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**ARTHROPOD DIVERSITY COMPARISON OF THREE
DIFFERENT HABITATS IN
MESA VERDE NATIONAL PARK**

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ABSTRACT

National Parks can be considered areas of isolated refuge for plant and invertebrate communities that are near successional maturity with limited human disturbance. Three areas differing in dominant plant species, substrate composition and location orientation are examined and compared in terms of arthropod family diversity. Trophic strategies and feeding guild structure are also analyzed. The main purpose of this study is to begin the process of establishing a baseline arthropod inventory for these areas which can serve as a tool to indicate their overall health and stability.

The results indicate that while the number of families and the number of individuals collected was nearly the same for all study areas (with one exception) the taxonomic structure varied from habitat to habitat. This may be an indication of some plant-insect specialization relationships. Weather conditions and environmental factors can vary from one year to the next causing population fluctuations among invertebrate families. For this reason such studies should be repeated over several years to provide a more accurate baseline inventory.

INTRODUCTION

Increased demands on land for development and agriculture have destroyed or altered many of the natural habitat communities for invertebrate populations. Because of this ever-growing demand, National Parks have become isolated refuges that allow plant and insect populations to establish themselves with minimum outside interference or disturbance. Mesa Verde National Park provides a tremendous opportunity to observe long established invertebrate communities that are likely to have reached a stable species-area concentration.

Any disturbance to an established habitat can greatly affect the natural balance of the community. The elimination of one species can produce long term adverse effects on both plant and animal members of the community (Opler 1981, as cited by Kendall and Van Vleet, 1993). According to S.D. Hendrix, et al., invertebrate communities tend to closely mimic certain patterns of plant communities in terms of successional age of the habitat and those invertebrates present (1988).

Small scale diversity studies by Straw and Ludlow, indicate a strong correlation between host plant biomass and species richness for a given habitat. Plant biomass seems to be a better indicator of richness than plant geographic range. It has been calculated using models that insect density increases with host plant density and that there is a critical plant density required to maintain insect populations (1994). The successional stage of an area also influences the type and abundance of both plants and animals. The more advanced the successional stage of the community, the more stable the habitat it provides. This allows arthropods to apply long term niche strategies, i.e., insect-plant specialized relationships. In general, the number of species present increases with the successional age of the area (Brown & Southwood, 1983). Other studies indicate that insect grazing can be a major selective force in maintaining plant diversity and the development of plant defense mechanisms (Brown, 1985).

The purpose of this study is to begin the process of establishing a baseline inventory for these habitats within the National Park. The areas included in this study are vastly different from one another in terms of dominant plant species, plant biomass, substrate and location orientation. Family diversity in each habitat will be examined and compared, as well as the trophic strategies they employ. The composition of the feeding guilds will also be explored. All sites marked for this study are believed to be in the mid (7-8 yr..) to late (greater than 60 yrs.) successional stage of development.

Obtaining a baseline inventory for habitat communities is critical in understanding the overall balance or stability of an area. This information is important not only for the preservation of the biodiversity in National Parks, but inventories have become an extremely important tool for long term management of natural resources (Kendall, 1995). Baseline inventories, can be used to determine basic patterns of population dynamics. Once a basic pattern has been established, the information can be used to pin-point potential problems that may adversely affect the balance of the community. For example, a decrease in the invertebrate population may indicate a change in one or more of the environmental elements that has rendered the area unsuitable for that population (Berryman, 1986). These changes can be subtle and may not be apparent with casual observation, but the decrease in invertebrate populations can indicate forthcoming problems. The information can also be used to forecast population outbreaks of pests that may require some type of control.

METHODS AND MATERIALS

Three study areas were selected in the Mesa Verde National Park. Selection was based on distinct habitat differences and were within 2376 meters (~1.5 mile) of one another (see appendix for location map). Within each area, three 15.2m² plots were measured and marked in a 3 X 3 grid (three rows of three, 7.6m apart). Three different methods were used for the collection of insects.

