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Biology of Nematodes in Desert Ecosystems

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ABSTRACT

Soil samples were collected weekly from four plant shrubs at Rock Valley from March 1973 to December 1974. The following information, derived from an April 1974 weekly sampling period, is given for nine samples at three depths and distances from the shrubs: mean number of nematodes/500 cm^3, corrected for extraction efficiency; mean individual weights; biomass; O_2 consumption in ml · m^{-2} · wk^{-1}; and calorific equivalents of O_2 consumption in cal/m^2. The data for the nematode community from 0-10 cm at the base of the shrubs during the week showed the number of nematodes/500 cm^3 soil to be 678, the mean individual nematode weight to be 0.277 μg, the total O_2 consumption to be 22 ml O_2 · m^{-2} · wk^{-1} and the calorific equivalent to be 106 cal · m^{-2} · wk^{-1}. The estimates of annual metabolism and productivity will be determined after studies on cryptobiosis in nematodes of desert soils have been completed. Analysis of the main effects during the 1974 Rock Valley study, such as the effect of seasonal distribution, shrubs, horizontal and vertical distribution on the nematode trophic groups, is presented. The seasonal distribution at Rock Valley in 1973 showed a significantly lower nematode density from April to July than in the winter months. Comparisons of the nematode community structure, nematode numbers/500 cm^3, biomass and geographical distribution are given for the Jornada, Curlew Valley and Silverbell sites. Analysis of the trophic levels at the four validation sites shows a greater percentage of microbial feeders (50-55%) in the nematode populations at Jornada, Silverbell and Rock Valley; whereas, at the Curlew Valley site, plant parasites represent 60% of the population.

INTRODUCTION

Numerically, nematodes comprise the dominant invertebrate group in the below-ground ecosystem at Rock Valley, Nevada. To assess their importance in the desert soil biota, a weekly sampling program was instigated in March 1973 in conjunction with other below-ground investigators, Bamberg (1973), McBrayer (1975) and Edney et al. (1974). The sampling program, completed in December 1974, emphasized the functional roles, spatial and seasonal distribution of nematodes and their relationships to dominant vegetation and abiotic factors. From these data, information on nematode biomass, metabolism and production can be calculated. Since nematodes in desert soils are in an apparent cryptobiotic state during long, dry periods, studies in 1975 will attempt to estimate the effect cryptobiosis has on nematode metabolism.

Sampling programs at the Jornada, Silverbell and Curlew Valley validation sites were expanded to provide additional information for eventual productivity estimation. The parameters measured at the undisturbed desert sites included nematode density, trophic group, species diversity and biomass estimation.

OBJECTIVES

The objectives of the continuing research project conducted during 1974 are similar to those outlined in the 1973 report (Freckman et al. 1974) and are extensions of the original objectives:

1. The investigation of the role of the soil nematode community in desert soil biology.
2. The characterization of the nematode community structure at Rock Valley, Nevada, as to biomass, species, trophic group, spatial and seasonal distribution, density and the influence of biotic and abiotic factors.
3. The estimation of nematode metabolism and annual production per hectare in Rock Valley desert soil.
4. Periodic sampling of the other three validation sites to further establish the geographic distribution, functional role and characteristics of the nematode population.

METHODS

Nine 200-cm^3 soil samples were collected at the Rock Valley Validation Site from each of four plant species, *Lycium andersonii*, *Krameria parvifolia*, *Ambrosia dumosa* and *Larrea tridentata*, as described in the 1973 report (Freckman et al. 1974; DSCODE A3UMB36). The soil was collected at three depths, 0-10 cm, 10-20 cm and 20-30 cm at three distances from the plant (Table 1). Position 1 = base of shrub (samples 1, 2, 3), Position 2 = edge of shrub canopy (samples 4, 5, 6), Position 4 = three shrub radii (samples 7, 8, 9). Samples were collected three times per month from March 1973-December 1973, and weekly from January 1974-December 1974. After mixing each sample, 100-cm^3 subsamples were processed by the sugar flotation sieving method (Byrd et al. 1966). This method extracts nematodes with 75% efficiency after two processings of each soil subsample (unpublished data). As the nematodes were counted they were placed in one of the following trophic groups: 1) fungivorous -- *Aphelenchus avenae*, *Aphelenchoides* spp., *Ditylenchus* spp.; 2) microbivorous -- mainly Cephalobidae; 3) omnivorous or predaceous -- Dorylaimina; and 4) plant parasites -- Tylenchida. Those which were damaged or unidentifiable comprised a third group. Results were expressed as numbers of nematodes/500 cm^3 soil.

