COO-1731-4

Final Report

for

43552

Contract No. AT (11-1)- 1731
Brigham Young University

Free Living Mites of the

Nevada Test Site
(COO-1731-4)

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INTRODUCTION

Although ecological studies at the Nevada Test Site began in 1951, studies of flora and fauna started in 1959 when Brigham Young University began working on some rather preliminary, but basic, ecological studies. Since that time, numerous biotic surveys have been made along with many varied ecological studies. The results of most of these are listed by Allred, Beck, and Jorgensen (1965), although some additional publications have appeared since. Many incidental collections of mites suggested that the fauna was extremely diverse, with numerous species that were yet to be described. Studies of desert mite fauna are conspicuous because of their absence. Thus far, they are almost limited to agricultural areas in the desert.

The importance of understanding nuclear weapons testing effects on plant and animal populations is apparent if one considers nuclear energy as a tactical weapon. This problem has been discussed briefly for several different plants and animals from the Nevada Test Site (Allred and Beck 1962, 1963a, 1963b; Allred, Beck, and Jorgensen 1963, 1965; Barnum 1964; Beatby 1965a, 1965b, 1966; Beck, *et al.* 1964; Jorgensen, Allred, and Beck 1963; Martin 1964; Muma 1963; Richards 1962; Shields and Wells 1962; Tanner and Jorgensen 1963; and Tanner and Packham 1965). Since many of the mites are plant feeders, their respective numbers and composition would be expected to change as the vegetation responds to nuclear weapons testing.

Some of the species present on desert vegetation are also found on agricultural crops (Baker and Tuttle 1964, Tuttle and Baker 1964) in large

enough numbers to cause considerable damage. Because of the possible use of nuclear energy as tactical weapon, and subsequent reaction by agricultural pests is important to know. This becomes even more important when one considers the population reactions to vegetative changes reported by Rodriguez (1951, 1958). Sax (1963) further demonstrated that low level radiation and herbaceous plants often reacts as a growth stimulant.

The objectives of these studies were to examine the effects of nuclear weapons testing on phytophagous mite distribution and composition, and to examine what free living mites are present at the Nevada Test Site. The results of these studies will be presented in sub-sections designed to meet the objectives stated above.

EFFECTS OF NUCLEAR WEAPONS TESTING ON FREE-LIVING MITE POPULATIONS

The stresses imposed on all levels of life by ionizing radiations have recently received considerable attention. Concern has developed from a general response to the biological implications that may attend increased levels of radioactive materials in the environment (Boffey 1969; Edwards 1969; and Morgan 1969), or a nuclear catastrophe (Eberhardt 1967). Studies of cellular and organismal responses have contributed substantially to what is known about these stresses, but less has been learned about responses at the community and population levels (Sacher 1966 and Casarett 1968).

While levels of radioactive materials have increased sharply during the past two decades, ionizing radiations are not recent phenomena (Woodwell 1963). Since they have always been among the natural components of the environment, Woodwell (1962 1967), and Platt (1962) suggested that they should be studied as natural environmental variables. Experimental designs to study

radiation stress should, therefore, include studies of their interactions with other environmental and biological components of the ecosystem.

With few exceptions (Auerbach 1958, Coleman and Macfadyen 1966, Teresi and Newcombe 1966, Marshall 1966, and Reeves 1971) methods of quantitatively measuring population responses to radiation stresses have been developed while studying either plant communities, small mammals, or reptiles. Arthropods, particularly mites and associated arachnids, have been neglected or only incidentally reported. Further, the form of radiation reported in earlier studies has almost always been gamma, while beta radiation has received relatively little attention.

Teresi and Newcombe (1966), stressed this omission and emphasized that the biological responses to beta radiation need to be better understood. They suggested that the total contact beta dose from fallout is much greater than the associated gamma dose, and is possibly a more relevant problem for study. This view was corroborated by Rhoads *et al.* (1968) who suggested that there is sufficient evidence of beta damage to desert plants to merit further investigation.

The objectives of this study were to examine two population responses (i.e., species diversity and trophic organization) of desert mites, under field conditions, to ionizing radiations--particularly the effects of beta radiation. The results may be used to estimate responses of similar populations during nuclear war, in contaminated environments, or perhaps in pest control programs. ✓

Location and Description of Sampling Sites

The study area (Fig. 1) at the United States Atomic Energy Commission Nevada Test Site was located on Pahute Mesa, 112 km northwest of Mercury,

Fig. 1. Nevada Test Site, Mercury, Nevada. Location of the study area is indicated with an arrow.

Nye County, Nevada. It was situated in a southern extension of the Great Basin Desert at an elevation of 1859 m, and was characterized by low hills. The United States Weather Bureau, Las Vegas, Nevada, recorded 18.7 cm annual rainfall at the study area during 1968, and 25.4 cm in 1969. See Allred, Beck, and Jorgensen (1963) for a detailed description of the area.

Artemisia spp. (Sagebrush) and *Juniperus osteosperma* (Juniper) formed the dominant vegetation (Rhoads, et al. 1968), while *Cowania mexicana stanburyana* (Desert rose), *Ephedra nevadensis* (Brigham tea), and *Grayia spinosa* (Hopsage) made up the major portion of the remaining flora. Frequent hybridization between *Artemisia tridentata* and *Artemisia arbuscula nova* made it impossible to distinguish these species in some locations.

Five sampling sites northwest and northeast of the Project Cabrioleet Ground Zero (G.Z.) were designated at Sites I, II, IIIa, IIIb and IV (Fig. 2).¹ The fallout cloud from Cabrioleet provided the source of radiation for this study. The five collection sites were selected on the basis of their positions relative to the fallout pattern, and the varying amounts of radiation damage to sagebrush. Sites II, IIIa, and IIIb (experimental sites) were located within the fallout pattern, whereas Sites I and IV (control sites) were not (Fig. 2). The five sites were not enclosed nor otherwise delimited with physical boundaries, but served as collection areas.

