SEAFARER EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS: SOIL ARTHROPOD POPULATIONS AFTER LONG-TERM EXPOSURE UNDER NATURAL CONDITIONS

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FOREWORD

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Respectfully submitted,

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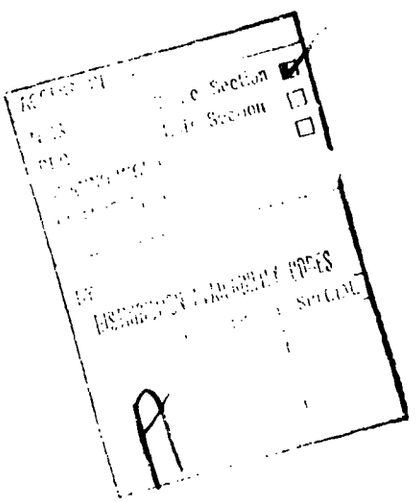

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1. SUMMARY

Data are presented of the 1976 soil arthropod monitoring program. This program is designed to disclose small, subtle populational changes after long-term exposure to Project Seafarer's electromagnetic fields. An unusually hot, dry summer compared with the previous wet summers prompted the question: do meteorological stresses combine with the Seafarer electromagnetic environment to produce perceptable populational changes? No such changes were found. In 1976, control and exposed arthropods generally had marked increases in numbers and their population curves developed in a normal manner during the course of the summer. Each arthropod group was represented in about the same proportion in the arid summer of 1976 as in the previous wet ones. Thus, there is no indication that possible changes in the electrical conductivity of the soil under different weather conditions has had any observable influence on soil arthropod demography. The cumulative productivities of the most numerous arthropods - Collembola and Cryptostigmata - have been practically identical in test and control plots for the last four years. During the same period predator-prey proportions have been as stable in test plots as in control plots. Analytic comparisons between paired test and control plots from 1972 to 1976 indicate that the predator-prey proportions do not differ in a statistically significant way in 22 of 36. Among the other 14, only 2 have differed significantly in more than 2 of the 4 years. The above and other data support a conclusion that seven years of ELF operation has had no demonstrable effect on soil arthropod populations.

2. INTRODUCTION

A soil arthropod monitoring program was initiated at the Wisconsin test facility (WTF) before antenna turn-on in summer 1969 and was expanded in 1971. This monitoring program has continued each summer with the exception of 1974. The interpretation of data, based on the extensive collections and analyses during the course of seven years, has been that Seafarer ELF fields have had no observable effect on population structure of soil arthropods (Greenberg 1972, 1973; Greenberg and Ash 1974, 1976).

It is now generally agreed that weak-field effects at Seafarer frequencies are probably not a cause for concern (Anonymous, 1972, 1976). This judgement is supported by laboratory and field studies. While recognizing the value of well designed, rigorously conducted laboratory studies one should not lose sight of the unique contribution of equally rigorous field studies. In any natural situation a combination of factors, or multiple stresses, are likely to have an effect quite different from any single factor in isolation. Unusually hot summers or cold winters, excessive drought or precipitation, and the resultant changes in soil conditions and food supply are a few of the obvious natural factors that may modify the "real-life" conditions of an ELF study. Meteorological conditions may change soil conductivity and may alter the receptivity/responsivity of soil animals to ELF fields which could show up as populational changes. The summer of 1976 was hotter and drier than the preceding several summers for which we have soil arthropod data. This provided an opportunity to observe the possible impact on soil arthropods of meteorological stresses acting in concert with the Seafarer ELF electromagnetic fields.

3. MATERIALS AND METHODS

3.1 Sampling Sites

The location, soil type, floral cover and distinctive features of each plot have been detailed in reports for 1971, 1973, and 1975, and have been published (Greenberg 1972, 1973; Greenberg and Ash 1974, 1976). Among the nine test plots and six control plots, the Old Hazleton test and control plots have been monitored since 1969; the Main test and control plots, and the Old Clover test and control plots have been monitored since 1971, and the remainder since 1972 (Figure 1).

3.2 Sampling Schedule

Each test and control plot was sampled four times at approximately monthly intervals, from June to September 1976. The sampling schedule coincided within a few days with the schedules of previous years.

3.3 Sampling Design

The same sampling and enumeration techniques used in previous years were employed, including coring, transportation, and extraction of samples. As in previous years, eight randomized core samples were taken monthly from each plot, except the Main test and control plots, where four cores were taken from each of the three test subplots and each of the three control subplots.

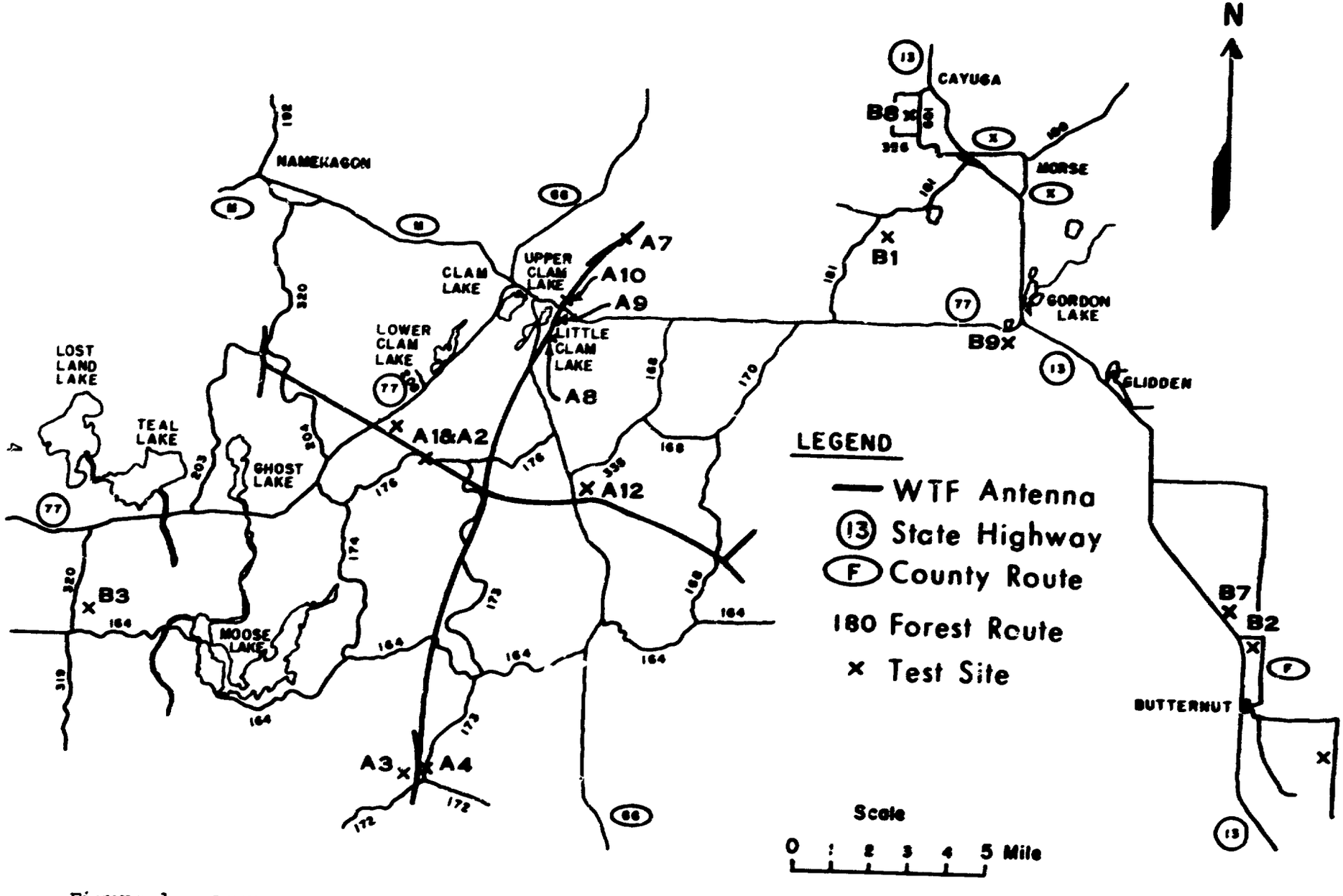


Figure 1. LOCATION OF EXPERIMENTAL PLOTS IN RELATION TO THE SEAFARER ANTENNA AT THE WISCONSIN TEST FACILITY.

3.4 Electric and Magnetic Field Measurements

The equipment employed for the electromagnetic field measurements described here were the specially constructed tuned voltmeters (TVM's) which were supplied by the Navy for ELF measurements, the commercially available Hewlett-Packard 302A wave analyzer, and the commercially available Hewlett-Packard 3581A signal wave analyzer. All three meters are battery operated. The TVM's and HP302A were used from 1972 through 1975, and the HP3581A was first used in 1976. The HP3581A is a newly available instrument, and was factory-modified for a 1 Hz bandwidth and battery operation. It is being used to replace the increasingly unreliable TVM's and the bulky HP302A.

The magnetic field was measured using a single axis magnetic field probe designed and built by IITRI. This probe is merely a many-turn coil with a ferrite core and terminating resistor. In each case, the field was measured in three perpendicular directions (north-south, east-west, and vertical), and the root of the sum of the squares was taken for each antenna condition. Appropriate conversion factors were used to convert the voltage reading at the output of the probe to an equivalent magnetic flux density. The 60 Hz values were measured with the antenna off.

The low impedance electric field (i.e., the horizontal electric field at the earth's surface) was measured with one-meter probe wires. Two perpendicular components of the horizontal electric field were read and the square root of the sum of the squares was calculated. All measurements were made by IITRI

field personnel.

3.5 Wisconsin Test Facility Operations

Since March, 1971, the Wisconsin Test Facility has been operated with 300 amperes in either the north-south or east-west antenna, or in both antennas simultaneously. In previous years, the operating schedule was roughly 5 days/week, 6 hours/day, at 42 or 45, 75 or 76 Hz. The schedule for June 1975 to June 1976 is summarized in Table 1 including monthly hours of operation, frequencies employed, and hours of modulated transmission. On August 20, 1976, 24-hour around-the-clock operation of both antennas was initiated.