Samples were collected at the same time daily, so soil temperatures are comparable. Temperatures were recorded at each of the nine sampling positions/plant with a YSI electric thermometer coupled with a 15-cm thermistor probe (Edney et al. 1974). Soil moisture content was determined for each position by the gravimetric method (105 C for 24 hr). Soil temperature and moisture data were incomplete for the 1973 data.

Table 1. Sample position numbers with respect to soil depth and distance from the shrub base at Rock Valley[1]

	Distance from shrub base in radii		
Depth (cm)	0	1	3
0-10	1	4	7
10-20	2	5	8
20-30	3	6	9

[1]After Edney et al., 1973 Progress Report. RM 28-35. Vol. 3:54-57.

The Rock Valley data were analyzed in two sections. The results from the March 1973 to March 1974 sampling program, termed Year I, were grouped into 10 five-week periods. The weekly samples in each five-week period were treated as replicates within each trophic group. Statistical analyses of the raw data from Year I were not possible because of extreme variability in numbers of nematodes. To smooth out the distribution and stabilize the variance, transformations were made to the (log of X) + 1 where X = the average number of nematodes within a five-week period. Standard analysis of variance procedures were then run on the transformed numbers (Snedecor and Cochran 1967).

The Rock Valley data from January 15, 1974-January 1, 1975 (Year II), were analyzed by dividing the 48 weeks sampled into 12 four-week periods. Transformations to the log (nematodes + 1) were made as in the 1973 data, because of the variability in nematode numbers. Means of log (nematodes + 1) within a four-week period were used for analysis. Standard analysis of variance and Duncan's multiple range test of mean differences were run on the transformed numbers (Snedecor and Cochran 1967).

The density of nematodes in 1 ha of Rock Valley soil to 30-cm depth was estimated for the Year II sampling program by following the formula of Bamberg et al. (1974) for root biomass estimates.

A year's weekly sampling of the Rock Valley nematode population (Year II) was a sufficient time period to estimate the nematode numbers, biomass, metabolism, production, assimilation and consumption. Because data for the entire year were not yet available, numbers, biomass and metabolism were determined only for one week of the year.

The determinations of nematode metabolic rates have been examined in several ways (Nielsen 1961, Klekowski et al. 1972, Marchant and Nicholas 1974, Yeates 1972). Klekowski et al. measured the respiratory and metabolic rates of 1-3 nematodes from each of 22 species with cartesian divers. The 22 species represented five different nematode trophic groups. A comparison of their results with those of other authors showed that energy metabolism for the different nematode trophic groups was similar. Therefore, the community metabolic rate at Rock Valley was based on the total numbers of nematodes and not on individual trophic groups. Klekowski et al. (1972) noted apparent differences in O_2 consumption between adults and juveniles. However, these differences were not determined in the Rock Valley estimates.

Our procedure for estimation of nematode metabolism is similar to Klekowski et al. (1972), Yeates (1973) and Wasilewska (1974). The numbers of nematodes/500 cm^3 were determined by averaging the nematode numbers found at Position 1 (0- to 10-cm depth) for the four plant species during the week of April 2, 1974. Previous work at Rock Valley in 1973 showed the differences in nematode numbers between the four plant species to be significant although the differences were much smaller than other effects. The number of nematodes/500 cm^3 was then corrected for extraction efficiency and calculated to numbers $\cdot$ m^{-2} $\cdot$ 0-10 cm $deep^{-1}$. Body weights of the nematode population were determined by length and width measurements of 100 randomly selected nematodes from the Position 1 (0-10 cm) sample and calculations were according to Andrassy (1956). Biomass was calculated as described in the 1973 report (Freckman et al. 1974). Calculation of respiratory rate (R) was according to the formula of Klekowski et al. (1972) and Wasilewska (1974), where R = 1.40 G 0.72, expressed in $\mu l\ O_2$ consumed (10^{-3})/individual per hr, and G is body weight in μg. The effect of soil temperature on nematode respiratory rate was corrected to 20 C, according to Winberg (1971). Metabolism of the community at Position 1, (0- to 10-cm depth) was determined by multiplying R (respiratory rate) x the number of nematodes (corrected for extraction efficiency) $\cdot$ m^{-2} $\cdot$ 10 cm $deep^{-1}$ x 168 hr/wk. A calorific equivalent of 4.8 cal/ml O_2 was used according to Yeates (1973). The procedure was repeated for each of the nine positions sampled (see Table 1).

The Jornada Validation Site, New Mexico, was sampled in December 1973 according to the random sampling pattern described in the 1973 report (Freckman et al. 1974). The samples were mixed individually and nematodes extracted as previously described for Rock Valley samples. The extracted nematodes were counted and the samples combined for biomass analysis. At least 100 nematodes from the combined samples were randomly selected for length and width measurements for use in calculating average weight of nematodes (Andrassy 1956). Biomass was calculated as previously described (Mankau et al. 1973).