Two dosimeter arcs, 610 m and 915 m from G.Z., were established within the projected northwestern pattern to monitor the fallout (Fig. 2) (Rhoads, et al. 1968). The actual pattern, however, moved northeast from G.Z.

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¹Project Cabrioleet was an underground, partially contained nuclear test in the Flowshare series. It was detonated Jan. 26, 1968 and had a yield of 2.3 ± 0.5 kt.

Fig. 2. Study area showing Ground Zero (G.Z.) of Cabriolet, direction of fallout cloud (indicated by arrow), location and distance from G.Z. of dosimeter arcs, and individual study sites. G.Z. coordinates were: longitude W $116^{\circ} 30' 52.0082''$, latitude N $37^{\circ} 16' 51.0715''$.

and completely missed, by several hundred meters, the dosimeters in the 915 m arc. When the study sites were established within the actual fallout pattern, the radiation levels of Sites IIIa and IIIb had to be estimated (Table 1). This was done by determining the rate of isotope decay of the known levels at the 601 m arc, and comparing these with the radiation levels recorded seven months following detonation, in August, 1968.

Site I was designated as a control in 1968 for the three sites within the fallout pattern. It was situated well outside of the pattern with its nearest exposure approximately 1500 m northeast of G.Z. (Fig. 2). The site was located in a shallow depression somewhat sheltered from the wind. Sagebrush appeared much more vigorous than similar plants in Site II, although they were much the same as those in Sites IIIa and IIIb.

Site II was nearest to the radiation source at 580 m from G.Z. (Fig. 2). This site was located on the southern, windward exposure of a low hill directly within the fallout path. Sagebrush was short and dwarfed, although the species composition was similar to that of the control site. Its stunted condition was possibly due to the physical exposure of the area, and locally heavy dust from a nearby road (Beatley, 1965).

Radiation damage to the sagebrush was not apparent for three months after detonation; but by late May occasional yellowing was seen. Color changes and death progressed through the summer until most of the leaves, on both the leeward and windward sides of the plants, had either fallen or had turned a dark brown-gray. There was no apparent recovery during the remaining period of the study and new foliage did not appear except for numerous sagebrush seedlings.

Site IIIa was located 150 m north of Site II, on the leeward side of the

Table 1. Average beta and gamma radiation levels at various locations within Sites II, IIIa, and IIIb.

Sampling Site	Distance from Ground Zero	Average Beta and Gamma Levels (Rads) Windward (W) and Leeward (L) Sides of Sagebrush ^a	
		Beta	Gamma
Site II	610m	W- 5783 L- 5783	W- 749 L- 661
Site IIIa Site IIIb	640m	W- 5139 L- 3212	W- 344 L- 397
Site IIIa Site IIIb	670m	W- 3694 L- 2409	W- 291 L- 317
Site IIIa Site IIIb	700m	W- 2088 L- 1605	W- 264 L- 264
Site IIIa Site IIIb	730m	W- 2088 L- 1766	W- 264 L- 238
Site IIIa Site IIIb	760m	W- 2088 L- 2088	W- 211 L- 185

^aSite IIIa, the windward plant parts; and Site IIIb, the leeward plant parts, shared the same location. Original radiation levels were obtained only for Site II, while those of Sites IIIa and IIIb were estimated.

same hill (Fig. 2). Foliage on the windward side of the sagebrush in this area, which had obviously been damaged by radioactive fallout, provided the collection material for this site.

Site IIIb was situated at the same location as Site IIIa (Fig. 2). This site, however, included those plants or plant parts which had been less exposed to the radiation (Table 1) because of shielding by Junipers, large rocks, other sagebrush, etc. Leaf color change at this site during 1968 was similar to that in Site II, thus making it easy to distinguish between the heavily irradiated plants of Site IIIa and the shielded plants of Site IIIb. With a major portion of the windward side of the plants dead (Site IIIa) the viable root system continued to provide the remaining few leeward branches of Site IIIb with an abundant nutrient supply during the latter part of 1968 and through the summer of 1969.

The result was unusually lush foliage and inflorescence ("flag effect") which provided abundant foliage for sampling during the summer of 1969.

Site IV was used as a backup control during 1961. It was located well outside of the fallout pattern, approximately 1400 m from G.Z. (Fig. 2). This site was established after the 1968 season to serve basically as a control for Site II. As with Site II, this control was situated on a southern, windward exposure and the sagebrush appeared short and stunted.

Methods of Collecting

Mites were collected from *Artemisia* spp. by gathering foliage 6 - 10 cm in length from arbitrarily selected plants. To minimize sampling bias, only one or two spurs were taken from any given plant at each monthly collection. Enough were taken to fill a 20 X 90 cm plastic bag to a depth of approximately 15 cm. Five such samples were collected from each site once a month from

June through September, 1968 and 1969.² Sites II and IIIa were sampled only during 1968 since the radiation damage or death of the host plants in these areas prevented collecting during the 1969 summer.

Samples were each placed in a modified Berlese funnels for 48 hours. The mites were then removed, and representatives of eighteen species groups were mounted in Hoyer's media for identification. The number of mites within each sample varied widely and rather than relying on estimates of the total numbers, all mites were counted.

Methods of Analyses

Quantitative measurements in population and community studies frequently employ sex ratios, age class distributions, coefficients of community (Woodwell and Oosting 1965), equitability indices (Lloyd and Ghelardi 1964), and similarity indices (Daniel 1963, and Daniel and Platt 1968). Use of such methods assumed that the various parameters involved were predictable. In the present study predictability of these parameters, and others of the population's composition, was uncertain; thus, the above measurements could not be used. Woodwell (1967) and Garrett (1969) suggested that an index of species diversity, by itself, was a meaningful criterion of a population's response to stress. Garrett (1969) further suggested that the highly random fluctuations inherent in these other methods were not characteristic of species diversity indices.