3.6 Statistical Treatment

Analysis of variance was performed on all data. The data were transformed using the angular or arcsine transformation which is appropriate for proportions to prevent the variance from being a function of the mean. Tests were performed after the methods of Sokal and Rohlf (1969), using standard 2-way analyses of variance with replication for all tests except the Main subplots which were tested using a 3-level nested anova. The confidence limits about the mean were calculated with a formula that assumes a normal approximation to the binomial, because of the large sample sizes (Huntsberger 1967).

4. RESULTS

4.1 Electric and Magnetic Field Measurements

Table 1 provides a summary of the operating schedule of WTF from June 1975 through May 1976. Operation was mainly at 75 or 76 Hz, totalling 346 hours on the E/W antenna, 252.5 hours on the N/S antenna, and 1,020 hours on both antennas operating simultaneously. Of these totals, modulated transmission was 215.5 hours (E/W), 85 hours (N/S), and 5 hours (both antennae).

Measurements of magnetic field strengths in test and control plots in summer 1976 are given in Table 2; data for 1972, 1973, and 1975 are presented for comparison. Fields at the test plots range from a low of 0.008 gauss at the Old Hazleton (A3) test plot to a high of 0.88 gauss at GG (A12) test plot. Magnetic field strengths at all control plots continue to be less than 0.001 gauss, and are at least one to two orders of magnitude less than those of the test plots. The values of the measured magnetic field show a certain degree of fluctuation from year to year showing a maximum 2-fold difference between measurements taken in 1975 and 1976 at Main test subplot (A1b), Old Hazleton test plot (A3), and GG test plot (A12). The reason for this is that the only locations where the field exceeds the 0.001 gauss level are physically near an antenna. Near the antenna, the magnetic fields may be expected to vary as the inverse of the distance from the test point to the antenna. As a result of this behavior, the highest values of the magnetic field occur closest to the antenna. At these locations, the positioning of the probe is most critical. This fact is borne out by measurement. The higher magnetic flux densities show a larger degree of change

Table 1. WTF Operation for June 1975 Through May 1976.

Hours of Operation/Month

	Antenna						
	42 or 45 Hertz			75 or 76 Hertz			
Month/Year	E/W	N/S	Both	E/W	N/S	Both	NSB
June 1975	19.5	19.5	1.5	21.5	21.5	16.	---
July	6.35	6.35	--	13.5	13.5	132.	---
August	--	--	--	21.0	--	147.	---
September	--	--	--	5 MOD	--	86.5 + 5 MOD	---
October	--	--	31.5	36 + 85 MOD	36 + 85 MOD	69.	10.5*
November	--	--	--	--	--	236.5	---
December	--	--	--	38.5	96.5	--	---
January 1976	--	--	--	--	--	--	--
February	--	--	--	--	--	--	--
March	--	--	--	31 MOD	--	184.	--
April	--	--	--	32.5 MOD	--	144.	--
May	--	--	--	62 MOD	--	--	--

E/W = East/West

N/S = North/South

Both = East/West and North/South

NSB = North/South Buried

MOD = Modulated Output

Antenna(s) at 300 A unless otherwise noted.

*Antenna at 100 A.

than the lower magnetic flux densities. This reflects the difficulty in obtaining exactly the same measurement locations and positioning of the probe year after year.

Table 3 gives the measured low impedance electric fields at the collecting sites for the period 1972-1976. The 45- and 75-Hz readings show some fluctuation that may be explained, in part, by uncertainty in placement of the sensor. However, since the electric field varies as the natural logarithm of the inverse of the distance from the antenna, this cannot account for all of the differences from year to year. The main explanation for the yearly variations in these data is that the low impedance electric field is more affected by the differences in the earth's conductivity and other factors such as nearby long conductors which occur between measurements. These factors probably account for the two-fold differences between the horizontal field measurements in 1975 and 1976, including the nine-fold difference at the South Roadside Test site (N/S antenna, 45 Hz). These differences, however, are generally small compared with the differences between each paired test and control site. The magnitude of these differences are summarized for three years in Table 4 and have been maintained at least since March 1971, when the antenna's operating current was raised to its present level of 300 amperes.

The 60 Hz fields are quite variable because they depend, in large part, upon conditions which cannot be controlled e.g. the current in nearby power lines, the quality of residence and pole grounds, the placement of power

TABLE 2. Magnetic Fields at Test and Control Plots.

Antenna Current 300 Amperes

Site	Magnetic Flux Density (Gauss)																			
	E/W Antenna								N/S Antenna											
	45 Hz				75 Hz				45 Hz				75 Hz				60 Hz			
	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976
Main Test (A1a)	0.049	0.080	0.060	0.087	0.061	0.090	0.074	0.08	b	b	b	b	b	b	b	b	b	a	b	b
Main Test (A1b)	0.036	0.033	0.028	0.040	0.032	0.044	0.038	0.051	b	b	b	b	b	b	b	b	b	a	b	b
Main Test (A1c)	0.045	0.040	0.040	0.051	0.041	0.042	0.046	0.055	b	b	b	b	b	b	b	b	b	a	b	b
Main Control (B1a)	b	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b
Main Control (B1b)	b	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b
Main Control (B1c)	b	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b
Old Clover Test (A2)	0.061	0.082	0.060	0.087	0.064	0.076	0.067	0.072	b	b	b	b	b	b	b	b	b	a	b	b
New Clover Test (A19)	b	b	b	b	b	b	b	b	0.091	0.140	0.082	0.085	0.085	0.091	0.072	0.071	b	a	b	b
Clover Control (B2)	b	b	b	b	b	b	b	b	b	b	b	0.001	b	b	b	b	b	a	b	b
GG Test (A12)	0.80	0.84	0.599	0.277	0.75	0.88	0.592	0.300	b	b	b	b	b	b	b	b	b	a	b	b
North Leg Test (A7)	b	b	b	b	b	b	b	b	0.031	0.035	0.037	0.037	0.035	0.035	0.035	0.028	b	a	b	b

TABLE 2 - Continued

Site	Magnetic Flux Density (Gauss)																			
	E/W Antenna								N/S Antenna											
	45 Hz				75 Hz				45 Hz				75 Hz				60 Hz			
	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976
North Leg GG Control (B7)	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b
Old Hazleton Test (A3)	b	b	b	b	b	b	b	b	0.016	0.020	0.015	0.012	0.015	0.018	0.021	0.008	b	a	b	b
New Hazleton Test (A4)	b	b	b	b	b	b	b	b	0.016	0.016	0.011	0.016	0.015	0.015	0.016	0.011	b	a	b	b
Hazleton Control (B3)	b	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b
Hardwood Test (A8)	b	b	b	b	b	b	b	b	0.031	0.028	0.031	0.041	0.033	0.024	0.034	0.025	b	a	b	b
Hardwood Control (B8)	b	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b
South Roadside Test (A9)	b	b	b	b	b	b	b	b	0.15	0.25	0.136	0.17	0.20	0.25	0.212	0.189	b	a	b	b
South Roadside Control (B9)	b	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	a	b	b

[a] No measurement taken.

[b] Magnetic field density less than 0.001 Gauss.

Table 3. Low Impedance Electric Fields at Test and Control Plots.

Antenna Current 300 Amperes

Site	Low Impedance Electric Field Intensity (Volts/Meter)																			
	E/W Antenna								N/S Antenna											
	45 Hz				75 Hz				45 Hz				75 Hz				60 Hz			
	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976
Main Test (A1a)	0.122	0.123	0.141	0.0880	0.199	0.178	0.187	0.165	0.0320	0.0360	0.0286	0.0210	0.0410	0.0400	0.0404	0.0422	0.0002	a	0.0001	0.0002
Main Test (A1b)	0.116	0.091	0.106	0.104	0.186	0.152	0.175	0.185	0.0280	0.0330	0.0274	0.0240	0.0310	0.0340	0.0386	0.0437	0.0002	a	0.0001	0.0002
Main Test (A1c)	0.147	0.119	0.128	0.0969	0.227	0.184	0.233	0.232	0.0310	0.0420	0.0293	0.0281	0.0430	0.0360	0.0473	0.0434	0.0002	a	0.0001	0.0002
Main Control (B1a)	0.0017	a	0.0014	0.0015	0.0012	0.0012	0.0009	0.0014	0.0020	0.0019	0.0017	0.0018	0.0015	0.0015	0.0011	0.0016	b	a	0.0001	0.0001
Main Control (B1b)	0.0023	a	0.0022	0.0015	0.0012	0.0016	0.0006	0.0019	0.0026	0.0028	0.0025	0.0016	0.0022	0.0022	0.0003	0.0024	0.0001	a	0.0001	0.0001
Main Control (B1c)	0.0021	a	0.0021	0.0015	0.0015	0.0015	0.0006	0.0018	0.0025	0.0024	0.0024	0.0010	0.0019	0.0020	0.0009	0.0022	0.0001	a	b	0.0001
Old Clover Test (A2)	0.126	0.118	0.130	0.0724	0.208	0.171	0.257	0.178	0.0320	0.0380	0.0333	0.0269	0.0280	0.0450	0.0467	0.0403	0.0002	a	0.0001	0.0002
New Clover Test (A10)	0.0050	0.0043	0.0044	0.0046	0.0057	0.0062	0.0042	0.0035	0.108	0.136	0.111	0.102	0.164	0.230	0.160	0.115	0.0001	a	0.0001	0.0001
Clover Control (B2)	0.0259	a	0.0221	0.0225	0.0144	0.0147	0.0085	0.0140	0.0318	0.0520	0.0241	0.0280	0.0142	0.0199	0.0088	0.0135	0.0102	a	0.0084	0.0075
GG Test (A12)	0.110	0.235	0.0853	0.142	0.153	0.270	0.302	0.520	0.0142	0.0260	0.0160	0.0300	0.0181	0.0295	0.0197	0.0301	b	a	b	b
North Leg Test (A7)	0.0028	0.0030	0.0024	0.0026	0.0020	0.0022	0.0018	0.0023	0.590	0.580	0.551	0.629	0.528	0.568	0.516	0.563	b	a	0.0001	b
North Leg Control (B7)	0.0012	a	0.0011	0.0014	0.0006	0.0009	0.0004	0.0008	0.0014	0.0017	0.0012	0.0013	0.0005	0.0004	0.0003	0.0007	0.0031	a	0.0046	0.0043
Old Hazleton Test (A3)	0.0025	0.0026	0.0024	0.0028	0.0035	0.0032	0.0039	0.0025	2.50	2.48	2.41	3.24	2.56	2.41	3.51	2.40	0.0003	a	0.0005	0.0003