The Silverbell Validation Site, Tucson, Arizona, was sampled twice in 1974. Soil samples were taken at the Silverbell site during a rainstorm in August 1974. Samples were collected to 20-cm depth from the bases of 14 plants, six *Larrea* spp., six paloverdes (*Cercidium floridum*) and two saguaro cacti (*Carnegiea gigantea*). The following day, 10 soil samples were taken randomly at the Santa Rita site, five from grasses and five from mesquite canopies. Previous data at Silverbell indicated a low recovery of nematodes during summer months. In order to process all of the soil collected at these two sites, a modification of the sugar-flotation sieving technique was used for processing the August 1974 samples. Data were expressed as numbers of nematodes/1000 g soil.

The Silverbell site was sampled in a pattern identical to that used at Rock Valley in November 1974 (Table 1). Nine samples were taken at each of four plants, two of *Larrea* sp., and two of *Ambrosia* sp., yielding a total of 36 samples. Methods of extraction have been described previously. The numbers of nematodes at each of the nine sampling positions were analyzed as averages of the four plants.

The Curlew Valley Validation Site was sampled in a pattern similar to Rock Valley. Three plants each of *Atriplex* sp. were sampled at three depths near the base of the plant and at the plant canopy. Additional samples were taken from three *Bassia* sp. and *Halogeton* sp. Methods for nematode extraction were described previously (Freckman et al. 1974). The numbers of nematodes/500 cm^3 at the six sampling positions around *Atriplex* sp. were analyzed as averages of the three plants.

RESULTS

Year I -- March 1973 to March 1974

Analysis of the nematode density at each of the four plant species, *Larrea tridentata*, *Lycium andersonii*, *Krameria parvifolia* and *Ambrosia dumosa*, showed that total numbers of nematodes were similar on all four plants. For further analyses of Year I data, numbers of nematodes or the (log of X) + 1 transformations were averages of the four plant species.

To analyze changes in nematode density with seasons at the nine sampling positions, the three coldest five-week periods (winter, December 1973-March 1974) and the three hottest five-week periods (summer, May 1973-August 1974) were compared. Analysis showed a significantly greater nematode density with the winter season at all positions except at Position 2, 10-cm depth (sample 4; Fig. 1). An attempt to relate the seasonal variations in nematode numbers to temperature and moisture data was unsuccessful because of incomplete temperature and moisture data in 1973.

An average of all trophic groups showed a significant decline in numbers of nematodes with increasing depth and distance from the plants during 1973 (Fig. 2). A similar pattern was observed in the 14-week sampling period discussed in the 1973 report (Freckman et al. 1974). Examination of the individual groups, fungal feeders and microbial feeders, showed a decrease in nematode numbers with depth and distance similar to the averages of all the trophic groups. Variation from this pattern occurred with the predator-omnivore group, which decreased greatly from the shrub canopy (Position 2) to the interspace (position 4) at 10-cm depth, and with the plant parasitic group, where nematode numbers were greater at the 20-cm depth near the plant than at 10 cm (Fig. 2).

A representation of trophic group interaction at the three depths and distances from the plants at Rock Valley is shown in Figure 3. In the nematode community structure, the microbial feeders are the most numerous group at all depths near the base of the plant (Position 1). At the 10-cm

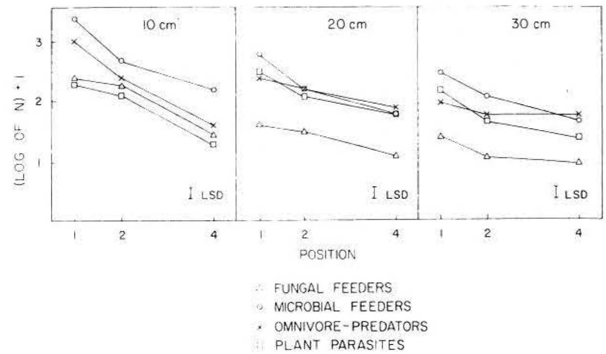

Figure 1. Seasonal distribution of nematodes at Rock Valley.