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²Duff from beneath the host plants was collected in a similar manner. Smaller bags, 30 X 60 cm, were filled approximately 10 cm deep and, as before, each bag constituted one sample. Each site was sampled five times during 1968 but the following year the collections were discontinued and the data was not used for analysis.

Pielou (1966) presented a series of diversity indices fitted to particular sampling methods and distributions. A version of Shannon's index (Pielou 1966), which was well fitted for the present study, was used:

$$\hat{H}_j = - \sum_{i=1}^s p \log p$$

where: $p = n_i / N_j$, and n_i is the total number of individuals in the i^{th} species of the j^{th} collection, and N_j is the total number of individuals in the j^{th} collection,
 s = the total number of species in the population (=18).

Basharin (1959) demonstrated $\hat{H}_j$ to be a biased estimator of H_j and if used, s must be known since the size of the bias depends on s . He further proved that the expectation of $\hat{H}_j$ is:

$$E(\hat{H}_j) = H_j - \frac{s-1}{2N_j}$$

Applying this correction factor, the index used in the present study becomes:

$$\hat{H}_j = \frac{s-1}{2N_j} - \sum_{i=1}^s p \log p$$

A second test of the population's response was determined by measuring the variation in sensitivity of the different trophic levels present. Rohde (1959) showed that under laboratory conditions the predatory mite of a two species interaction was predictably more sensitive to radiation stress than was the prey mite. In the present study, an analysis of the fluctuations in time and space, of the numbers of individuals within each level was made by comparing the ratios of predaceous mites with phytophagous and scavenger forms.

Percentages were used rather than total numbers so that his test, like the species diversity indices, would be less dependent on the wide variations caused by sampling methods. Ratios were computed with:

$$\Delta = \frac{P_i}{T_i - V_i}$$

where: P_i = the percentage of total number of mites in the i^{th} collection that were predaceous,

T_i = the percentage of total number of mites in the i^{th} collection that were phytophagous,

V_i = the percentage of total number of mites in the i^{th} collection that were scavengers.

RESULTS

Seventeen phenotypically distinct groups of mites were identified (Tables 2 and 3). Of these, one was parasitic, ten predaceous, four scavengers, and two phytophagous (Table 4). Several specimens could not be identified and properly grouped so they were collectively placed in a miscellaneous grouping, bringing to 18 the number used for analyses. All groups were not represented in each collection or sample, and in several instances only one or two individuals of a given group were collected during the entire two year study (Tables 2 and 3). Others, such as the many species of Tenuipalpidae, were present in large numbers and in all samples. All species groups exhibited patchy distributions, resulting in wide variations among the sample means used to compute the species diversity indices and, further, caused some fluctuation among the ratios of the trophic level tests.

Table 2. Numbers of mites in each species group for all samples taken, 1968.

Site Number and Month	Trombiculidae	Ecdellidae	Nanorchestidae	Tenneriffidae	Anystidae	Phytoseiidae	Stigmatidae	Smarididae	Neophyllobius	Parasitengona	Trombididae	Oribatidae #1	Oribatidae #2	Oribatidae #3	Tydeidae	Tenuipalpidae	Tetranychidae	Miscellaneous	Total
Site I																			
June	2	1	0	0	2	98	2	0	2	0	14	6	2	0	204	92	0	4	429
July	0	0	2	0	0	61	4	0	1	0	0	0	0	0	32	155	0	7	266
Aug	0	0	1	0	1	40	10	0	2	0	0	0	1	0	67	71	0	7	201
Sept	0	1	3	0	13	56	0	0	0	0	0	0	0	0	162	62	0	4	301
Total	2	2	6	0	16	255	16	0	5	0	14	6	3	0	465	380	0	22	1197
Site II																			
June	0	0	64	0	1	0	2	0	0	0	4	0	0	0	0	94	0	11	176
July	0	0	22	0	1	1	5	0	0	0	0	0	2	0	0	93	4	10	138
Aug	1	1	18	0	21	1	0	0	0	0	0	0	4	2	0	174	0	12	234
Sept	0	0	1	0	17	0	2	0	0	0	0	0	1	0	0	105	3	14	142
Total	1	1	115	0	40	2	9	0	0	0	4	0	7	2	0	466	7	47	690
Site IIIa																			
June	0	0	61	0	2	0	9	0	0	0	8	4	3	0	15	71	1	9	186
July	0	0	7	0	0	0	6	0	0	0	5	0	0	0	1	107	7	10	145
Aug	1	0	14	0	3	0	3	0	0	0	0	2	0	0	3	60	1	8	95
Sept	0	0	0	0	18	0	3	0	0	0	0	3	0	0	4	24	0	9	61
Total	1	0	82	0	23	0	21	0	0	0	13	9	3	0	23	262	9	36	487

Table 2. (continued)

Site Number and Month	Trombiculidae	Bdellidae	Nanorchestidae	Tennereffidae	Anystidae	Phytoseiidae	Stigmatidae	Smarididae	Neophylobius	Parasitengona	Trombididae	Oribatidae #1	Oribatidae #2	Oribatidae #3	Tydeidae	Tenuipalpidae	Tetranychidae	Miscellaneous	Total
Site IIIb																			
June	4	0	57	0	28	2	12	0	0	1	21	15	1	0	54	69	1	21	287
July	0	0	2	4	4	12	6	0	0	0	3	1	0	0	0	58	4	1	95
Aug	0	0	8	0	19	1	1	0	0	0	0	1	0	0	0	152	2	8	192
Sept	0	0	1	0	99	6	6	0	0	0	0	0	0	0	0	82	1	11	200
Total	4	1	68	4	105	25	25	0	0	1	24	17	1	0	54	361	8	41	775

Table 3. Numbers of mites in each species group for all samples taken, 1969.

