year, and several vertical strata might present results which remove these effects. St. John et al. (2006) found that collecting samples at different vertical soil stratum can produce a different picture of mite abundance, a phenomenon that could be explained by alternate root characteristics at greater depths, especially among plant species adapted for drought (St. John et al. 2006b) . An increase in spatial and temporal replicates could reduce these effects.

Another factor that may have had an effect on mite abundance is that some mites such as the families Oppiidae and Suctobelbidae have more specific food preference tied to the stage of litter decomposition (Wallwork, 1983). As

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decomposition degrades the plant material, a population shift involving these Acarine families is expected. To account for these effects, frequent sampling coupled with chemical analysis of the plant litter to identify various stages of decomposition is suggested.

A fungal analysis could further illuminate the causes of the high grass Oribatid abundance. The fungal growth may have been greater under the Bermuda due to nutrient quality, availability, or soil conditions. More research is needed on specific fungal-mite trophic relationships to explore the possibility that mites favor some fungi over others.

4.3 Summary

I found the greatest Oribatid abundance at the mowed grass monoculture site, instead of the more productive woodland and riparian communities as I had predicted. Moisture was not found to be positively correlated with Oribatid abundance, since the highest abundance was not at the site with the highest moisture. Though some of the plant community types responded similarly from May through August 2007, time did not affect each community similarly.

The results of this study present an intriguing outcome which suggests a need for further research in many areas. The repetitive addition of the high-quality, peak productivity *Cynodon* grass to the soil environment may have enabled the Oribatid mite population to thrive.

The Oribatid soil mites include 45,000 named species (Maraun, et al. 2007). The current study's taxonomic categorization of subclass is too general to offer a complete picture of the Oribatid community and its interactions, and so a categorization