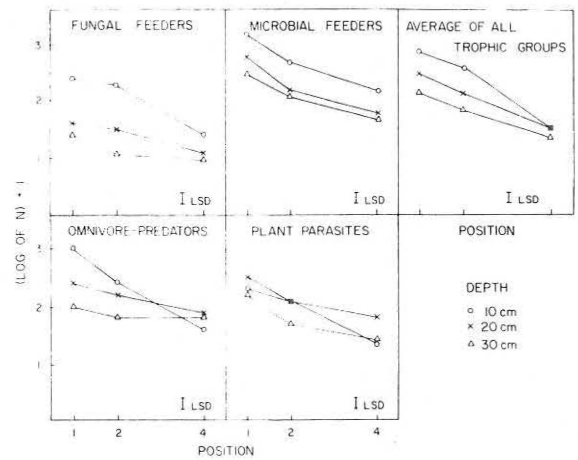

Figure 2. Relationship of individual trophic groups with depth and position from the plant, 1 = base of shrub, 2 = shrub canopy and 4 = interspace or three times the shrub radii. Points are averages of nematodes at four plant species, Rock Valley, March 1973-March 1974.

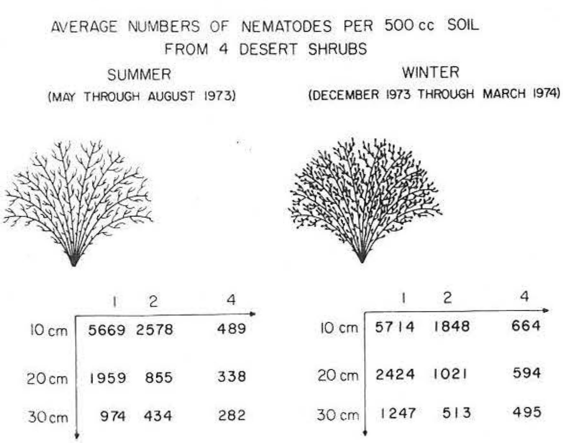

Figure 3. Interaction of nematode trophic groups at 0-10-, 10-20- and 20-30-cm depths and at three positions from the plant, 1 = base of shrub, 2 = shrub canopy and 4 = interspace or three times the shrub radii. Points are averages of nematodes at four plant species, Rock Valley, March 1973-March 1974.

depth, the numbers of predator-omnivores > fungal feeders > plant parasites. However, at 2- and 30-cm depths (all positions), the fungal feeders are the least numerous nematode group. The increase in numbers of plant parasites at the 20- and 30-cm depths near the plant is also apparent from these graphs.

YEAR II -- JANUARY 1974-DECEMBER 1974

Analysis of the main effects in the 1974 Rock Valley study has been completed and results are presented in Tables 2-16. Interaction data will be presented in the 1975 report.

The densities of the nematode trophic groups varied with the four plant species at Rock Valley in 1974. This variation was not as apparent in the 1973 data, except with the plant parasites which were more numerous under *Lycium* and *Larrea* (Table 13). The density of predator-omnivores was not significantly different from plant to plant whereas the density of microbivores and fungivores was slightly higher under *Ambrosia* and *Krameria*, respectively (Tables 6, 2).

The 1974 spatial distribution data indicated that the density of fungivores was significantly greater at 0-10 cm (Table 3); plant parasites were more numerous at 11- to 20-cm depths (Table 14); and the numbers of microbivores and predator-omnivores decreased significantly with depth (Tables 7, 10). There was a significant decrease in numbers of nematodes in all trophic groups as distance from the plant increased (Tables 4, 8, 11, 15).

An analysis of the seasonal distribution of nematodes in each of the trophic groups indicates a decrease in nematode numbers from the middle of April until the middle of October 1974. The lowest numbers of nematodes were recovered from July 28 to August 24 for all trophic groups except the plant parasites, which had the lowest numbers from September 22 to October 19 (Tables 5, 9, 12, 16).

Table 2. Fungivorous nematodes associated with four plant species at Rock Valley during 1974

Plant	No. of Nematodes[1]
Larrea tridentata	1.84 Y[2]
Ambrosia dumosa	1.74 YZ
Lycium andersonii	1.83 Y
Krameria parvifolia	1.63 Z

[1]Numbers are means of log (nematodes +1). Means represent 432 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 3. Vertical distribution of fungivorous nematodes at three depths at Rock Valley during 1974

Depth (cm)	No. of nematodes[1]
10	2.24 Y[2]
20	1.52 Z
30	1.52 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 4. Horizontal distribution of fungivorous nematodes at three distances from the plant at Rock Valley during 1974

Distance from the plant	No. of nematodes[1]
Base of plant	2.13 X[2]
Plant canopy	1.84 Y
Interspace	1.32 Z

[1]Numbers are means of log (nematodes +1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 5. Seasonal distribution of fungivorous nematodes at Rock Valley during 1974