Pitfall Traps

Pitfall traps were 4cm x 6cm glass jars buried in the ground with the top of the jar at the soil line. The jars were filled to the top with water. Specimens were collected at 2-3 day intervals from June 9, 1995 through July 27, 1995. Nine traps per plot were used for a total of twenty-seven traps in each area. Samples were collected by pouring the contents of each trap through a small aquarium net, then into a labeled container with 70% ethanol for transport.

Sweep Net

A sweep net was used for collection every two weeks from July 1, 1995 through September 14, 1995. Thirty sweeps per plot were performed by making three passes of ten sweeps each per 15.2m² plot. Specimens collected were placed in a killing jar, and transferred to labeled containers with 70% ethanol for transport.

Specimens collected from all of the methods described above were transported back to the lab. After they were sorted from debris, the samples were identified to family and pinned or placed in a labeled vial containing 70% ethanol.

STUDY AREAS

Area 1.

Elevation 2121m-2134m (6960'-7000'). Pinyon (*Pinus edulis*) and Juniper (*Juniperus spp.*) dominate the area with a heavy growth of scrub oak (*Quercus spp.*). The area is located at the base of a steep north facing slope with loess type substrate. The area also contains a large number of downed trees in varying stages of decay. Ground cover is sparse and includes *Astragalus spp.*, Broom Snake Weed (*Gutierrezia sarothrae*) and Musk Thistle (*Carduus nutans*) and others.

Area 2.

Elevation 2219m-2231m (7280'-7320'). This habitat is a very steep (>45°) south facing slope with a loose shale substrate. Vegetation is sparse and the most common species, predominantly medium sized shrubs, include Mountain Mahogany (*Cercocarpus montanus*), Mormon Tea (*Ephedra viridis*) and pinyons (*Pinus edulis*). Ground cover consists of an occasional *Astragalus spp.* and other species.

Area 3.

Elevation 2219m-2231m (6920'-6960'). This study site is covered by a dense growth of sagebrush (*Artemisia tridentata*) mixed with saltbrush (*Atriplex canescens*) and rabbitbrush (*Chrysothamnus nauseosus*). Ground cover is moderate and includes hookers onion (*Allium acuminatum*), globe mallow (*Sphaeralcea ambigua*), other small plants and sparse grasses. This area is bordered on the north by an access road and on the west by a small grassy meadow surrounded by Pinyon-Juniper forest.

Composition of the invertebrate communities were compared using several methods. The number of different families as well as the abundance in each family was compared between habitats. The Shannon-Weaver index (Shannon and Weaver 1963) was used to measure diversity for each area and compared. Specific feeding strategies employed by the different families collected are categorized using the numerical designations assigned by Dr. Robert Lavigne of the University of Wyoming, Laramie, Wyoming. These classifications were then combined into five more general feeding guilds as defined by Moran and Southwood, 1982, and modified by S.D. Brown et al., 1988, to illustrate the percent relative abundance for each feeding guild.

The Lavigne classification key indicates that an individual can utilize more than one feeding strategy depending on its developmental stage. When the strategies were regrouped into the more general feeding guilds, these individuals were included in all categories that applied.

Samples collected by sweepnet and pitfall methods were considered separately except when evaluating the percent relative abundance for the feeding guilds. Formicidae were excluded from the feeding guild percentages and the diversity index because the large fluctuation in the numbers collected indicated that some of the traps may have been placed in close proximity to a nest site. Collembola were also excluded because they are prone to sporadic population explosions that are more a factor of temperature and climate than habitat (Hendrix, Brown and Dingle, 1988). Although they were collected in relatively high numbers, the order Thysanura was included in the feeding guild percentages, but not in the diversity index because they appeared to be fairly evenly dispersed throughout the sagebrush study site during the collection period.