and identification as close to species as possible is necessary. In order to account for Oribatid movement in the soil, which can range from several centimeters to up to 42 centimeters a day (Renker et al. 2005), a greater number of temporal and spatial replicates are needed to avoid island biogeographic effects. Collection at several depth horizons will eliminate any factors due to diurnal vertical vagility, or preferential strata-related habitation. A more thorough understanding of the sub-surface biota is needed to understand its effects upon the Oribatid community. This will require a survey of the soil fungal communities, the non-Oribatid mites and other soil arthropods. Nutrient analyses at each sampling will help to illuminate relationships between floral and faunal communities.
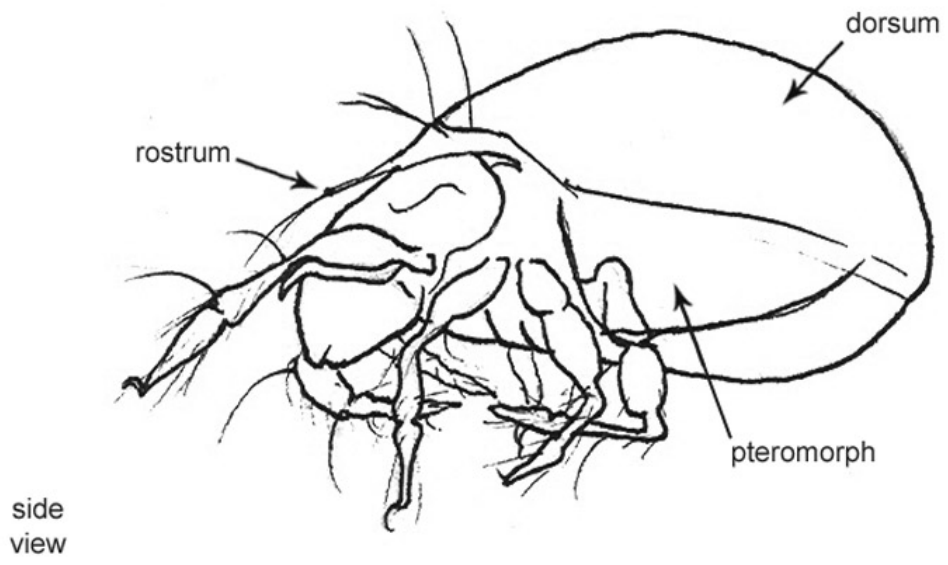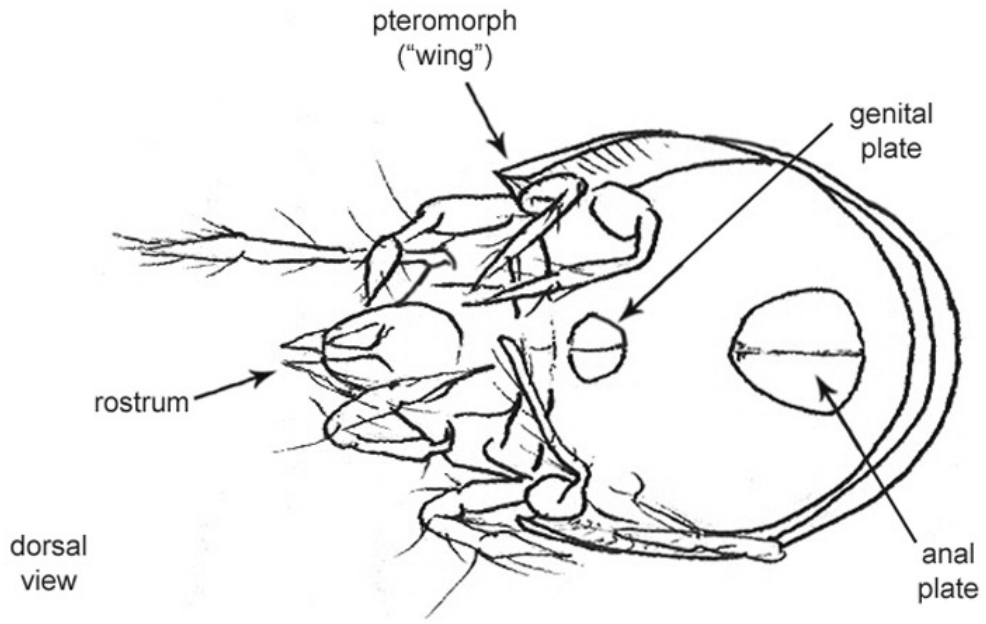
Including one or more of these aspects of the Samuell Farms location into an extension of this exploratory experiment will allow for a more thorough understanding of the soil processes at the site and therefore, greater confidence in the results. From this data, application to analogous locations can be more confidently ascertained.

It remains to be seen whether Oribatid abundance will consistently be higher in a mowed, *Cynodon* monoculture than in more productive plant communities such as woodlands. Illuminating the factors which enable this phenomenon will contribute to a better understanding of soil processes in general, and particularly those involving grassy lawn monocultures and productivity correlations.

APPENDIX A

BASIC ORIBATID ANATOMY

http://www.zoology.ubc.ca/~srivast/mites/gloss.html

pteromorph
("wing")

genital
plate

rostrum

anal
plate

dorsal
view

dorsum

rostrum

side
view

pteromorph

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APPENDIX B

LIST OF SITE BIOTA

	Family	Genus
Site F		
Purple Clover	Leguminosae	*Trifolium*
Wild Carrot	Apiaceae	*Daucus*
Mexican Hat	Asteraceae	*Ratibida*
Indian Blanket	Asteraceae	*Gaillardia*
Goose Grass	Poaceae	*Eleusine*
Horse Mint	Lamiaceae	*Monarda*
Texas Paintbrush	Scrophulariaceae	*Castilleja*
Big Bluestem	Poaceae	*Andropogon*
Ragweed	Asteraceae	*Ambrosia*
Site R		
Privet	Oleaceae	*Ligustrum*
Ash	Oleaceae	*Fraxinus*
Hackberry	Ulmaceae	*Celtis*
Cedar Elm	Ulmaceae	*Ulmus*
Mulberry	Moraceae	*Morus*
Giant Cane	Poaceae	*Arundo*
Carolina Cherry Laurel	Rosaceae	*Prunus*
Poison Ivy	Anacardiaceae	*Toxicodendron*
Site W		
Privet	Oleaceae	*Ligustrum*
Cedar Elm	Ulmaceae	*Ulmus*
Osage Orange (Bois 'd Arc)	Moraceae	*Maclura*
Chinaberry	Meliaceae	*Melia*
Site G		
Bermuda	Poaeceae	*Cynodon*
Winter Rye	Poaeceae	*Lolium*