Months	No. of nematodes[1]
1/13- 2/9	1.90 UVW[2]
2/10- 3/9	1.83 VWX
3/10- 4/6	2.02 U
4/7 - 5/4	2.01 U
5/5 - 6/1	1.72 XY
6/2 - 6/29	1.76 WX
6/30- 7/27	1.59 Y
7/28- 8/24	1.29 Z
8/25- 9/21	1.73 XY
9/22-10/19	1.43 Z
10/20-11/16	1.95 UV
11/16-12/14	1.93 UV

[1]Numbers are means of log (nematodes + 1). Means represent 144 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 6. Microbivorous nematodes associated with four plant species at Rock Valley during 1974

Plant	No. of nematodes[1]
L. tridentata	2.32 YZ[2]
A. dumosa	2.28 Z
L. andersonii	2.37 Y
K. parvifolia	2.39 Y

[1]Numbers are means of log (nematodes + 1). Means represent 432 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 7. Vertical distribution of microbivorous nematodes at three depths at Rock Valley during 1974

Depth (cm)	No. of nematodes[1]
10	2.71 X[2]
20	2.21 Y
30	2.10 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 8. Horizontal distribution of microbivorous nematodes at three distances from the plant at Rock Valley during 1974

Distance from plant	No. of nematodes[1]
Base of plant	2.74 X[2]
Plant canopy	2.33 Y
Interspace	1.96 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letters do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 9. Seasonal distribution of microbivorous nematodes at Rock Valley during 1974

Months	No. of nematodes[1]
1/13- 2/29	2.32 WX[2]
2/10- 3/9	2.42 TUVW
3/10- 4/6	2.58S
4/7 - 5/4	2.33 VWX
5/5 - 6/1	2.29 X
6/2 - 6/29	2.36 UVWX
6/30- 7/27	2.38 TUVWX
7/28- 8/24	1.91 Z
8/25- 9/21	2.43 TUV
9/22-10/19	2.13 Y
10/20-11/16	2.48 T
11/16-12/14	2.46 TU

[1]Numbers are means of log (nematodes + 1). Means represent 144 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 10. Vertical distribution of predaceous and omnivorous nematodes at three depths at Rock Valley during 1974

Depth (cm)	No. of nematodes[1]
10	2.30 X[2]
20	2.17 Y
30	1.92 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 11. Horizontal distribution of predaceous and omnivorous nematodes at three distances from the plant at Rock Valley during 1974

Distance from plant	No. of nematodes[1]
Base of plant	2.52 X[2]
Plant canopy	2.14 Y
Interspace	1.73 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 12. Seasonal distribution of predaceous and omnivorous nematodes at Rock Valley during 1974

Months	No. of nematodes[1]
1/13- 2/9	2.15 VWX[2]
2/10- 3/9	2.21 UVW
3/10- 4/6	2.26 UV
4/7 - 5/4	2.13 VWX
5/5 - 6/1	2.13 VWX
6/2 - 6/29	2.10 WX
6/30- 7/27	2.04 XY
7/28- 8/24	1.71 Z
8/25- 9/21	2.32 U
9/22-10/19	1.92 Y
10/20-11/16	2.30 U
11/16-12/14	2.30 U

[1]Numbers are means of log (nematodes + 1). Means represent 144 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 13. Plant parasitic nematodes associated with four plant species at Rock Valley during 1974

Plant	No. of nematodes[1]
L. tridentata	1.91 Y[2]
A. dumosa	1.79 Z
L. andersonii	1.98 Y
K. parvifolia	1.75 Z

[1]Numbers are means of log (nematodes + 1). Means represent 432 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 14. Vertical distribution of plant parasitic nematodes at three depths at Rock Valley during 1974

Depth (cm)	No. of nematodes[1]
10	1.81 Z[2]
20	2.04 Y
30	1.73 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 15. Horizontal distribution of plant parasitic nematodes at three distances from the plant at Rock Valley during 1974

Distance from plant	No. of nematodes[1]
Base of plant	2.26 X[2]
Plant canopy	1.88 Y
Interspace	1.44 Z

[1]Numbers are means of log (nematodes + 1). Means represent 576 counts.

[2]Numbers followed by the same letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

Table 16. Seasonal distribution of plant parasitic nematodes at Rock Valley during 1974

Months	No. of nematodes[1]
1/13- 2/9	2.02 V[2]
2/10- 3/9	2.12 V
3/10- 4/6	1.98 VW
4/7 - 5/4	1.97 VW
5/5 - 6/1	1.78
6/2 - 6/29	1.74 XY
6/30- 7/27	1.83 WX
7/28- 8/24	1.60 Y
8/25- 9/21	1.79 X
9/22-10/19	1.42 Z
10/20-11/16	2.10 V
11/16-12/14	1.98 VW

[1]Numbers are means of log (nematode + 1). Means represent 144 counts.