Table 3. - Continued

Site	Low Impedance Electric Field Intensity (Volts/Meter)																			
	E/W Antenna								N/S Antenna											
	45 Hz				75 Hz				45 Hz				75 Hz				60 Hz			
	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976
North Hazleton Test (A4)	0.0018	0.0016	0.0016	0.0020	0.0015	0.0013	0.0015	0.0010	0.890	0.784	0.662	1.08	0.985	0.876	0.963	0.642	b	a	0.0002	b
Hazleton Control (B1)	0.0029	a	0.0029	0.0033	0.0024	0.0024	0.0027	0.0023	0.0033	0.0031	0.0028	0.0039	0.0029	0.0025	0.0030	0.0025	0.0005	a	0.0002	0.0003
Hardwood Test (A8)	0.0014	0.0053	0.0039	0.0093	0.0044	0.0057	0.0042	0.0050	0.0704	0.0890	0.0661	0.101	0.0930	0.149	0.107	0.115	b	a	0.0001	b
Hardwood Control (B8)	0.0013	a	0.0014	0.0016	0.0007	0.0007	0.0005	0.0013	0.0014	0.0013	0.0016	0.0016	0.0009	0.0009	0.0007	0.0017	0.0008	a	0.0016	0.0011
South Roadside Test (A9)	0.0090	0.0087	0.0080	0.0086	0.0099	0.0081	0.0103	0.0071	0.143	0.106	0.107	0.930	0.291	0.176	0.246	0.117	0.0001	a	0.0008	0.0001
South Roadside Control (B9)	0.0010	a	0.0011	0.0009	0.0007	0.0001	0.0008	0.0006	0.0010	0.0012	0.0011	0.0008	0.0006	b	0.0007	0.0006	0.0018	a	0.0055	0.0039

a = No measurement taken.

b = < 0.00005 volt/meter.

Table 4. Magnitude of the Difference Between Low Impedance Electric Fields at Test and Control Plots at 75 Hz[a].

Test Series	Test/Control		
	1973	1975	1976
Main[b]	95-150x	198-414x	87-166x
Old Clover[b]	12x	30x	13x
New Clover[c]	12x	18x	9x
North Leg[c]	1456x	1613x	804x
GG[b]	310x	794x	400x
Old Hazleton[c]	945x	1064x	960x
New Hazleton[c]	344x	325x	257x
Hardwood[c]	157x	149x	68x
South Roadside[c]	5500x	362x	195x

[a] In all cases the E fields are greater in the test plots by the figure shown.

[b] E/W antenna operating.

[c] N/S antenna operating.

lines, and the amount of current allowed to flow in power system neutrals. Of all these factors, the only one that remains relatively constant from year to year is the placement of the lines. Even this may change, however, as power systems are upgraded and expanded.

4.2 Soil Arthropod Data

Table 5 gives the monthly averages of Prostigmata, Mesostigmata, Cryptostigmata, and Collembola per core per plot during summer 1976; 95 percent confidence limits of these means are given in Table 6. The annual densities attained by these arthropods in 1972, 1973, 1975, and 1976 are summarized for purposes of comparison in Table 7, and their population curves in the Main, Old Clover, and New Hazleton plots from 1971-1976 are depicted in Figures 2-4.

Predator-prey proportions were determined from these data and analyses of variance were performed as follows: test plot versus control plot, for 1976 and previous years (Table 8 and 9); extent of variability within each plot since 1972 and significance of monthly predator-prey proportions on a plot by plot basis since 1972 (Table 10). Predator-prey proportions seen in perspective are depicted in Figures 5-8; also shown in these graphs is the total number of soil arthropods per square meter of soil to a depth of 0.1 meter. This unit of arthropod density is universally used and provides a basis for comparison with other work. Figure 9 presents the seven-year ratio of Cryptostigmata to Collembola in the Old Hazleton test and control plots.

Table 5. Monthly Means Per Core of Mites and Collembola, 1976.

Test Site	Month	Mesostig-mata	Prostig-mata	Crypto-stigmata	Collem-bola	Control Site	Month	Mesostig-mata	Prostig-mata	Crypto-stigmata	Collem-bola
Main (A1)	June	15.42	14.75	93.42	63 75	Main (B1)	June	17.17	4.67	96.08	33.17
	July	16.92	15.58	111.83	2[illegible].58		July	18.67	11.08	120.92	50.75
	Aug.	21.00	50.17	204.00	24.33		Aug.	13.75	31.42	117.33	59.67
	Sept.	17.42	72.5[illegible]	259.00	20.75		Sept.	14.75	44.17	256.67	46.00
Clover (A2)	June	3.25	3.75	36.50	8.37	Clover (B2)	June	6.00	4.75	20.37	27.12
	July	5.37	9.75	107.[illegible]	6.00		July	11.62	6.75	61.87	42.37
	Aug.	4.50	20.00	719.87	[illegible].37		Aug.	14.00	9.75	72.25	32.62
	Sept.	11.62	6.00	947.25	7.37		Sept.	11.62	10.37	109.37	34.50
New Clover (A10)	June	4.00	11.50	42.50	29.87						
	July	2.37	4.37	32.00	22.75						
	Aug.	7.87	8.87	74.00	24.62						
	Sept.	8.37	12.25	98.75	16.62						
[illegible] [illegible]zleton (A3)	June	12.37	19.37	194.00	147.00	Hazleton (B3)	June	14.87	30.37	101.87	66.50
	July	5.75	20.62	90.50	111.12		July	13.50	53.37	151.75	96.62
	Aug.	5.50	28.12	234.75	104.12		Aug.	16.62	28.62	255.12	52.75
	Sept.	9.12	36.87	243.12	100.87		Sept.	6.75	25.75	296.00	15.50
New Hazleton (A4)	June	14.62	34.12	180.12	67.25						
	July	13.62	44.37	207.12	106.62						
	Aug.	14.12	31.37	236.75	100.00						
	Sept.	4.37	26.62	249.37	33.37						
North Leg (A7)	June	4.75	11.25	37.12	32.75	North Leg & G.G. (B7)	June	10.50	2.75	26.87	15.87
	July	5.00	11.87	41.62	17.75		July	14.00	6.37	35.87	8.75
	Aug.	4.00	8.37	61.50	13.12		Aug.	15.00	15.87	79.12	16.12
	Sept.	4.87	25.50	225.75	27.25		Sept.	9.37	15.62	102.00	11.87
G.G. (A12)	June	28.37	25.00	104.62	207.37						
	July	10.87	13.75	45.00	22.00						
	Aug.	21.87	26.75	146.75	57.37						
	Sept.	13.75	55.62	272.25	57.25						

TABLE 5. - Continued

Test Site	Month	Mesostig-mata	Prostig-mata	Crypto-stigmata	Collem-bola	Control Site	Month	Mesostig-mata	Prostig-mata	Crypto-stigmata	Collem-bola
Hardwood (A8)	June	5.00	19.75	29.50	23.62	Hardwood (B8)	June	9.25	3.00	12.62	11.12
	July	4.12	18.37	42.37	32.87		July	4.50	7.50	20.37	18.37
	Aug.	6.37	16.50	55.50	25.87		Aug.	13.25	7.50	41.75	23.37
	Sept.	11.87	38.12	162.37	29.50		Sept.	13.37	7.12	82.50	41.50
South Roadside (A9)	June	9.50	11.00	32.75	40.00	South Roadside (B9)	June	16.12	9.00	44.50	12.37
	July	5.12	9.62	45.87	22.50		July	13.50	8.12	82.37	28.25
	Aug.	7.50	23.75	78.75	11.12		Aug.	6.00	13.50	81.12	25.12
	Sept.	7.62	28.75	185.25	13.87		Sept.	16.25	21.75	220.50	72.00

Table 6. Ninety-Five Percent Confidence Limits of Mean Numbers of Microarthropods per Core Sample.

Site	Mesostigmata		Prostigmata		Cryptostigmata		Collembola	
	Test	Control	Test	Control	Test	Control	Test	Control
Main	17.69 (13.67-21.70)	16.08 (14.42-17.74)	25.75 (18.30-33.19)	22.83 (10.10-35.56)	167.06 (124.10-210.02)	147.75 (96.98-198.52)	32.35 (19.35-45.35)	47.40 (37.16-57.64)
Clover	6.19 (3.10-9.27)	10.81 (8.27-13.35)	9.87 (5.47-14.28)	7.91 (5.73-10.08)	452.69 (251.95-653.42)	65.97 (47.08-84.85)	6.78 (4.38-9.18)	34.09 (22.45-45.73)
New Clover	5.66 (3.82-7.49)	10.81 (8.27-13.35)	9.25 (6.78-11.72)	7.91 (5.73-10.08)	61.81 (40.89-82.73)	65.97 (47.08-84.85)	23.47 (15.03-31.91)	34.09 (22.45-45.73)
Old Hazleton	8.19 (5.96-10.42)	12.94 (9.96-15.92)	26.25 (19.26-33.24)	34.53 (26.63-42.43)	215.59 (148.41-282.77)	201.19 (147.64-254.73)	115.78 (90.09-141.47)	57.84 (43.20-72.49)
New Hazleton	11.69 (7.68-15.70)	12.94 (9.96-15.92)	34.12 (23.70-44.55)	34.53 (26.63-42.43)	218.34 (174.90-261.78)	201.19 (147.64-254.73)	76.81 (46.58-107.05)	57.84 (43.20-72.49)
North-Leg	4.66 (3.78-5.53)	12.22 (9.20-15.24)	14.25 (10.03-18.46)	10.16 (6.33-13.98)	91.50 (53.76-129.24)	61.09 (45.45-76.74)	22.72 (16.82-28.62)	13.16 (10.31-16.00)
G.G.	18.72 (12.44-24.99)	12.22 (9.20-15.24)	30.28 (18.97-41.59)	10.16 (6.33-13.98)	142.44 (88.44-196.44)	61.09 (45.45-76.74)	46.62 (32.97-60.28)	13.16 (10.31-16.00)
Hardwood	6.84 (5.12-8.56)	10.09 (7.15-13.04)	23.19 (16.99-29.39)	6.28 (4.28-8.28)	72.44 (49.16-95.71)	39.31 (26.46-52.16)	27.97 (20.04-35.90)	23.59 (16.21-30.98)
South Roadside	7.44 (5.87-9.01)	12.97 (10.09-15.85)	18.28 (12.42-24.14)	13.12 (8.18-18.07)	85.66 (57.87-113.44)	107.12 (66.18-148.07)	21.87 (16.08-27.67)	34.44 (18.91-49.97)

Table 7. Population Densities[a] of Soil Arthropods in 1972, 1973, 1975, and 1976.