Site Number and Month	Trombiculidae Bdellidae		Nanorchestidae Tennereffidae		Anystidae	Phytoseiidae	Stigmatidae	Smarididae	Neophyllobius	Parasitengona	Trombididae	Oribatidae #1	Oribatidae #2	Oribatidae #3	Tydeidae	Tenuipalpidae	Tetranychidae	Miscellaneous	Total
Site I																			
June	0	0	2	0	5	1	10	0	0	0	6	1	0	0	71	30	6	3	135
July	0	0	0	0	5	67	9	0	0	0	1	2	0	0	353	119	3	9	568
Aug	3	0	3	2	10	36	19	0	1	0	0	0	0	0	110	109	0	4	297
Sept	2	0	0	2	2	16	18	0	0	0	0	1	0	0	296	275	0	2	614
Total	5	0	5	4	22	120	56	0	1	0	7	4	0	0	830	533	9	18	1614
Site IIb																			
June	3	0	2	0	7	0	2	0	0	0	8	0	0	1	2	34	5	2	65
July	1	0	3	0	2	0	0	1	0	0	4	0	0	0	0	94	0	4	106
Aug	0	0	3	0	8	1	3	0	0	0	0	1	0	0	0	149	4	0	169
Sept	0	0	2	0	10	1	3	0	0	0	0	3	0	0	1	278	0	0	298
Total	4	0	10	0	27	2	8	1	0	0	12	4	0	0	3	553	9	6	638
Site IV																			
June	1	0	1	0	3	0	18	0	0	0	9	2	5	0	5	234	1	2	281
July	0	0	7	0	3	0	4	0	0	0	7	1	2	0	1	423	0	6	454
Aug	2	2	11	0	10	0	30	0	0	0	0	1	2	0	0	889	3	0	950
Sept	0	0	2	0	4	0	14	0	0	0	1	0	3	0	3	996	0	0	1023
Total	3	2	21	0	20	0	66	0	0	0	17	4	12	0	9	2512	4	8	2708

Table 4. Trophic designation and relative abundance of mites collected, 1968 and 1969.

Species Observed	Trophic level	Percentage of Total Collection		
		Site I, II, IIIa and IIIb		Site IV ^a
		1968	1969	1969
1. Trombiculidae	parasitic	0.2	0.5	0.1
2. Bdellidae	predaceous			
3. Nanorchestidae	"			
4. Tenneriffidae	"			
5. Naystidae	"			
6. Phytoseiidae	"	28.5	12.1	4.7
7. Stigmatidae	"			
8. Smaridiidae	"			
9. Neophylobius	"			
10. Parasitengona	"			
11. Trombidiidae	"			
12. Oribatidae #1	scavenger			
13. Oribatidae #2	"	18.7	37.4	0.9
14. Oribatidae #3	"			
15. Tydeidae				
16. Tenuipalpidae	phytophagous	47.8	48.9	93.9
17. Tetranychidae	"			
18. Miscellaneous	undetermined	4.7	0.9	0.3

^aSite IV is considered separately in this comparison since it did not qualify as a two year collection site.

Species Diversity ($\hat{H}$)

Site I (Fig. 3). Diversity indices declined through both summers in this control. There was, however, more fluctuation between the monthly values of 1969 than during 1968. Initially, the values were 1.4 in June, 1968 and 1.6 in June, 1969. These then dropped to 1.2 in September, 1968 and 1.0 in September, 1969.

Site II (Fig. 4). This area was the most heavily irradiated of the study sites (Table 1). Diversity indices fluctuated through the summer of 1968 increasing slightly from 1.2 in June to 1.4 in September. Data were not obtained in 1969.

Site IIIa (Fig. 5). Heavy irradiation was also received in this area but not to the same extent as in Site II. Diversity indices dropped between June and July, 1968 from 1.5 to 1.2 and then increased to 2.0 in September. Again, data were not obtained during 1969.

Site IIIb (Fig. 6). The plants and plant parts included within this area received relatively moderate irradiation (Table 1), and $\hat{H}$ showed a rapid decrease during both summers. In 1968 it dropped from 1.9 in June to 1.3 in September. During the following year it again dropped, this time from 1.9 in June to 0.7 in September.

Site IV (Fig. 7). Within this second control, a slight but persistent decline in $\hat{H}$ was observed. The pattern was similar to that in Site I during 1969, but the decline was only from 0.8 in June, 1969 to 0.2 in September. These smaller figures were also reflected in the small variances about the means of each $\hat{H}$. Also, the number of individual mites collected, but not the number of species, far exceeded those collected from any other site during either year (Tables 2 and 3).

Fig. 3. Species diversity indices for mites in Site I, 1968 and 1969.

Fig. 4. Species diversity indices for mites in Site II, 1968.

Fig. 5. Species diversity indices for mites in Site IIIa, 1968.

Fig. 6. Species diversity indices for mites in Site IIIb, 1968 and 1969.

Fig. 7. Species diversity indices for mites in Site IV, 1969.

Trophic Level Organization (Δ)

The respective percentages of mites comprising given trophic levels shifted markedly between 1968 and 1969 (Table 4). The overall average percentage of phytophagous forms remained approximately 48%, but the predaceous species declined within the same sites from 28.5% in 1968 to 12.1% in 1969, and scavenger forms increased from 18.7% to 37.4%. The percentage of the single parasitic species also doubled, but its numbers appeared too few to be considered important (Tables 3 and 4). Yearly differences in climatic conditions made analyses of the trophic associations among collections for the same year more meaningful than between years (Tables 5 and 6).