[2]Numbers followed by the same letter are not significant at P + 0.05, according to Duncan's Multiple Range Test.

Data for estimation of nematode density per hectare of soil to 30-cm depth at Rock Valley during Year II are shown in Tables 17 and 18. These nematode densities are associated with the four plant species which provide 75% of the plant cover at the site. Taking into account the contributions of other plant species, and correcting for extraction efficiency, the overall density of nematodes at Rock Valley is estimated to be 12.7×10^{9} nematodes/ha to 30-cm depth.

The mean individual nematode weights, biomass and estimated respiratory rates in ml O_2 consumed $\cdot$ $m^{-2} \cdot wk^{-1}$ to 10-cm depth and the calorific equivalents are shown in Table 19 for the week of April 8, 1974, at Rock Valley. The

Table 17. Estimated nematode densities (numbers x 10^6 nematodes/ha)[1] from four Rock Valley shrubs in 1974. Data pertain to top 30-cm depth

Plant	Shrub Bases (Samples) (1, 2, 3)	Shrub Canopy (Samples) (4, 5, 6)	Inter-Spaces (Samples) (7, 8, 9)	Total
Larrea tridentata	299	2,620	884	3,800
Ambrosia dumosa	177	184	616	978
Lycium andersonii	305	2,470	714	3,480
Krameria parvifolia	265	258	796	1,310
				9,570

[1]Corrected for extraction efficiency.

Table 18. Mean nematode densities (numbers/500 cm^3 soil)[1] taken at three depths in association with four plant species at Rock Valley in 1974

Sampling location	Larrea tridentata	Ambrosia dumosa	Lycium andersonii	Krameria parvifolia
1	7506[2]	4468	8020	7368
2	2269	2592	2538	1847
3	1294	1209	1363	1205
4	3042	2394	2971	3166
5	1071	1297	1158	1127
6	717	637	687	759
7	779	657	558	714
8	725	601	646	655
9	528	542	526	574

[1]Corrected for extraction efficiency.

[2]Numbers are averages of 49 counts, except for Krameria sp., N = 48 weeks.

Table 19. Mean individual weights, biomass and oxygen consumption of nematodes sampled the week of April 8, 1974,[1] Rock Valley, Nevada

Sample No.[2]	Depth (cm)	No. of nematodes/500cm^3	Mean individual weight (μg)	Biomass Kg/ha	Total O_2 consumption ml O_2/m^2/10 cm depth/week	Calorific equivalent of O_2 consumption cal/m^2/week
1	10	678	0.277	0.75	22	106
2	20	613	0.153	0.37	13	62
3	30	361	0.106	0.15	5	23
4	10	1074	0.277	1.19	29	138
5	20	480	0.153	0.29	10	49
6	30	347	0.106	0.15	5	24
7	10	429	0.277	0.47	10	50
8	20	233	0.153	0.14	5	24
9	30	336	0.106	0.14	4	22

[1]Means of four plants sampled during week 15.

[2]See Table 1 for sampling pattern.

figures for oxygen consumption are lower, yet similar, to those reported by Klekowski et al. (1972) and Yeates (1973) for other ecosystems.

The nematodes recovered during the dry season by the sugar-flotation sieving extraction method (SFS) are coiled, inactive and in a cryptobiotic state from 15 min to 1 hr after addition of the sugar solution to the desert soil samples. This was determined by continuous observation of the nematodes immediately following the SFS extraction. Nematodes extracted from irrigated agricultural fields by the SFS method are actively moving immediately after extraction. Additional data accumulated on soil temperature and moisture in 1974 and studies on life stages of the nematode populations will be beneficial in calculating estimates of annual respiratory rates and productivity.

Twenty-three soil samples from the bajada and playa of the Jornada Validation Site were analyzed for nematode density, average nematode weight, biomass and trophic structure of the nematode community. The average number of nematodes, corrected for extraction efficiency, was 838/500 cm^3, considerably lower than the average at other validation sites. A comparison of nematode data, previously cited in the 1973 report (Freckman et al. 1974), and corrected for extraction efficiency, is shown in Table 20. The trophic structure appears similar to that of the other validation sites, with 57.0% of the population micro-

Table 20. Numbers of nematodes (corrected for extraction efficiency), average nematode weight (μg live wt) and nematode biomass (g/m^2) at four Desert Biome validation sites