Site	Prostigmata				Mesostigmata				Cryptostigmata				Collembola				Totals			
	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976
Main Test A1a	156	186	282	303	210	208	246	322	856	2653	1990	2490	376	240	612	511	1598	3287	3130	3626
A1b	266	149	336	483	181	230	297	258	1080	1150	1943	3249	512	634	547	645	2039	2163	3123	4635
A1c	180	9	279	450	228	99	260	269	1304	729	1528	2280	645	370	527	397	2357	1291	2594	3396
Main Con- B1a	201	64	100	631	267	156	195	255	1142	959	1076	3561	471	436	531	1010	2081	1615	1902	5457
trol B1b	138	141	218	238	177	189	328	213	508	796	1441	1716	327	487	673	534	1150	1613	2660	2701
B1c	138	85	61	227	214	94	171	304	852	772	398	1815	624	546	231	731	1828	1497	861	3077
Clover Test A2	124	113	117	316	210	132	139	198	1377	935	1234	14486	1080	774	357	217	2791	1954	1847	15217
New Clover Test A10	70	66	200	296	184	154	126	181	674	1049	1711	1978	1408	1181	858	751	2536	2450	2895	3206
Clover Con- trol B2	77	44	234	253	130	93	342	346	378	456	2176	2111	1556	816	2323	1091	2141	1409	5075	3806
Old Hazle- ton A3	88	95	265	840	101	150	261	262	1787	1799	3104	6899	1243	1093	3084	3705	3219	3137	6704	11706
New Hazle- ton A4	341	256	486	1092	532	310	486	374	3428	3097	4714	6987	2212	1685	1689	2458	6534	5348	7345	10911
Hazle- ton Con- trol B3	231	273	625	1105	361	256	442	414	2033	2169	3906	6438	2227	1679	1457	1851	4852	4377	6430	9808
North Leg Test A7	43	73	293	456	51	68	146	149	865	958	1906	2928	450	465	1061	727	1409	1564	3406	4260
GG Test A12	238	169	435	969	210	216	342	599	702	755	1850	4558	547	305	845	1492	1697	1445	3472	7618
N.L.-G.G. Con- trol B7	86	119	575	325	280	514	442	391	1731	2187	2157	1955	381	245	613	321	2478	3065	3787	3092

TABLE 7. - Continued

Site	Prostigmata				Mesostigmata				Cryptostigmata				Collembola				Totals			
	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976	1972	1973	1975	1976
Hardwood Test A8	406	316	364	742	213	143	250	219	1479	1398	1488	2318	1081	884	573	895	3179	2741	2675	4174
Hardwood Control B8	154	87	169	201	167	75	181	323	463	234	798	1253	659	652	706	755	1443	1048	1854	2537
South Roadside Test A9	234	276	356	585	140	143	231	238	640	938	843	2741	606	558	406	700	1620	1915	1842	4264
South Roadside Control B9	329	258	626	420	405	341	474	415	2474	1921	3487	3428	742	573	717	1102	3950	3093	5304	5365
% Total	.07	.06	.06	.09	.08	.08	.08	.05	.49	.55	.56	.67	.35	.30	.27	.18				
Totals	3500	2863	4194	9932	4282	3571	5359	5730	23973	24955	37756	73191	17147	13623	17810	19993	48903	45012	66906	108851

[a]Each figure is the summer total collected for that group, representing 32 core samples per plot for all plots but the Main subplots where a total of 16 core samples were taken from each subplot.

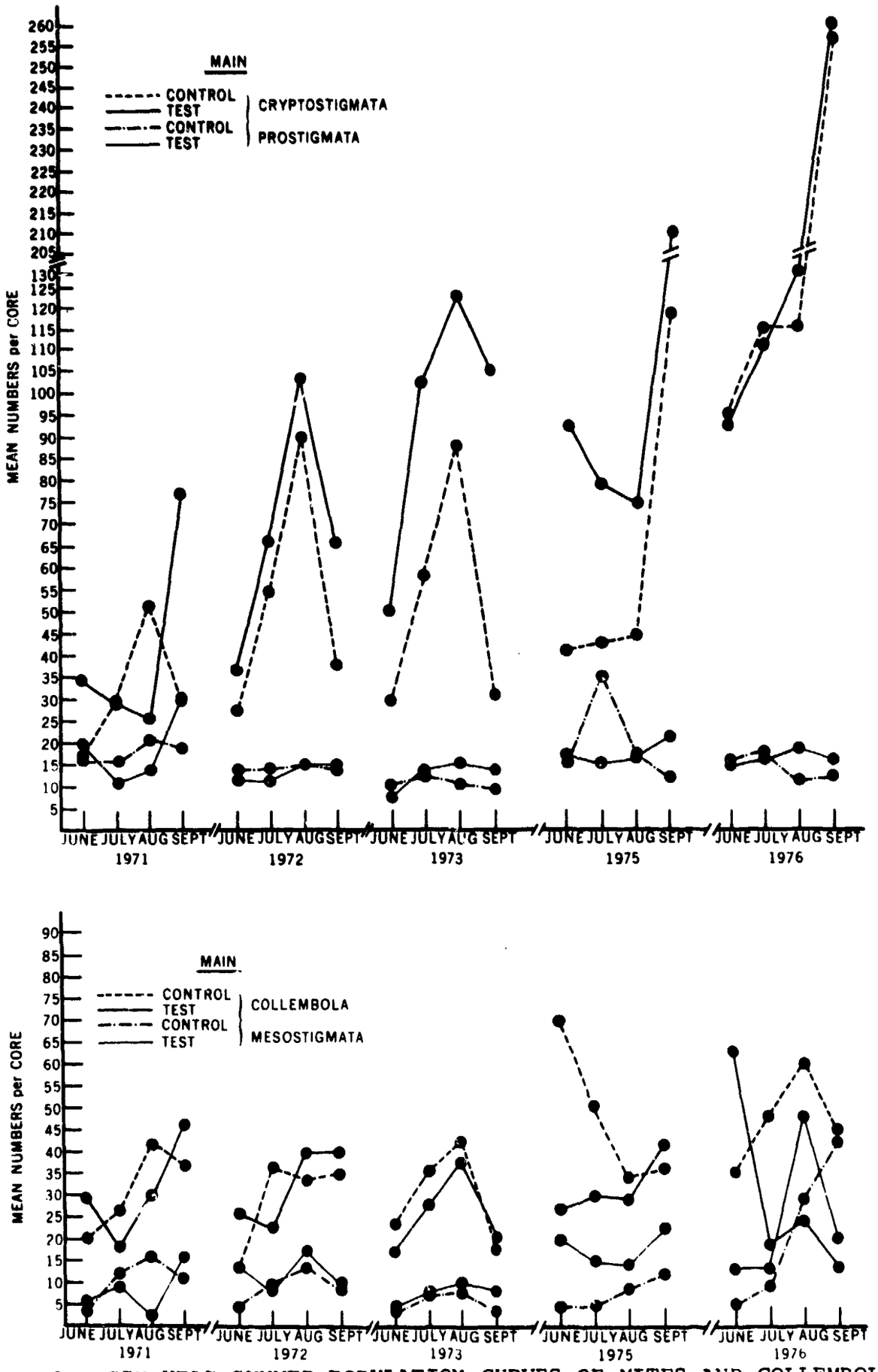


Figure 2. SIX-YEAR SUMMER POPULATION CURVES OF MITES AND COLLEMBOLA IN MAIN EXPERIMENTAL PLOTS, BASED ON MONTHLY MEANS.