Key to Numerical Designations for Trophic Strategies and Feeding Guilds

	Lavigne	S.D. Hendrix*
1.	Plant tissue feeder	Phytophagous
2.	Plant sap feeder	Phytophagous
3.	Pollen/Nectar feeder	Phytophagous
4.	Seed feeder	Phytophagous
5.	Entomophagous predator	Predator
6.	Entomophagous parasitoid	Parasitoid
7.	Omnivore	Scavenger
8.	Saprophages	Scavenger
9.	Non-feeding stages	* *
10.	Blood feeding	Predator

*Hendrix includes the additional category of Tourist defined as, "...non-predatory species which have no permanent association with the vegetation but which use it for shelter, sustenance, basking or sexual display" (Hendrix, et al. 1988).

RESULTS

During the collection period between June 13, 1995 and September 14, 1995, a total of 2,846 individuals belonging to 69 different families were collected from the three study sites using pitfall traps and sweepnets. Of the fifty-three families of arthropods collected by pitfall trap, only eleven of were common to all three study sites. The numbers are similar for those insects collected by sweep net. Of the forty-eight families collected, ten were common to all three study sites with the same collection method (Tables 1-4). Trophic strategies employed by the different families was also analyzed and is illustrated in Tables 1-4.

The sites are all established habitats and the diversity of families and the abundance were comparable at all of the sites, as illustrated in Figures 2 and 3. The exception is the number of individuals collected by pitfall traps at the shale slope site where the number of individuals collected is significantly fewer. This is an area of very sparse vegetation and these results are consistent with the findings of Straw and Ludlow which established a strong correlation between the available vegetation and species abundance (1994).

This correlation is not apparent with the sweepnet method of collection where the number of individuals collected was slightly higher in the shale area than at the other sites. Many of the families collected by sweepnets are strong fliers. The increased abundance seen in the shale slope habitat may indicate a higher tourist population due to the accessibility or openness of the area and the extra warmth provided by the south facing orientation of the slope.

Results of the Shannon-Weaver diversity index provided similar values for all three study areas and for both collection methods (Table 5). The values obtained for the pitfall trap collection suggests that the south facing shale slope area expresses the most

TABLE 1. The number of individuals collected in each family and the trophic strategies they employ. Analysis reflects pitfall trap method of collection only.**

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategy Larvae	Adult
Alydidae	2			2	2
Apocrita	2			5	5
Asilidae	1			5	5
Coreidae	1			2	2
Dermestidae	3			8	8
Myrmeleontidae	2			5	5
Pteromalidae	1			6	3
Apidae	1		1	3	3
Aradidae	1		2	8	8
Bruchidae	1		1	4	3
Elateridae	1		1	4	1
Nematocera	3		3	1, 5, 8	3, 10
Scarabidae	7		6	1, 8	18
Scolytidae	1		4	1	1
Wasp (unk)	2		2	6	3
Buprestidae	2	8		1	*
Diptera (unk)	2	3		*	*
Ichneumonidae	1	1		6	3
Poduridae	275	25		8	8
Acarina	5	24	16	*	7, 8
Acrididae	2	8	4	1	1
Araneida	32	16	38	5	5
Carabidae	3	2	27	5	5

**See Methods and Materials section for key to feeding strategies

Table 1. Continued

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategy	
				Larvae	Adult
Cicadellidae	1	1	20	2	2
Curculionidae	10	9	2	1	1
Formicidae	537	422	216	*	7
Lygaeidae	1	1	2	2	2
Machilidae	23	3	346	8	8
Sphecidae	1	2	2	5	3
Tenebrionidae	47	19	41	1	8
Chrysomelidae		4	2	1	1
Gelechiidae		10	1	1	3
Gryllidae		22	6	7	7
Hemiptera (unk)		3	3	2	2
Homoptera (unk)		1	2	2	2
Mutillidae		1	3	6	3
Delphacidae		1		2	2
Eulophidae		2		6	3
Mantidae		1		5	5
Solpugida		1		5	5
Staphylinidae		1		5	5
Therevidae		1		5	*
Vespidae		3		5	3, 5
Aphidae			2	2	2
Chilipoda			1	5	5
Cyclorrhapha			5	*	*