	No./500cm^3	Ave wt in μg	Biomass(g/m^2)
Curlew Valley			
Agropyron	2266	.24	0.21
Atriplex	2482	.24	0.24
Artemisia	4299	.24	0.42
Halogeton	2599	.24	0.25
Chrysothamnus	1584	.24	0.15
Bassia	2012	.24	0.19
Jornada	839	.15	0.05
Rock Valley			
1973 random samples	1553	.24	0.15
Silverbell			
1973 random samples	1671	.15	0.10
1974 Larrea sp. and Ambrosia sp.	1381	.158	0.08

Table 21. Taxonomic list of desert nematodes*

Trophic groups	Curlew Valley	Rock Valley	Tucson	Las Cruces
FUNGAL FEEDERS				
Aphelenchus avenae	+	+	+	+
Aphelenchoides	+	+	+	+
Ditylenchus	+	+	+	+
PLANT PARASITES				
Apratylenchus belli	+	-	-	-
Heterodera	+	-	-	-
Leipotylenchus abulbosus	+	-	-	-
Megadorus	+	-	-	-
Merliniius grandis	-	+	-	-
Nacobbus	+	-	-	-
Paratylenchus	-	-	+	-
Tylenchorhynchus 106	-	+	-	-
Tylenchorhynchus 107	+	+	-	-
Tylenchorhynchus 167	-	+	-	-
Tylenchorhynchus acutus	+	-	-	-
Tylenchorhynchus canalis	+	-	-	-
Tylenchorhynchus capitatus	+	-	-	-
Tylenchorhynchus cylindricus	-	+	+	-
Tylenchorhynchus latus	+	-	-	-
Tylenchorhynchus	+	+	+	+
Tylencholaimellus	+	-	-	-
PREDATOR-OMNIVORES				
Dorylaimina	+	+	+	+
Eudorylaimus sp.	-	+	+	-
Eudorylaimus monohystera	-	+	-	-
Mononchus	-	-	-	-
Pungentus	-	+	-	+
MICROBIVOROUS				
Acrobeles	+	+	+	+
Acrobeles complexus	-	-	-	-
Elaphonema	-	+	-	+
Leptonchus	-	+	-	-
Plectus	-	-	-	+

*Updated 1974. Samples contain a number of unidentified spp. not listed here.

bivorous and 30% predaceous-omnivorous. The percentage of the plant parasitic nematodes found in the population examined is low (6%), and is lower than the Silverbell and Rock Valley populations.

The species list is shown in Table 21. A predaceous mononchid, previously undescribed at the other sites, comprised 50% of a soil sample taken at the base of an apache plume in the bajada arroyo.

Analysis of the August 1974 sampling at the Silverbell and Santa Rita sites indicated a similarity in average numbers of nematodes/1000 g soil and in the composition of the nematode community structure (Table 22). Grasses are more abundant at the Santa Rita site, and are good hosts for the plant-parasitic nematodes present. This may account for the larger percentage of plant parasites at the Santa Rita site and, indirectly, through increased organic matter, could account for the larger percentage of microbivores.

Table 22. Percentage of nematodes in trophic groups at the Silverbell and Santa Rita validation sites, August 1974

Trophic group	Silverbell[1] %	Santa Rita[2] %
Microbivores	50	57
Predator-omnivores	34	21
Plant parasites	9	14
Fungivores	4	7
Unidentifiable	3	1
Total No./1000 g	5516	5672

[1]Data are averages of 14 plants.

[2]Data are averages of 10 plants.

The nematode distribution with depth and distance from the plant in the November 1974 Silverbell sampling, appears to be similar to the nematode distribution at Rock Valley. There was a decrease in numbers of nematodes with increasing depth and distance from the plant. The greatest nematode numbers were found in the 0- to 10-cm level, near the base of the plants (Table 23). In this population, predator-omnivores were most numerous (48%) followed by microbial feeders (31%) >plant parasites (13%)>fungivores (6%). The average number of nematodes/500 cm^3, the average weight and the biomass of the nematodes are shown in Table 19.

The results of the Curlew Valley sampling of *Atriplex* sp. showed little similarity to the Rock Valley data. Numbers of nematodes near the plant were greater than at the plant canopy (Table 24). However, there does not appear to be a decrease in numbers of nematodes with increasing depth to 30 cm as in Rock Valley (Fig. 3) or Silverbell (Table 23). The community structure is also different from the warmer deserts, with plant parasites representing 61% of the nematode population at 0-10 cm (Table 25). The percentage of plant parasites at the other three validation sites is 6-20%. The microbivorous nematodes are 18-22% of the Curlew Valley population, whereas they represent approximately 50% of the populations at Silverbell, Santa Rita and Jornada.