APPENDIX C

DALLAS COUNTY SOIL MAP

http://www.nhnct.org/geology/soilmap.html
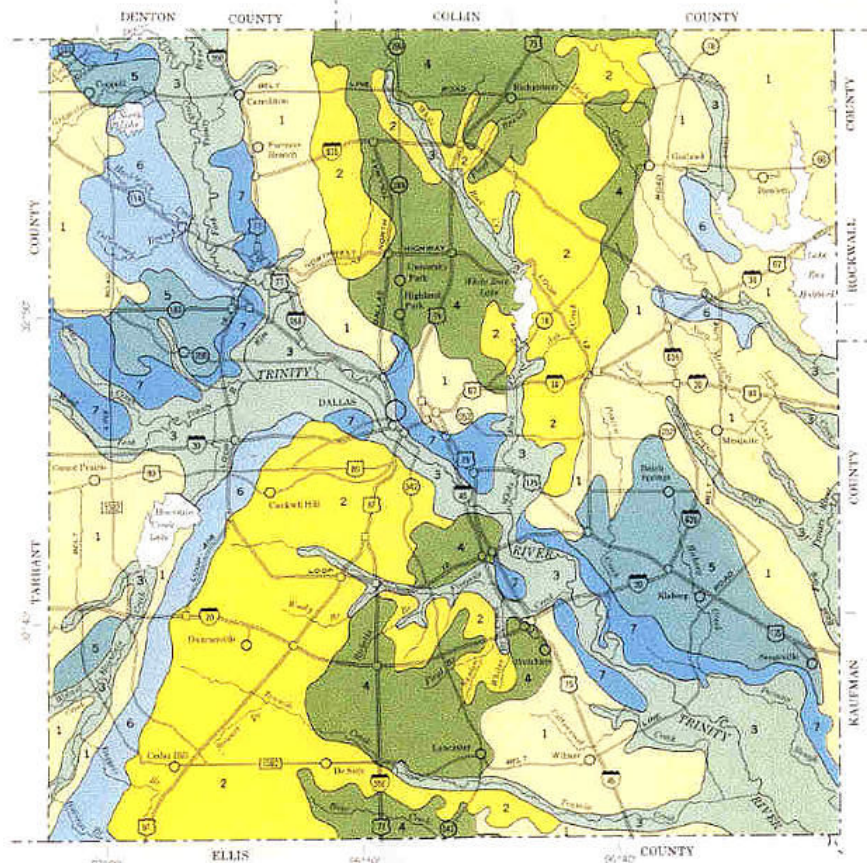
LEGEND

1	**HOUSTON BLACK-HEIDEN:** Deep, nearly level to strongly sloping, clayey soils; on uplands
2	**EDDY-STEPHEN-AUSTIN:** Very shallow, shallow, and moderately deep, gently sloping to moderately steep, loamy and clayey soils; on uplands
3	**TRINITY-FRIO:** Deep, nearly level, clayey soils; on flood plains
4	**AUSTIN-HOUSTON BLACK:** Moderately deep and deep, nearly level to sloping, clayey soils; on uplands
5	**WILSON-RADER-AXTELL:** Deep, nearly level to gently sloping, loamy soils; on uplands
6	**FERRIS-HEIDEN:** Deep, gently sloping to strongly sloping, clayey soils; on uplands
7	**SILAWA-SILSTID-BASTSIL:** Deep, nearly level to sloping, loamy and sandy soils; on stream terraces

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