**See Methods and Materials section for key to feeding strategies

Table 1. Continued

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategy Larvae	Adult
Dactylopiidae			1	2	2
Diplopoda			1	8	8
Gryllacrididae			5	*	*
Halictidae			2	3	3
Isopoda			3	8	8
Megachilidae			1	3	3
Scydmaenidae			1	*	*

Table 2. Families common to all three study areas of Mesa Verde National Park. Includes samples from pitfall trap collection method only.**

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategy Larvae	Adult
Acarina	5	24	16	*	7, 8
Acrididae	2	8	4	1	1
Araneida	32	16	38	5	5
Carabidae	3	2	27	5	5
Cicadellidae	1	1	20	2	2
Curculionidae	10	9	2	1	1
Formicidae	537	422	216	*	7
Lygaeidae	1	1	2	2	2
Machilidae	23	3	346	8	8
Sphecidae	1	2	2	5	3
Tenebrionidae	47	19	41	1	8

** See Methods and Materials section for key to feeding strategies

TABLE 3. Sweep net analysis for all three study areas. The number of individuals collected in each family and their feeding strategies.**

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategy	
				Larvae	Adult
Acarina	1			*	7, 8
Alydidae	1			2	2
Apidae	1			3	3
Braconidae	1			6	3
Membracidae	2			2	2
Ostomidae	1			5	*
Hemerobiidae	1			5	5
Sphecidae	2			5	3
Pieridae	1			1	3
Aphididae	8	1		2	2
Chalcididae	1	2		6	3
Eulophidae	1	3		6	3
Culicidae	2	1			
Cercopidae	7	1	2	2	2
Chrysomelidae	34	50	25	1	1
Cicadellidae	20	2	14	2	2
Curculionidae	3	4	8	1	1
Diptera	3	2	2	8	3
Formicidae	7	1	12	*	7
Gryllidae	1	1	5	7	7
Miridae	3	10	4	2, 5	2, 5
Pteromalidae	3	5	3	6	3
Araneida	7	5	19	5	5
Lygaeidae	2		6	2	2

** See Method and Materials section for key to feeding strategies

TABLE 3. Continued

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategy	
				Larvae	Adult
Nabidae	3		1	5	5
Acrididae		1	1	1	1
Cleridae		1	1	5	5
Anthicidae		1		1	3
Bombyliidae		1		3	3
Bruchidae		9		4	3
Carabidae		1		5	5
Dermestidae		1		8	8
Elateridae		11		4	1
Mordellidae		1		1	3
Tachinidae		1		6	3
Wasp (unk)		4	1	6	3
Acanaloniidae			5	2	2
Asilidae			1	5	5
Chrysopidae			1	5	5
Coccinellidae			3	5	5
Coleophoridae			1	1	3
Colletidae			1	3	3
Halictidae			1	3	3
Otitidae			1	8	*
Pentatomidae			1	2	2
Raphidiidae			1	5	5
Reduviidae			2	5	5