DISCUSSION

The intensive sampling program at Rock Valley during the past two years has yielded a wealth of information on nematodes in desert soils. Over the 1974 sampling period,

Table 23. Nematode numbers/500 cm^3 at Silverbell Validation Site,[1] November 1974

Depth (cm)	Distance from shrub base		
	1	2	4
0-10	4524	2674	841
10-20	1417	1092	575
20-30	492	525	292

[1]Numbers are averages of 4 plants, corrected for extraction efficiency.

Table 24. Numbers of nematodes*/500 cm^3 at three depths associated with *Atriplex* sp. at the Curlew Valley Validation Site

Depths (cm)	Base of plant	Plant canopy
0-10	1633	814
11-20	1537	614
21-30	1765	920

*Numbers are means of three samples, corrected for extraction efficiency.

1764 samples from Rock Valley alone were processed for nematode analysis. The additional samples from other sites made a total of 1850 samples processed and analyzed for nematodes.

Data on the seasonal distribution of nematodes at Rock Valley indicated that densities were lowest from the middle of May 1974 through October 1974. Presumably, the higher levels of nematodes in the winter months were associated with increased soil moisture and decreased soil temperatures. Correlation of the abiotic data with the seasonal distribution of nematodes will be reported at a later date.

The spatial distribution pattern of nematodes in the 1973 Rock Valley study showed higher densities near the plant in the upper 10 cm of soil. Population densities decreased further away from the plants where environmenntal conditions are more extreme and food sources more limiting. The larger plant parasitic density at 11-20 cm is probably associated with the root profiles of the four plants. Data on root weights have not yet been correlated with the nematode data.

Any differences in spatial distribution of nematodes such as those occurring at the Curlew Valley site are probably associated with the abundance of the food source, i.e., a larger or deeper root distribution, increased amounts of organic matter and increased biological activity. At present, we have no information on the abundance of the available food sources for nematodes in desert soils.

The density of nematodes associated with four shrubs at Rock Valley, as calculated by the method of Bamberg et al.

Table 25. Percentage[1] of nematodes in four trophic groups associated with *Atriplex* sp. at the Curlew Valley Validation Site

Depth (cm)	Fungivores	Microbivores	Predator-Omnivores	Plant Parasites	Total No. Nematodes/500 cm^3
0-10	9%	20%	6%	61%	1224
11-20	2	18	30	47	1076
21-30	5	22	21	48	1342

[1]Percentage based on means of six samples.

(1974), appears unusually high (9.570×10^6 nematodes · ha^{-1} · 0-30 cm $deep^{-1}$). However, when recalculated to numbers/m^2, there are 1.242×10^6 nematodes · m^{-2} · 0-30 cm $deep^{-1}$. This is slightly lower than Yeates' (1973) report of 1.43×10^6 nematodes · m^{-2} · 6-cm $depth^{-1}$ in a Danish beech forest, and Smolik's (1974) estimate of 2.0-6.0 $\times 10^6$ nematodes · m^{-2} · 60-cm $depth^{-1}$ in the Grasslands Biome study, where 70% of the nematodes occur in the upper 20 cm of soil.

An estimate of the annual metabolism and productivity of nematodes in desert soils would be in error unless the duration of the nematode cryptobiotic state was determined. Cryptobiosis is a means of survival during severe environmental stress, and cryptobiotic nematodes have no detectable metabolic rate (Bhatt and Rhode 1970, Crowe and Clegg 1973).

The annual nematode respiratory rate at Rock Valley can be estimated on the basis of the weekly data (0-10 cm) presented here, but it will be lower once information on cryptobiosis of desert nematodes is known. An annual estimate would be 5490 cal· m^{-2} · yr^{-1} at sample 1, which is lower than Yeates' (1973) estimate of 10,800 cal · m^{-2} · 0-6 cm $depth^{-1}$ · yr^{-1} for a Danish beech forest, and considerably lower than Wasilewska's (1974) estimate of 136 kcal · m^{-2} · 0-25 cm $deep^{-1}$ · yr^{-1} for an agricultural field.

EXPECTATIONS

Investigations on cryptobiosis of nematodes in desert soils and its effects on the metabolism of the nematode community will begin in 1975. Field experiments at the Mercury, Nevada, site will be in conjunction with Paul Franco and Al Phillips of UCLA, and will study nematode populations as affected by increased moisture levels. This information and data from laboratory studies will aid in estimating the annual respiration, productivity and assimilation of the nematode community at Rock Valley. The composition of the nematode population as to the adult and juvenile life stages will be determined during 1975. Parameters concerning spatial and geographical distribution, trophic group dynamics, biomass metabolism and the relationship of nematodes to abiotic and biotic factors will be compared to those of Rock Valley to study the importance of nematodes in the transfer of energy in desert ecosystems. Considerable time will also be allocated to preparing data for publication.

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