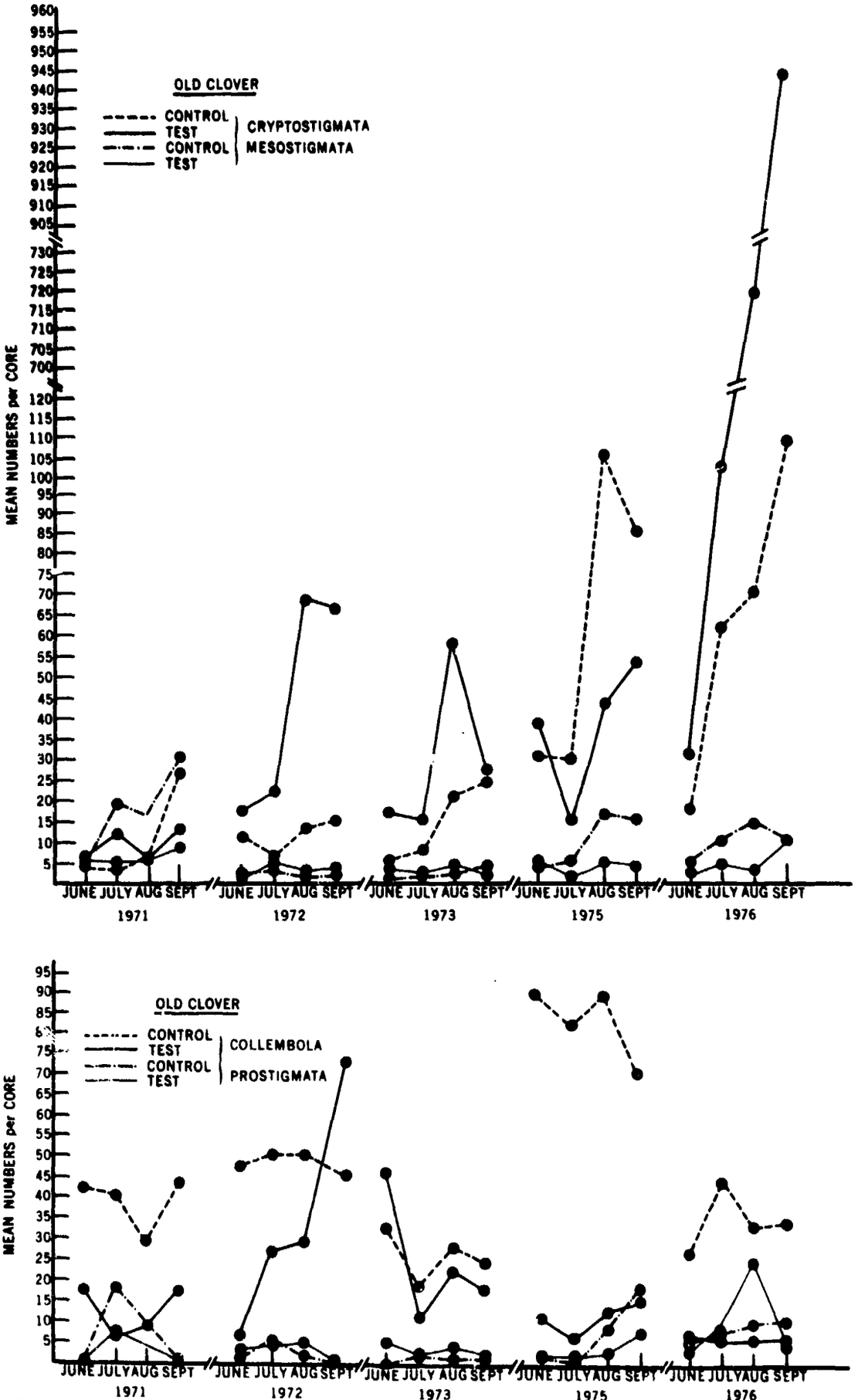
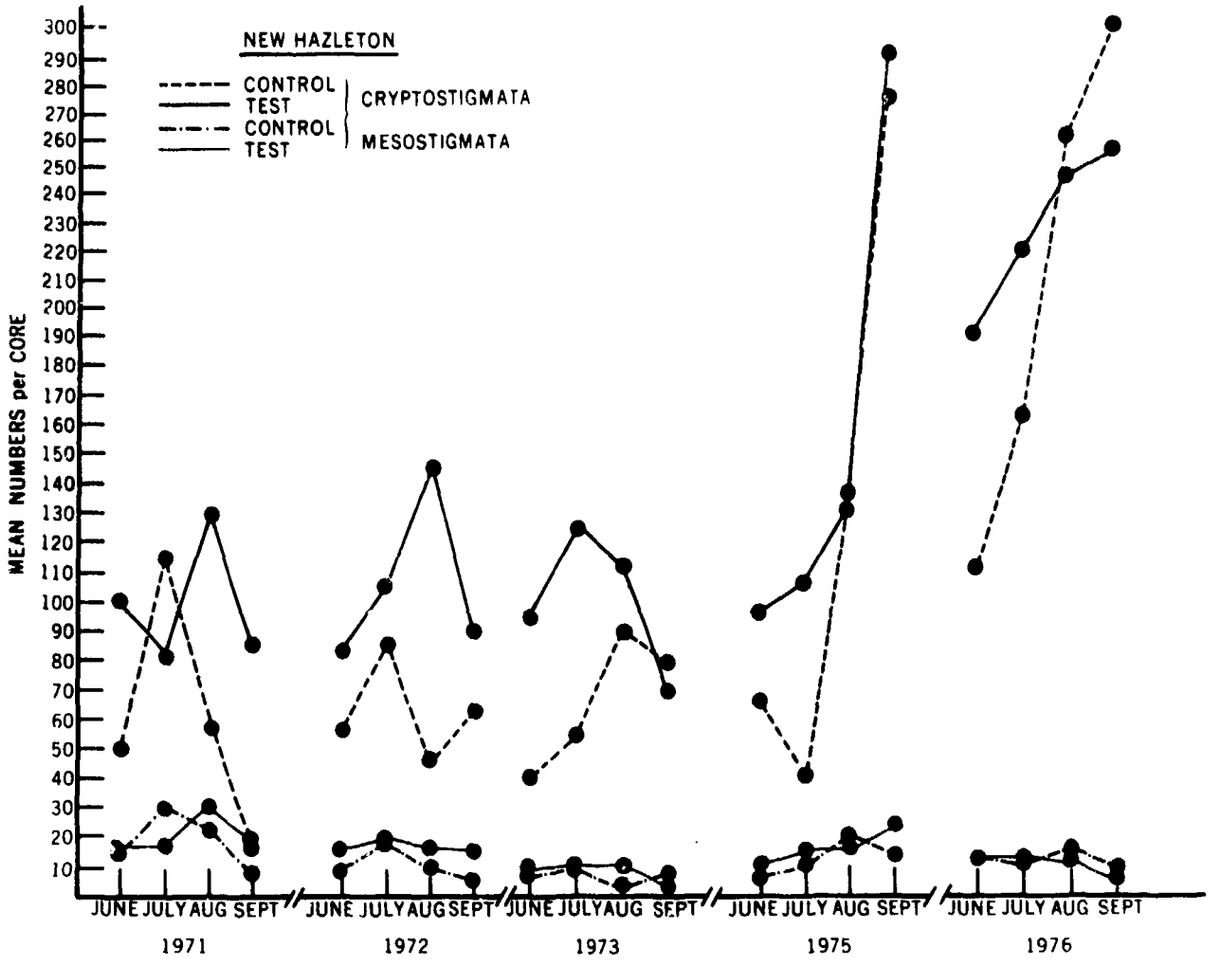


Figure 3. SIX-YEAR SUMMER POPULATION CURVES OF MITES AND COLLEMBOLA IN OLD CLOVER EXPERIMENTAL PLOTS, BASED ON MONTHLY MEANS.



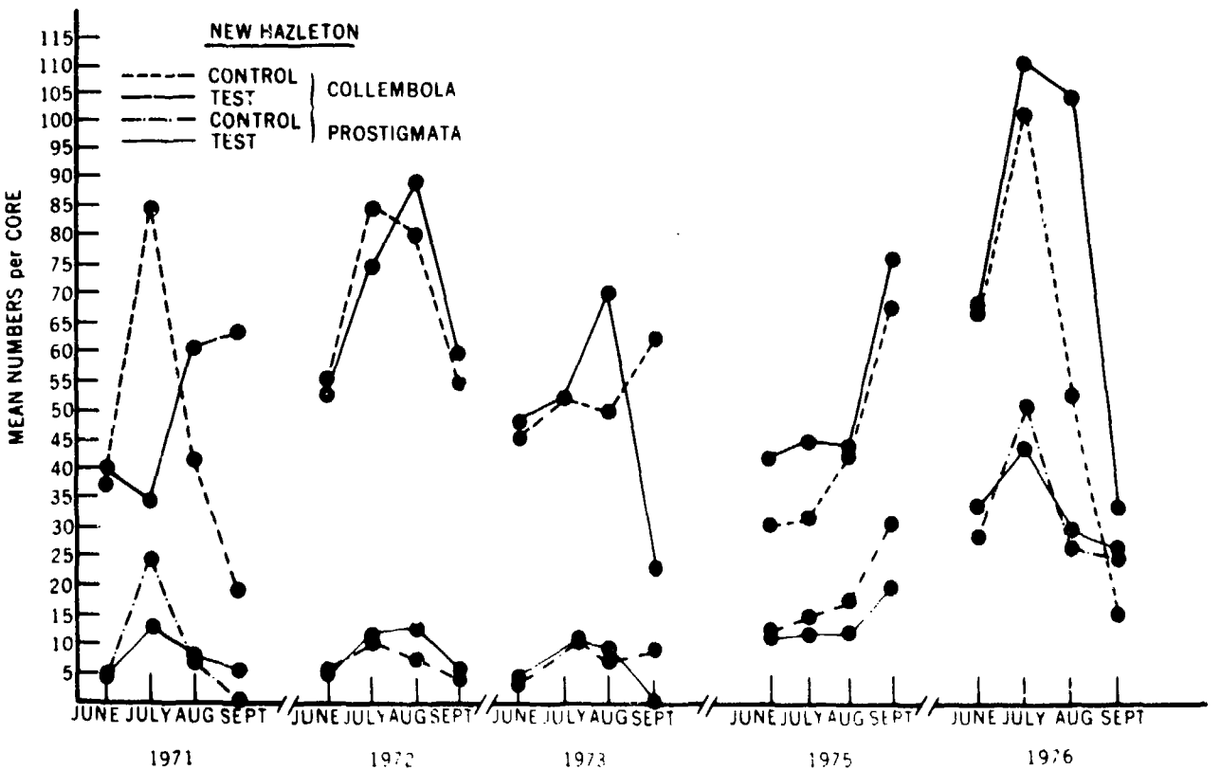


Figure 4. SIX-YEAR SUMMER POPULATION CURVES OF MITES AND COLLEMBOLA IN NEW HAZLETON EXPERIMENTAL PLOTS, BASED ON MONTHLY MEANS.

Table 8. Results of Two-way Analysis of Variance and Mean Proportions of Predators in Paired Plots.