Site I (Fig. 8). Within the first control during 1968, the ratio of phytophagous and scavenger forms to predaceous mites remained between .32 and .39, a relatively stable pattern. During 1969, however, monthly fluctuations ranged from .31 in August to .06 in September.

Site II (Fig. 9). The trophic ratios exhibited a sharp drop during 1968, going from .78 in June to .29 in July, followed by a gradual decline to .18 in September.

Site IIIa (Fig. 10). The greatest single, between-month drop in Δ was observed in this site from June, 1968 to July. The initial figure of .85 dropped to .15 by July and then progressed upward through the remaining summer months to .67 in September.

Site IIIb (Fig. 11). Delta (Δ) dropped sharply, from .88 in June, 1968 to .18 in August and then rose even more abruptly to a high value of 1.2 in September. During 1969 a similar but smaller drop was plotted in this

Fig. 8. Ratio of predaceous mites to phytophagous and scavenger forms in Site I, 1968 and 1969.

Fig. 9. Ratio of predaceous mites to phytophagous and scavenger forms in Site II, 1968.

Fig. 10. Ratio of predaceous mites to phytophagous and scavenger forms in Site IIIa, 1968.

Fig. 11. Ratio of predaceous mites to phytophagous and scavenger forms in Site IIIb, and 1968 and 1969.

Table 5. Percentage of montly collections belonging to different trophic levels, 1968.

Site Number and Month	Parasitic	Predaceous	Scavenger	Phytophagus	Miscellaneous
Site I					
June	0.46	27.73	49.41	21.44	0.93
July	0.00	25.56	12.03	58.27	2.63
Aug	0.00	26.68	33.83	35.32	3.48
Sept	0.00	24.25	53.82	20.59	1.32
Site II					
June	0.00	40.34	00.00	53.40	6.25
July	0.00	21.01	1.44	70.28	7.24
Aug	0.42	17.52	2.56	74.35	5.12
Sept	0.00	14.08	0.70	76.05	9.85
Site IIIa					
June	0.00	43.01	11.82	38.70	4.83
July	0.00	12.41	0.68	78.62	6.89
Aug	1.05	21.05	5.26	65.26	8.42
Sept	0.00	34.42	11.47	39.34	14.75
Site IIIb					
June	1.39	43.20	24.39	24.39	7.31
July	0.00	32.63	1.05	65.26	1.05
Aug	0.00	15.10	0.52	80.20	4.16
Sept	0.00	53.00	00.00	41.50	5.50

Table 6. Percentage of monthly collections belonging to different trophic levels, 1969.

Site Number and Month	Parasitic	Predaceous	Scavenger	Phytophagus	Miscellaneous
Site I					
June	0.00	17.77	53.33	26.66	2.22
July	0.00	14.43	62.50	21.47	1.58
Aug	1.01	23.56	37.03	36.70	1.34
Sept	0.32	6.18	48.37	44.78	0.32
Site IIIb					
June	4.61	29.23	3.07	60.00	3.07
July	1.53	8.48	0.00	86.79	3.77
Aug	0.00	8.87	0.59	90.53	0.00
Sept	0.00	5.36	1.34	93.62	0.00
Site IV					
June	0.35	11.03	4.27	83.62	0.71
July	0.00	4.62	0.88	93.17	1.32
Aug	0.21	5.57	0.31	93.89	0.00
Sept	0.00	2.11	0.60	97.28	0.00

site in a series of percentage readings which, like those of Site I, were smaller during the second season. Delta then leveled at .09 in July and remained relatively constant through August and September.

Site IV (Fig. 12). Very little monthly fluctuation was observed in this site during 1969. Delta (Δ) dropped from .12 in June to .02 in September. This was shown to be the most stable pattern, as well as the smallest of the ratios found in any of the sites during the entire study period.

DISCUSSION

Studies of population and community responses to ionizing radiation have largely neglected the mites. Because of their large numbers and diverse habits, however, mites comprise a significant part of the terrestrial community and should not be ignored. Furthermore, when references to the responses of mites to ionizing radiation have been made, the form of radiation has usually been gamma. This almost exclusive use of gamma radiation appears unjustified, since, as Teresi and Newcombe (1966) pointed out, the potential contact beta load from fallout is much greater than the potential associated gamma.

This study reports responses of naturally occurring desert mites to ionizing radiation. Responses were determined by analyses of species diversity indices and trophic level fluctuations. The major form of radiation was beta, but an attempt was not made to partition the effects of gamma and beta; thus, the major part of the population's response was assumed to be due to the greater magnitude of the beta radiation (Table 1) (Van Hook, 1970).

Fig. 12. Ratio of predaceous mites to phytophagous and scavenger mites in Site IV, 1969.

Species Diversity

Seasonal changes would be expected to cause a decreasing species diversity as the summer progressed within all of the sites, and further, the species diversity within the irradiated sites would likely decrease proportionately more (Woodwell, 1967; and Garrett, 1969). This predicted decrease in diversity was observed in the control sites, reflecting the normal seasonal changes, but within the experimental sites diversity increased. This increase under high environmental stress challenged the results reported by Woodwell (1967), Garrett (1969), and others who have reported decreasing diversity indices caused by increased stress.

Interpretation of these analyses necessitates first recognizing some factors about the species diversity index which, when altered, could change it. Increases or decreases in species diversity can result from increases or decreases in the equitability, or evenness, of the distribution of the individuals among the species. That is, the more equitable the distribution, the more diverse the population. Conversely, the more erratic or uneven the distribution, the less likely an individual will belong to a given species and the less diverse the population. This could occur if large numbers of individuals in one or two species were associated with many species containing very few individuals. By decreasing the number within the more abundant species, the difference between them and those with fewer numbers is decreased. The diversity index, therefore, is increased as the numbers approach equitability.