** See Method and Materials section for key to feeding strategies

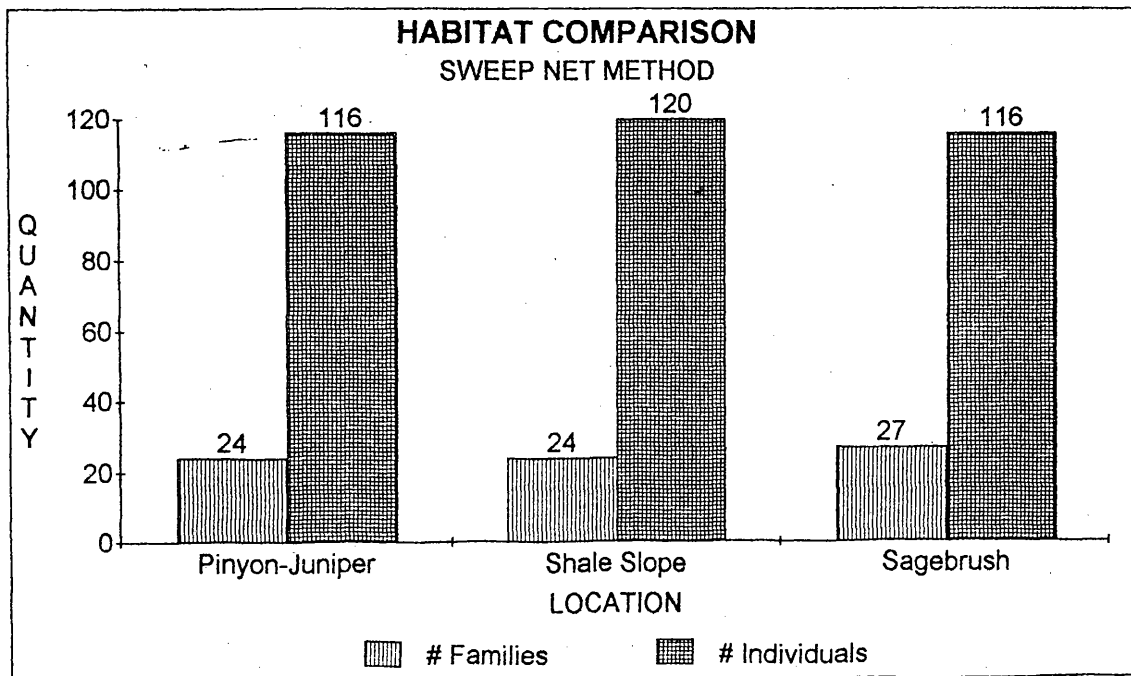
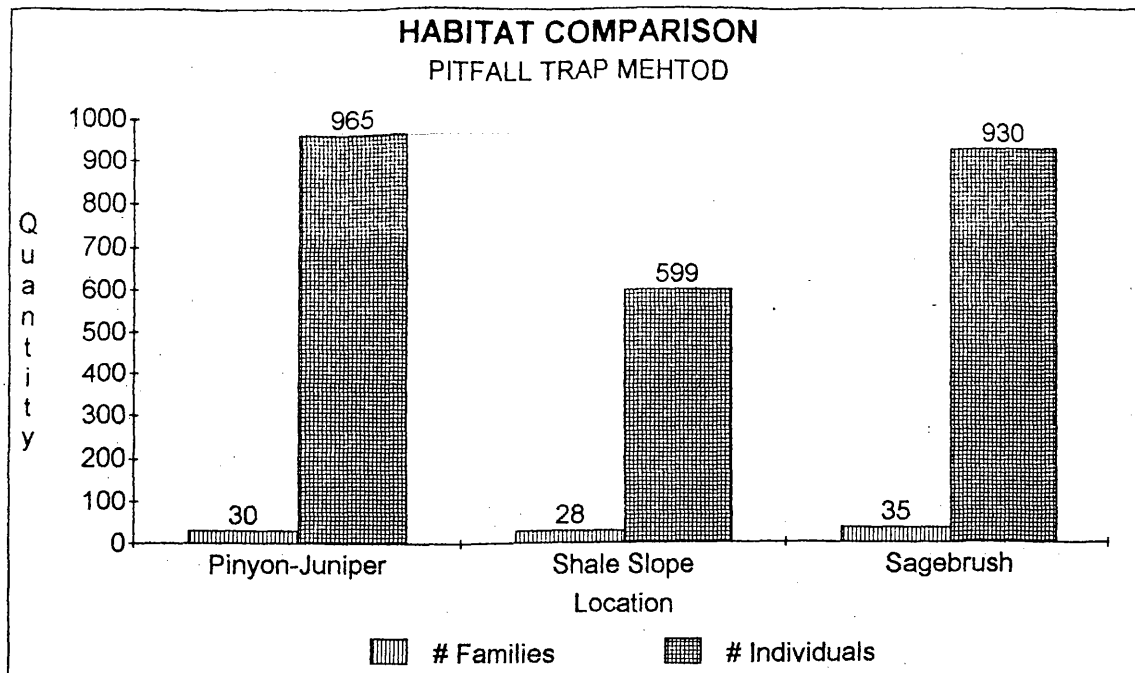


Fig.1. Comparison of families and individuals using both methods of collection.