Site	Average proportion predators[a] in test	Average proportion predators in control	Test vs control	Months
Main (A1,B1)	0.1950	0.1744	n.s.[b]	n.s.
Clover (A2,B2)	0.0749	0.1761	P<.001	.005>P>.001
New Clover (A10,B2)	0.1631	0.1761	n.s.	n.s.
Old Hazleton (A3,B3)	0.1052	0.1703	P<.001	.01>P>.025
New Hazleton (A4,B3)	0.1289	0.1703	.025>P>.01	P<.001
North Leg (A7,B7)	0.1735	0.2406	P<.001	P<.001
GG (A12,B7)	0.2395	0.2406	n.s.	P<.001
Hardwood (A8,B8)	0.2530	0.2476	n.s.	P<.001
S. Roadside (A9,B9)	0.1996	0.2080	n.s.	P<.001

[a]Prostigmata and Mesostigmata.

[b]Not significant at the .05 level of significance.

Table 9. Predator-Prey Proportions in Test vs. Control Plots. Analysis of Variance Per Year.

Plot/Year	1972	1973	1975	1976
Main	NS[a]	NS	NS	NS
Old Hazleton	S[b]	S	S	S
New Hazleton	NS	NS	S	S
Old Clover	S	NS	NS	S
New Clover	NS	NS	NS	NS
N. Leg	NS	S	S	S
G.G.	S	NS	NS	NS
Hardwoods	NS	NS	NS	NS
S. Roadside	S	NS	S	NS

[a]Not significant at 5% level of probability.

[b]Significant.

Table 10. Mean Proportion of Predators in Plots with 95% Confidence Limits and Analysis of Variance for 1972, 1973, 1975, and 1976.

Site	Range	1972	1973	1975	1976	Prob. Yr.	Prob. Mo.
Main Test							
A1a	.133	.277 (.255-.298)	.144 (.132-.156)	.169 (.155-.182)	.210 (.197-.223)	sig .025>P>.01	n.sig P ~ .75
A1b	.043	.220 (.201-.240)	.184 (.168-.201)	.203 (.189-.217)	.177 (.166-.188)	n.sig .25>P>.10	n.sig .25>P>.10
A1c	.052	.186 (.171-.202)	.156 (.136-.175)	.208 (.192-.223)	.199 (.186-.212)	n.sig .50>P>.25	n.sig .75>P>.50
Main Control							
*B1a	.13	.271 (.252-.290)	.141 (.124-.158)	.155 (.139-.171)	.147 (.138-.156)	sig .005>P>.001	n.sig P ~ .25
*B1b	.069	.268 (.242-.294)	.224 (.204-.245)	.205 (.190-.221)	.199 (.184-.214)	n.sig .50>P>.25	sig P ~ .005
*B1c	.116	.205 (.186-.223)	.153 (.135-.172)	.269 (.240-.299)	.177 (.163-.190)	sig .01>P>.005	n.sig P ~ .75
Clover							
A2	.072	.147 (.134-.160)	.131 (.116-.146)	.127 (.112-.142)	.075 (.071-.079)	sig P~.005	sig P<.001
A10	.063	.114 (.102-.126)	.100 (.88-.112)	.160 (.147-.174)	.163 (.150-.176)	sig .005>P>.001	n.sig .25>P>.10
*B2	.079	.097 (.084-.109)	.098 (.083-.113)	.116 (.108-.124)	.176 (.164-.188)	sig P<.001	n.sig P>.75
Hazleton							
A3	.038	.067 (.059-.076)	.076 (.067-.085)	.075 (.069-.081)	.105 (.994-.110)	sig P~.001	n.sig .50>P>.25
A4	.032	.142 (.134-.151)	.110 (.101-.118)	.132 (.125-.140)	.129 (.123-.135)	n.sig P~.10	n.sig .25>P>.10
*B3	.068	.127 (.118-.137)	.144 (.134-.153)	.195 (.185-.205)	.170 (.163-.177)	sig P<.001	sig P<.001

Table 10 - cont.

Site	Range	1972	1973	1975	1976	Prob. Yr.	Prob. Mo.
North Leg-G.G.							
A7	.082	.123 (.106-.140)	.091 (.077-.105)	.141 (.129-.152)	.173 (.162-.184)	sig .01>P>.005	n.sig .50>P>.25
A12		.293 (.272-.315)	.277 (.254-.300)	.213 (.199-.227)	.239 (.229-.249)	n.sig P~.05	sig P<.001
*B7	.095	.146 (.132-.160)	.206 (.192-.220)	.226 (.213-.239)	.241 (.226-.256)	sig P<.001	n.sig P~.05
Hardwood							
A8	.076	.206 (.192-.220)	.185 (.170-.199)	.261 (.244-.278)	.253 (.240-.266)	sig .005>P>.001	n.sig P~.10
*B8	.087	.225 (.203-.246)	.161 (.139-.183)	.217 (.198-.236)	.248 (.231-.265)	n.sig P~.05	n.sig .25>P>.10
South Roadside							
A9	.159	.250 (.229-.271)	.201 (.183-.219)	.359 (.337-.381)	.200 (.188-.212)	sig P<.001	sig P<.001
*B9	.051	.192 (.179-.204)	.201 (.187-.215)	.243 (.231-.254)	.208 (.197-.219)	n.sig .10>P>.05	sig P~.005

*Control Plot.

Overall mean range:
1. All test plots, all years = 0.75;
2. All control plots, all years = .087.

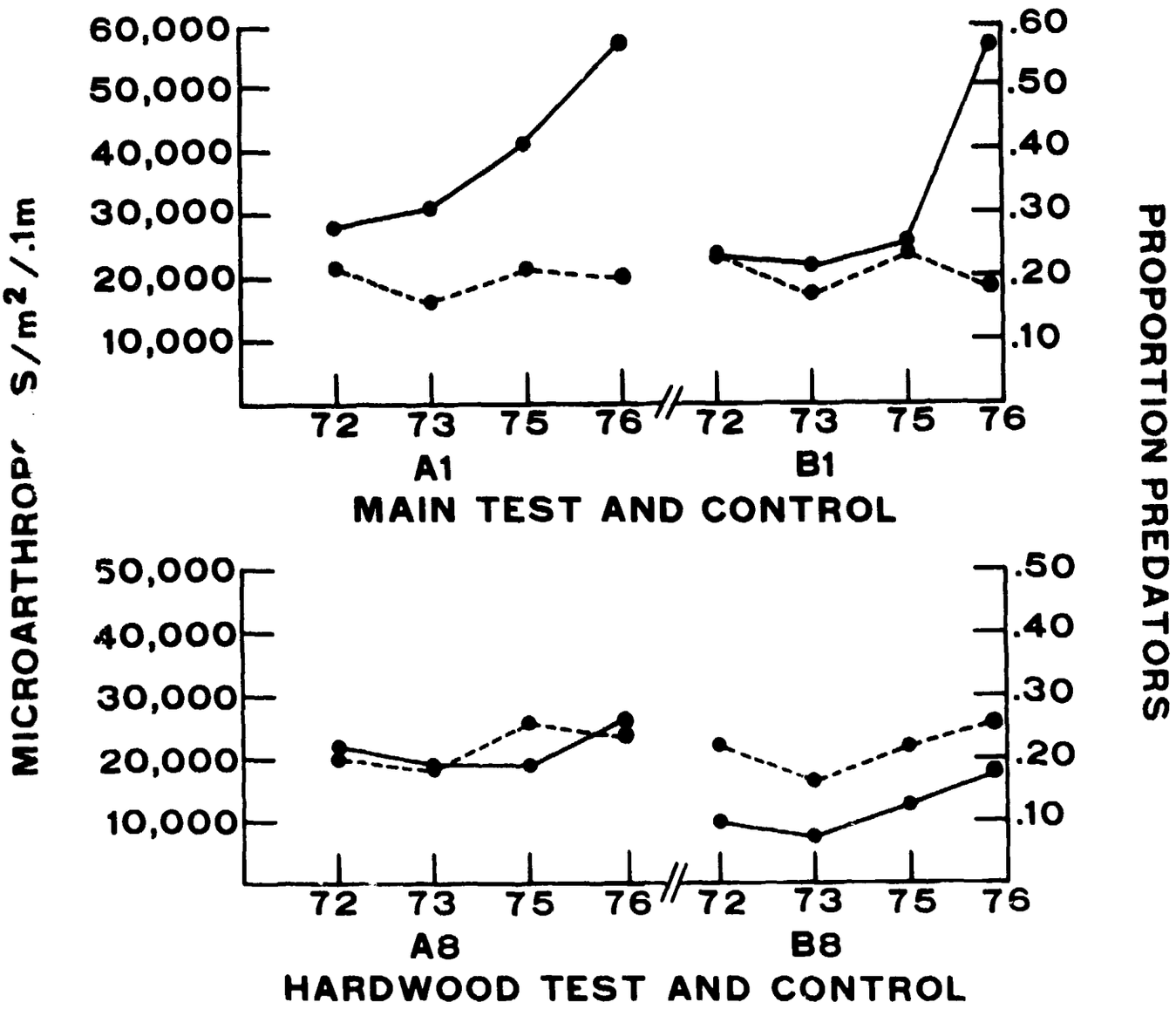


Figure 5. FOUR-YEAR SOIL ARTHROPOD DENSITIES PER SQUARE METER PER 0.1 METER TOPSOIL (· · · ·) AND PREDATOR PROPORTIONS (-----) IN PAIRED PLOTS.