The stable and increasing diversity indices within the experimental sites were explained on the basis of decreasing numbers of the most abun-

dant groups (Tables 2 and 3). In all study sites except Site I, Tenuipalpidae numerically dominated the collections. Even in Site I it comprised almost 23 % of the individuals taken during both summers. However, Tydeida comprised another 38.8% of the collections in 1968 and 51.4% in 1969 (Tables 2 and 3). Increases in the numbers of these two groups caused the decreasing evenness, resulting in decreased diversity indices during 1969. Increasing numbers of Tenuipalpidae in Site II decreased the diversity and caused the index to fluctuate throughout the 1968 summer. Conversely, decreasing numbers of this group in Site IIIa contributed to the increase in diversity during 1968. Diversity indices for Site IIIb decreased during 1968 and 1969. This was likely because the relatively small radiation fallout on this site did not cause it to depart from the seasonal decrease. This was particularly apparent in 1969 when recovery was under way. The relative lack of change in the indices during 1968 was apparently due to the modifying effect of several species groups (Tenuipalpidae, Anystidae, Nanorchestidae, and Tydeidae).

The results suggest that species diversity tended to increase or remain stable when subjected to radiation stress. This was due to a more even distribution of individuals among the groups (particularly the decrease in Tenuipalpidae), rather than increasing numbers of the groups themselves.

Trophic Level Organization

MacArthur (1955), Auerbach (1958, and Edwards (1969) reported a decreasing predator-prey ratio when stress increased, and Rhode (1959)

stated that a mite predator was more sensitive to the radiation stress than was the mite prey. Analyses of the trophic level organization generally agreed with these findings, and in the two control sites either a decreasing or fluctuating predator-prey ratio was observed. This was assumed to be the normal seasonal pattern. Results from irradiated Sites IIIa and IIIb, however, did not conform to the predicted results but rather, increased sharply after an initial drop.

As with the species diversity analyses, these ratios were greatly influenced by the phytophagus Tenuipalpidae and increased or decreased according to changes within that group. However, a relatively large proportion of the collections from Sites IIIa and IIIb was composed of several predaceous groups (Nanorchestidae, Anystidae, Stigmatidae, and Trombididae). Because of these groups the predator-prey ratio increased during the late summer, 1968, in spite of the increased radiation stress in these sites. This was also true for the increased ratio in Site I during August, 1969.

It is suggested that because of the apparently unpredictable and often extreme variations in the distribution patterns of these groups that more must be learned concerning their biology, and furthermore, that it is advisable to closely correlate controlled-laboratory investigations of radiation stress with those of naturally occurring populations.

FREE LIVING MITES COLLECTED
FROM THE NEVADA TEST SITE

Mites were collected from at least 111 plant species. In all there were over 500 collections taken from a diverse variety of species, ranging from the very short lived annuals to the persistent perennial shrubs and trees. An effort was made to sample all of the major perennials and as many of the more persistent annuals as possible.

Collection Methods

Plant material and/or debris was collected in paper bags and returned to the laboratory where the collected material was placed in Modified Berlese funnels for 48 hours. Mites were recovered in 70% ethyl alcohol and retained until samples could be mounted for identification. The plant species that were sampled were:

Acanthopappus Shockleyi
Ambronia orbiculata
Ameiokia tessellata
Artemisia ludoviciana
Asclepias erosa
Atriplex canescens
Atriplex hymenelytra
Atriplex sp.

Baccharis sergiloides
Baileya pleniradiata
Berula erecta

Castilleja chromosa
Chrysothamnus sp.
Cleome lutea
Cowania Stanburyana
Cuscuta nevadensis

Dalea Fremontii

Amaranthus fimbriatus
Amelanchier utahensis
Argemone munita
Artemisia tridentata
Astragalus lentiginosus
Atriplex confertifolia
Atriplex polycarpa

Baileya multiradiata
Baileya sp.
Buddleia utahensis

Chrysothamnus nauseosus
Chrysothamnus viscidiflorus
Coleogyne ramosissima
Cryptantha confertiflora
Cymopterus deserticola

Dalea polyadenia

Elymus cinereus
Ephedra funerea
Ephedra viridis
Eriogonum caespitosum
Eriogonum inflatum
Eriogonum microthecum
Eriogonum umbellatum
Eriophyllum Pringlei
Eschscholzia glyptosperma
Euphorbia albomarginata

Fallugia paradoxa

Gaura coccinea
Grayia spinosa

Haplopappus nanus

Juncus balticus

Koehia americana

Langloisia Schottii
Lepidium Fremontii
Lycium andersoni

Maehaeranthera tortifolia
Mimulus sp.
Mirabilis pudica

Nicotiana trigonophylla

Oenothera Boothii
Oenothera megalantha
Oxystylis lutea

Pectis papposa
Penstemon petalatus
Petalonyx nitidus
Pinus monophylla
Prunus fasciculata
Psilostrophe Cooperi
Purshia tridentata

Quercus Gambelii

Rhus trilobata
Rumex crispus

Encelia virginensis
Ephedra nevadensis
Eriogonum brachypodium
Eriogonum fasciculatum
Eriogonum intrafractum
Eriogonum triahopes
Eriogonum sp.
Erodium cicutarium
Euonide urens
Eurotia lanata

Franseria dumosa

Gilia sp.
Gutierrezia microcephala

Hymenoclea salsola

Juniperus osteosperma

Krameria parvifolia

Larrea divaricata
Lupinus argenteus
Lycium pallidum

Menodora spinescens
Mirabilis Froebelii

Oenothera kernensis
Oryzopsis hymenoides

Penstemon Bridgesii
Peraphyllum ramosissimum
Phacelia cremulata
Prosopis juliflora
Psathyrotes ramosissima
Purshia glandulosa

Ribes velutinum

Salazaria mexicana
Salix Goodingii
Salsola Kali
Sphaeralcea ambigua
Stanleya pinnata
Stephanomeria pauciflora
Symphoricarpos longiflorus

Tamarix pentandra
Tetradymia sp.
Typha dominicensis

Verbena braconata

Yucca brevifolia
Yucca sp.