Table 4. Families Common to all three study sites for sweep net collection.**

Family	Pinyon Juniper	Shale Slope	Sagebrush Valley	Trophic Strategies	
				Larvae	Adult
Cercopidae	7	1	2	2	2
Chrysomelidae	34	50	25	1	1
Cicadellidae	20	2	14	2	2
Curculionidae	3	4	8	1	1
Diptera	3	2	2	8	3
Formicidae	7	1	12	*	7
Gryllidae	1	1	5	7	7
Miridae	3	10	4	2, 5	2, 5
Pteromalidae	3	5	3	6	3
Araneida	7	5	19	5	5

**Table 5. Shannon-Weaver diversity indices for all three study sites.
Pit fall and sweep net results are compared.**

Collection Method	Pinyon Juniper	Shale Slope	Sagebrush Valley
PIT FALL	3.433	3.917	3.909
SWEEP NET	3.659	3.276	3.857

diversity in invertebrate families (3.917). The area with the second greatest diversity was the sagebrush valley with an index value of 3.909, followed by the pinyon-juniper forest with a value of 3.433. The sweepnet indices were also similar to each other but slightly different in priority than the pitfall results. The sagebrush produced the highest value, 3.857, followed by the pinyon-juniper site with a value of 3.660. The shale slope offered the lowest value of the three at 3.276. When all six values are compared, the maximum difference is 0.641 (max-min).

Feeding Guilds

The feeding guild percent distribution is represented in Table 6. Coleoptera composed the largest percentage of phytophagous arthropods in all three study areas, comprising more than half of all phytophagous arthropods collected. Homoptera was the second most prevalent order found in both the pinyon-juniper and sagebrush areas with 23% and 26% respectively. In the shale slope area Homoptera made up only 6% of the phytophagous arthropods collected. As mentioned earlier, the vegetation is very sparse in this area and could be a contributing factor. Arthropods grouped together in the "other" category include Lepidoptera and Diptera.

Araneida dominated the predators at all study sites with more than fifty percent of all predators collected falling into this order. Coleoptera was the second most prevalent predator found in the sagebrush area but Hemiptera was second in both the pinyon-juniper and shale slope habitats. The "other" predator category includes: Hymenoptera, Neuroptera, Chilopoda and Solpugida.

Parasitoids consisted solely of Hymenoptera and Diptera. The Hymenoptera clearly dominated at all study sites, however, this result may be a reflection of collection timing rather than a true indication of the numbers present.

Of the scavengers, Coleoptera dominated the pinyon-juniper forest, however, had the Collembola been included they would have represented the majority. This is due to