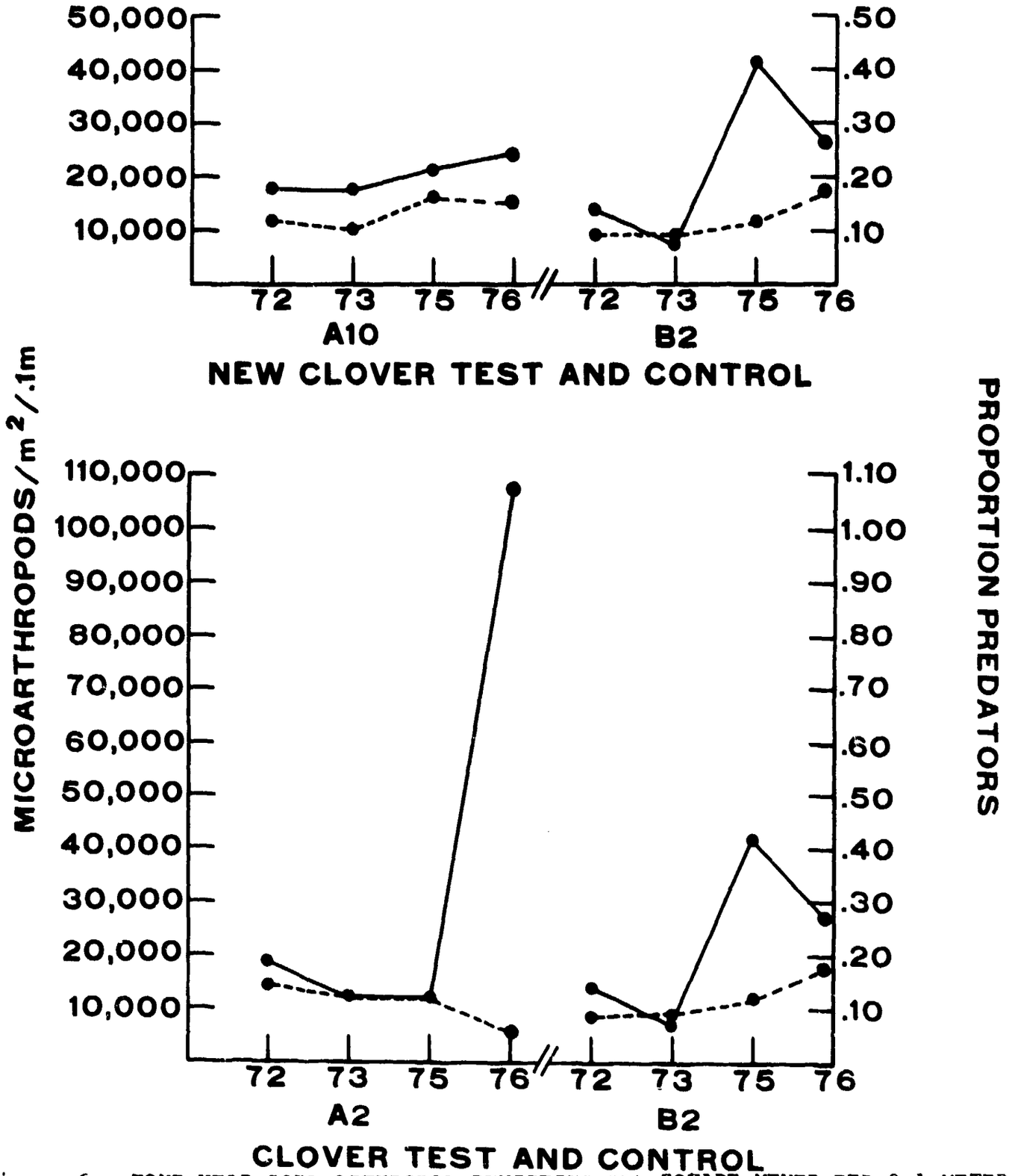


Figure 6. FOUR-YEAR SOIL ARTHROPOD DENSITIES PER SQUARE METER PER 0.1 METER TOPSOIL (_____) AND PREDATOR PROPORTIONS (-----) IN PAIRED PLOTS.

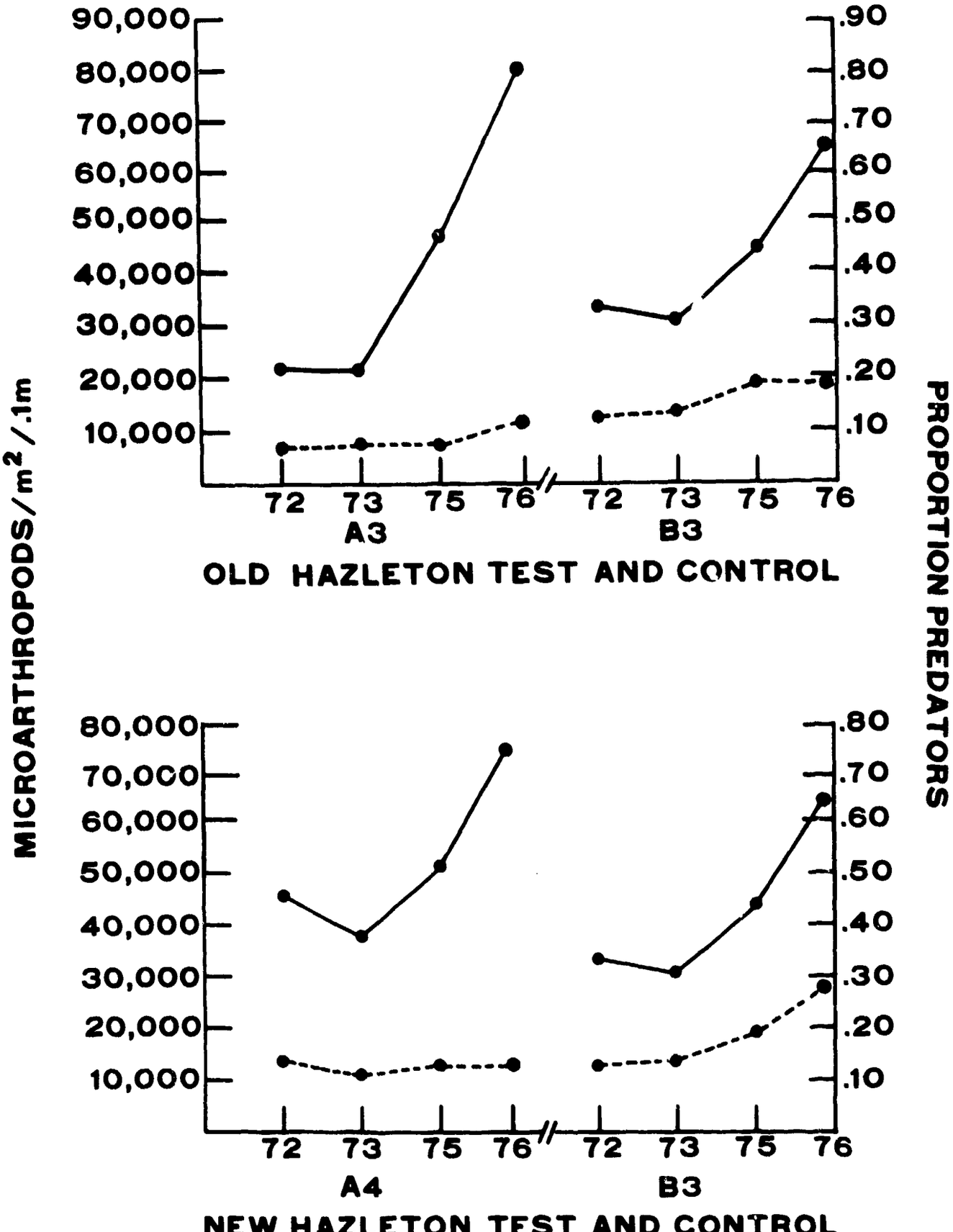


Figure 7. FOUR-YEAR SOIL ARTHROPOD DENSITIES PER SQUARE METER PER 0.1 METER TOPSOIL (_____) AND PREDATOR PROPORTIONS (-----) IN PAIRED PLOTS.

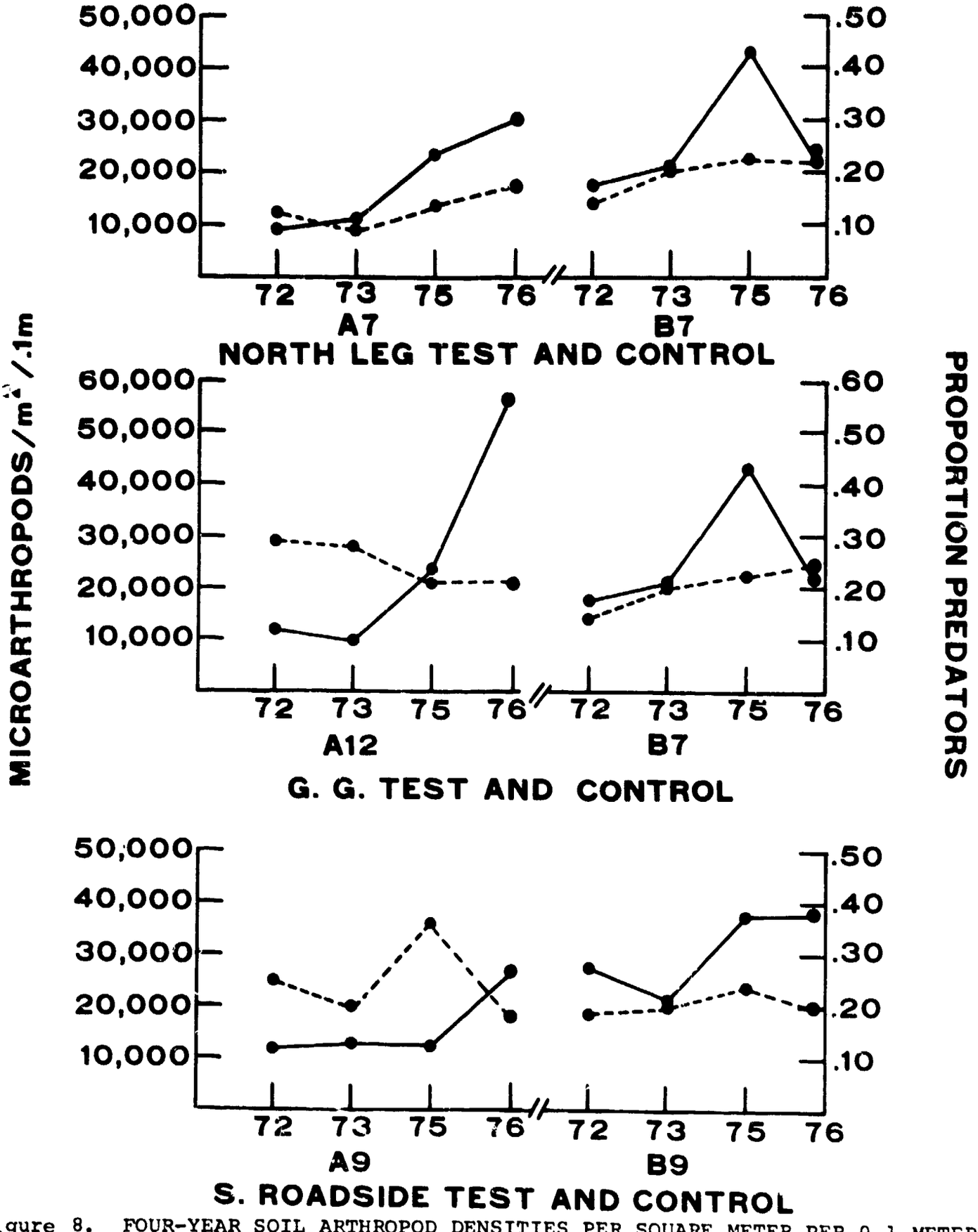


Figure 8. FOUR-YEAR SOIL ARTHROPOD DENSITIES PER SQUARE METER PER 0.1 METER TOPSOIL (_ _ _ _) AND PREDATOR PROPORTIONS (-----) IN PAIRED PLOTS.