Salicornia virginica
Salvia Dorrii
Scopolophila Rixfordii
Sphaeralcea sp.
Stephanomeria Parryi
Suaeda Torreyana

Tetradymia canescens
Thamnosma montana

Viguiera multiflora

Yucca schottigera

In addition to the plant species that were sampled, numerous samples of debris, bark, etc., were also collected to obtain the ground dwellers.

Results

The results of the faunal sampling have produced dozens of species, many of which have not yet been described. Since the phytophagous are more closely tied to their plant hosts, only they have partitioned into species as far as the following host association is concerned.

Acaridae

Atriplex canescens
Coleogyne ramosissima
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Pinus monophylla

Atriplex confertifolia
Elymus cinereus
Grayia spinosa
Kochia americana
Lycium andersoni
Salix Goodingii

Alicorhagiidae

Atriplex canescens
Atriplex sp.
Ephedra nevadensis
Grayia spinosa
Kochia americana
Lycium andersoni
Pinus monophylla
Salix Goodingii

Atriplex confertifolia
Coleogyne ramosissima
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Lycium pallidum
Salsola Kali
Yucca brevifolia

Anystidae

Atriplex canescens
Coleogyne ramosissima
Eriophyllum Pringlei
Grayia spinosa
Larrea divaricata
Lycium pallidum
Salsola Kali

Atriplex confertifolia
Gymopterus deserticola
Eurotia lanata
Kochia americana
Lycium andersoni
Pinus monophylla

Ascidae

Atriplex canescens
Juniperus osteosperma
Salix Goodingii

Atriplex confertifolia
Pinus monophylla

Bdellidae

Bdella longicornis

Atriplex canescens
Grayia spinosa
Kochia americana
Pinus monophylla

Atriplex confertifolia
Juniperus osteosperma
Lycium andersoni
Salix Goodingii

Bdella sp.

Atriplex confertifolia

Spinibdella bifurcata

Larrea divaricata

Spinibdella crotini

Atriplex canescens
Coleogyne ramosissima
Eurotia lanata
Kochia americana
Lycium andersoni
Oryzopsis hymenoides
Salix Goodingii
Yucca brevifolia

Atriplex confertifolia
Ephedra nevadensis
Grayia spinosa
Larrea divaricata
Lycium pallidum
Pinus monophylla
Salsola Kali

Cyta latirostris

Atriplex confertifolia
Lycium andersoni

Grayia spinosa
Pinus monophylla

Balbidae

Atriplex canescens
Coleogyne ramosissima
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Lycium pallidum
Pinus monophylla
Yucca brevifolia

Atriplex confertifolia
Ephedra nevadensis
Grayia spinosa
Kochia americana
Lycium andersoni
Oryzopsis hymenoides
Salsola Kali

Caeculidae

Atriplex canescens
Coleogyne ramosissima
Grayia spinosa
Kochia americana
Lycium andersoni
Oryzopsis hymenoides
Yucca brevifolia

Atriplex confertifolia
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Lycium pallidum
Pinus monophylla

Camisiidae

Atriplex canescens
Coleogyne ramosissima
Juniperus osteosperma
Lycium andersoni

Atriplex confertifolia
Grayia spinosa
Kochia americana
Pinus monophylla

Cheyletidae

Atriplex confertifolia
Larrea divaricata
Lycium pallidum

Coleogyne ramosissima
Lycium andersoni

Cryptognathidae

Atriplex confertifolia

Pinus monophylla

Cunaxidae

Cunaxa capreolus

Atriplex confertifolia
Grayia spinosa
Larrea divaricata
Pinus monophylla
Salsola Kali

Ephedra nevadensis
Kochia americana
Oryzopsis hymenoides
Salix Goodingii

Cunaxa sp.

Pinus monophylla

Cunaxaides americanus

Coleogyne ramosissima

Larrea divaricata

Salix Goodingii

Kochia americana

Pinus monophylla

Salsola Kali

Cymbaeremaeidae

Atriplex canescens

Coleogyne ramosissima

Eurotia lanata

Kochia americana

Lycium andersoni

Oryzopsis hymenoides

Salsola Kali

Atriplex confertifolia

Ephedra nevadensis

Grayia spinosa

Larrea divaricata

Lycium pallidum

Pinus monophylla

Eremaeidae

Atriplex confertifolia

Eurotia lanata

Juniperus osteosperma

Lycium pallidum

Salix Goodingii

Coleogyne ramosissima

Grayia spinosa

Lycium andersoni

Pinus monophylla

Erythraeoidea

Atriplex canescens

Atriplex sp.

Elymus cinereus

Fraseria dumosa

Grayia spinosa

Kochia americana

Larrea divaricata

Lycium pallidum

Salsola Kali

Atriplex confertifolia

Coleogyne ramosissima

Eurotia lanata

Gilia sp.