Table 6. Percent distribution of arthropods by taxa into feeding guilds.**

FEEDING GUILD	P & J %	S.E. +/-	So Slope %	S.E. +/-	Sagebr. %	S.E. +/-
<u>PHYTOPHAGOUS</u>						
Homoptera	22.3	0.716	6	0.125	26.1	0.464
Hemiptera	6	0.202	7.7	0.422	9.1	0.26
Coleoptera	64.5	0.459	63.4	0.242	51.1	0.359
Hymenoptera	5.4	0.179	12.6	0.285	9.1	0.26
Orthoptera	1.2	0	4.9	0.184	2.8	0
Other	0.6	0.401	5.5	0.125	1.7	0
<u>PREDATORS</u>						
Aranae	62.5	0.359	55.3	0.174	57.6	0.323
Coleoptera	6.25	0.333	13.2	0.501	31.3	0.266
Hemiptera	9.375	0.202	26.3	0.501	6.1	0.333
Diptera	9.375	0	2.6	0	1	0
Other	12.5	0	2.6	0	4	0.143
<u>PARASITIDS</u>						
Hymenoptera	80	0.25	80	0.286	100	0
Diptera	20	0	20	0	*	
<u>SCAVENGERS</u>						
Coleoptera	70.4	0	44.4	0	1.3	0
Thysanura	28.4	1.04	6.7	0	83.8	2.1
Orthoptera	1.2	0	48.9	0.395	3.9	0.282
Others	*		*		0.97	0
<u>TOURISTS</u>						
Diptera	100	0	100	0	63.6	0
Other	*	0	*		36.4	0

** See Methods and Materials section for key to feeding guilds

population explosions that occurred twice during the collection period. These were very concentrated explosions, found in only two of the pit traps on two different dates, and were not perceived to be major contributors to the entire area. The dominant scavenger found at the shale slope site was Orthoptera (Gryllidae) with 48%, followed closely by Coleoptera with 44%.

Thysanura (Machilidae) was the dominant scavenger in the sagebrush area with 83%. It is not clear whether this order should be excluded or designated as the dominant taxa. When Thysanura were included in the diversity index, the value dropped from 3.909 to 2.437. They do not live communally like ants so nest site proximity is not a factor, nor are they prone to population explosions of the magnitude of Collembola. The number of individuals collected was fairly consistent and evenly dispersed over the site during the entire collection period but they account for the majority of the arthropods found at the sagebrush site. Orthoptera (Gryllacrididae) constitute the second most prevalent scavenger of the sagebrush area. In the other scavenger category were Isopoda and Diplopoda.

The tourists consisted primarily of Diptera, though possibly a few of the Hymenoptera would fit into this category (see methods and materials section for definition of "Tourist"). The other designation in the tourist category includes Coleoptera, specifically the family Scolytidae. Members of this family were found at the sagebrush area. This is a beetle whose entire life cycle takes place in and around pine trees and ^{is} does not normally found in sagebrush. Because this valley^{is} surrounded by pine forest it is likely that emerging adult beetles were passing through the area.

DISCUSSION

The communities studied are in the later stages of succession, relatively free from human disturbance and considered stable in terms of the habitats they provide. But even in a stable environment there is some fluctuation in population from year to year due to variation in weather conditions and changing environmental factors. For example, drought conditions or an unusually wet year can greatly influence arthropod diversity and abundance in any area.

Collections performed over a single year or one season cannot be considered a reliable indication of what may be present in a subsequent year. For this reason studies should be repeated over several years to establish a more accurate baseline inventory.

The samples included in this study were limited to the mobile terricolous families and those collected on the vegetation with a sweep net. This collection by no means represents a complete inventory of any of the habitats studied. For example, termites (Isoptera) were observed in the pinyon-juniper forest and in the sagebrush valley under decaying wood but never presented themselves for collection by either method used in the study so they were not included. Many families of Lepidoptera were also observed the sagebrush site as well as many Odonata.

There were nearly the same number of families and individuals collected at each study site for both methods of collection, but the taxonomic structure varied from one habitat to the other. For pitfall collection less than 21% of the specimens collected were found in all three areas; less than 20% for the sweep net samples, indicating a degree of plant-insect specialization in each habitat. This is the expected pattern in areas that have reached mid to late successional stages (Brown and Southwood, 1983).

When the large populations of Machilidae, Poduridae and Formicidae are included, scavengers make up the majority of the arthropods found. If these three are

excluded, the phytophages become the most dominant feeding guild represented. These findings are consistent with the results of S.D. Hendrix, et al. in their 1988 study on feeding guilds and succession.

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APPENDIX

Map of Study Sites at Mesa Verde National Park