Juniperus osteosperma

Langloisia Schottii

Lycium andersoni

Pinus monophylla

Yucca brevifolia

Galumnidae

Atriplex confertifolia

Pinus monophylla

Gamasolaelaptidae

Atriplex canescens

Coleogyne ramosissima

Grayia spinosa

Kochia americana

Lycium andersoni

Salix Goodingii

Yucca brevifolia

Atriplex confertifolia

Eurotia lanata

Juniperus osteosperma

Larrea divaricata

Pinus monophylla

Salsola Kali

Hermaniidae

*Atriplex canescens**Salsola Kali*

Hypochthaniidae

Atriplex canescens
Coleogyne ramosissima
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Lycium pallidum
Salix Goodingii

Atriplex confertifolia
Ephedra nevadensis
Grayia spinosa
Kochia americana
Lycium andersoni
Pinus monophylla
Yucca brevifolia

Laelaptidae

Artemisia tridentata
Coleogyne ramosissima
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Pinus monophylla
Yucca brevifolia

Atriplex canescens
Eriophyllum pringlei
Grayia spinosa
Kochia americana
Lycium pallidum
Salsola Kali

Lohmanniidae

Atriplex canescens
Coleogyne ramosissima
Grayia spinosa
Kochia americana
Lycium andersoni
Salsola Kali

Atriplex confertifolia
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Pinus monophylla

Nanheymanniidae

*Juniperus osteosperma**Pinus monophylla*

Nanorchestidae

Atriplex canescens
Coleogyne ramosissima
Eurotia lanata
Juniperus osteosperma
Larrea divaricata
Lycium pallidum
Pinus monophylla
Salsola Kali
Yucca sp.

Atriplex confertifolia
Ephedra nevadensis
Grayia spinosa
Kochia americana
Lycium andersoni
Oryzopsis hymenoides
Salix Goodingii
Yucca brevifolia

Oribatulidae

Atriplex canescens
Coleogyne ramosissima
Grayia spinosa
Lycium andersoni
Oryzopsis hymenoides

Atriplex confertifolia
Eurotia lanata
Kochia americana
Lycium pallidum
Salix Goodingii

Oripodidae

Salix Goodingii

Pachygnathidae

Juniperus osteosperma

Pinus monophylla

Pachylealaptidae

Atriplex canescens
Eurotia lanata
Salix Goodingii

Atriplex confertifolia
Pinus monophylla

Paleacaridae

Atriplex canescens
Coleogyne ramosissima
Kochia americana
Lycium pallidum
Salix Goodingii

Atriplex confertifolia
Eurotia lanata
Larrea divaricata
Pinus monophylla
Salsola Kali

Paratydeidae

Yucca brevifolia

Pyemotidae

Atriplex canescens
Lycium pallidum
Salsola Kali

Atriplex confertifolia
Salix Goodingii

Raphignathidae

Atriplex canescens
Coleogyne ramosissima
Eurotia lanata
Kochia americana
Larrea divaricata
Lycium pallidum
Pinus monophylla
Salsola Kali
Yucca sp.

Atriplex confertifolia
Ephedra nevadensis
Grayia spinosa
Juniperus osteosperma
Lycium andersoni
Oryzopsis hymenoides
Salix Goodingii
Yucca brevifolia

Rhagidiidae

Atriplex canescens
Kochia americana

Grayia spinosa
Larrea divaricata

Scutacaridae

Coleogyne ramosissima
Larrea divaricata

Kochia americana
Salsola Kali

Sphaerolichidae

Larrea divaricata

Tenuipalpidae

Aegyptobia sp. 1

Lycium andersoni

Lycium pallidum

Aegyptobia sp. 2

Lycium andersoni

Lycium pallidum

Aegyptobia sp. 3

Atriplex confertifolia

Aegyptobia sp. 4

Kochia americana

Aegyptobia sp. 5

Atriplex confertifolia
Grayia spinosa
Lycium andersoni

Eurotia lanata
Kochia americana

Aegyptobia sp. 6

Coleogyne ramosissima

Aegyptobia sp. 7

Atriplex canescens

Atriplex confertifolia

Aegyptobia sp. 8

Lycium andersoni

Lycium pallidum

Aegyptobia sp. 9

Atriplex canescens
Coleogyne ramosissima
Salix Goodingii

Brevipalpus sp.

Kochia americana

Atriplex confertifolia
Grayia spinosa
Yucca brevifolia

Lycium pallidum

Tetranychidae

Bryobia curiosa

Atriplex canescens
Yucca brevifolia

Bryobia desertorum

Atriplex canescens
Eurotia lanata
Lycium andersoni

Bryobia drummondi

Larrea divaricata

Bryobia praetiosa

Lycium pallidum

Bryobia sp.

Atriplex canescens
Eurotia lanata

Eotetranychus sp.

Atriplex canescens
Coleogyne ramosissima
Kochia americana
Lycium pallidum
Yucca brevifolia

Monoceronychus sp.

Atriplex sp.

Parabryobia sp.

Grayia spinosa
Lycium pallidum

Elymus cinereus

Atriplex confertifolia
Larrea divaricata

Atriplex confertifolia

Atriplex confertifolia
Eurotia lanata
Lycium andersoni
Salsola Kali

Salsola Kali

Larrea divaricata

Petrobia latens

Atriplex canescens

Grayia spinosa

Lycium pallidum

Eurotia lanata

Larrea divaricata

Trombiculidae

Artemisia tridentata

Atriplex confertifolia

Grayia spinosa

Kochia americana

Lycium andersoni

Atriplex canescens

Coleogyne ramosissima

Juniperus osteosperma

Larrea divaricata

Pinus monophylla

Trombididae

Artemisia tridentata

Atriplex confertifolia

Grayia spinosa

Kochia americana

Lycium andersoni

Atriplex canescens

Coleogyne ramosissima

Juniperus osteosperma

Larrea divaricata

Pinus monophylla

Tucherellidae

Tucherella coleogynis

Atriplex canescens

Coleogyne ramosissima

Atriplex confertifolia

Tydeidae

Atriplex canescens

Coleogyne ramosissima

Grayia spinosa

Kochia americana

Lycium andersoni

Pinus monophylla

Salsola Kali

Atriplex confertifolia

Eurotia lanata

Juniperus osteosperma

Larrea divaricata

Lycium pallidum

Salix Goodingii

Uropodidae

Atriplex canescens

Pinus monophylla

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