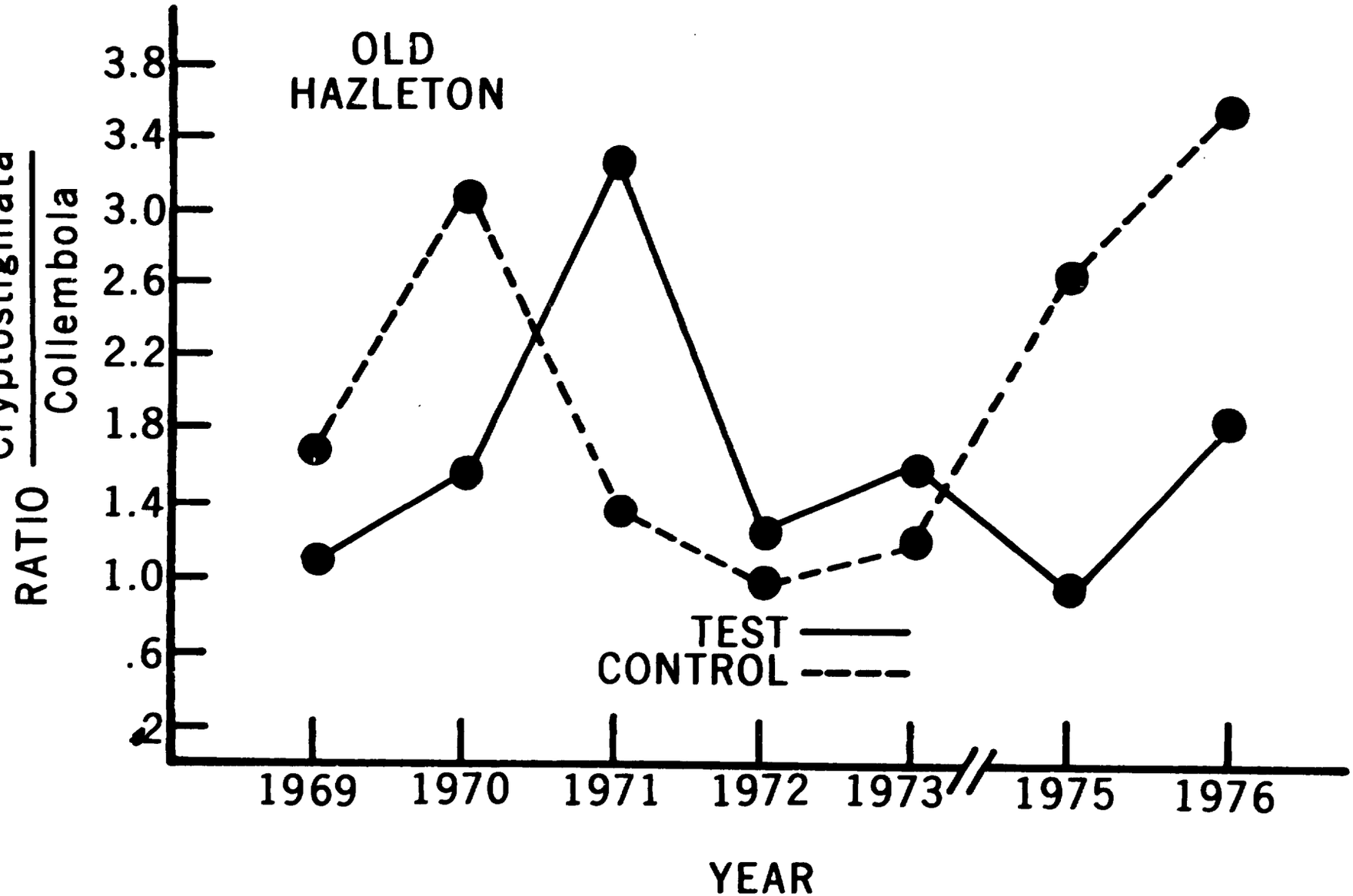


Figure 9. SEVEN-YEAR RATIO OF CRYPTOSTIGMATA TO COLLEMBOLA IN OLD HAZLETON PAIRED PLOTS.

5. DISCUSSION

The unusually hot and dry summer of 1976 added meterological stress to the "real-life" situation in which soil arthropods were exposed to ELF electromagnetic fields. This provided the opportunity to evaluate the effect of multiple stress in the context of our long-term population studies. Air temperature data summarized in Table 11, indicate that the summer of 1976 was the hottest since 1972. Compared with 1975, for example, mean daytime maxima were much higher, being 12°F, 7°F, and 7°F higher in June, July, and August, respectively. Night time lows were about the same as in other years. Associated with the heat was a dry spell when only 9.03 inches of rain fell from May through August. This is about half the rainfall recorded by the U.S. Forest Service in other relevant years (Table 12). These physical factors were reflected in the friability of the core samples when removed from the ground. There was relatively little moisture in the soil horizons that we sampled.

Small arthropods are particularly susceptable to dessication because of their relatively large surface area compared to their volume. For this reason they occur with the greatest frequency in moist rather than arid situations. Much to our surprise, total population densities rose by 163 percent in 1976 over 1975 (Table 7), in 17 of 19 test and control plots alike. Major contributors were Prostigmata (237%) and Cryptostigmata (194%); absolute increases occurred in Mesostigmata (107%) and Collembola (112%), as well, but their proportions decreased relative to the first two groups. Comparison of the 1976 group-by-group densities with those of previous years reveals the following:

Table 11. Mean Maximum and Minimum Temperatures (°F) at Wisconsin Test Facility.[a]

Month	1972		1973		1975		1976	
	Max	Min	Max	Min	Max	Min	Max	Min
June	74	43	76	50	70	49	82	49
July	74	46	77	53	75	55	82	48
August	77	53	77	55	77	52	84	50

[a]U.S. Forest Service data.

Table 12. Precipitation (Inches)[a]

Year	May	June	July	August	Total
1972[b]	2.51	4.97	6.82	8.71	23.01
1973[b]	5.83	4.63	4.06	7.78	22.30
1975[b]	3.01	6.28	2.64	4.73	16.66
1976[c]	1.09	3.78	1.64	2.52	9.03

[a]U.S. Forest Service data.

[b]Taken at Glidden.

[c]Taken at WTF.

1. Prostigmata - densities increased in 11 of 11 test plots and 6 of 8 control plots;

2. Mesostigmata - densities increased in 6 of 11 test plots and 3 of 8 control plots;

3. Cryptostigmata - densities increased in 11 of 11 test plots and 5 of 8 control plots; and

4. Collembola - densities increased in 6 of 11 test plots and 5 of 8 control plots.

Although the increase of soil arthropods in the test plots was greater, the increase among control populations was sufficiently widespread among the arthropod groups in various habitats to minimize the likelihood of an ELF effect. This is well borne out by examination of the population curves developed over the years by arthropods in the Main plots (Figure 2) and New Hazleton plots (Figure 4).

The proportions of each arthropod group in the wet summers of 1972, 1973, and 1975 were close to those in 1976, despite the latter's heat and aridity. Thus, during these years Prostigmata have been 6--7% of the total population, Mesostigmata 8%, and Cryptostigmata 49-56%; as the latter increased, their co-saprophages, the Collembola, have steadily declined. These are all non-ELF effects. In terms of actual numbers that all test versus all control plots have produced in the last 4 years we find some productivities remarkably similar, particularly those of Cryptostigmata and Collembola where there is a mere 1% and 2% difference, respectively. The less abundant Prostigmata and Mesostigmata are 17% and 20% higher in the test plots, respectively. Con-

sidering that this is a field study attended by many natural uncontrolled variables this evidence justifies the likely conclusion that soil arthropod productivity has not been affected by ELF electromagnetic fields.

The demography of the oldest study plots best illustrates the long-term trends emerging from the monitoring program.

1. Main plots - Exposed and control Cryptostigmata have markedly similar population curves (Figure 2) with a gradual increase since 1971 and absence of a September crash in the last two years. If this increase is a methodological artifact, it is not shown by the other arthropods. The Mesostigmata curves are also quite similar, whereas Collembola are quite erratic. In some years, their curves are synchronous (1973) and in other years they are disparate (1976). In 1975, control Collembola peaked in June and then crashed, while the test population developed more typically; this was reversed in 1976. Total Collembola in the 3 Main test subplots since 1972 is 6016, or an average of 1504 per year, compared with 5870, averaging 1468 per year, in the control subplots. This difference is only 2-1/2%. Prostigmata reached their highest numbers this year in test and control plots. Four-year total arthropod production is 33,239 in the test plots versus 26,443 in the controls, a 20% difference which we do not consider substantial evidence for an ELF effect, given the many natural variables which could influence productivity.

2. Old Clover - Unaccountable factors resulted in a roughly 14-fold increase in Cryptostigmata in the test plot in 1976 over 1975 (Figure 3); the control curve was similar temporally, but

without the amplitude. Corresponding curves for Meso- and Prostigmata aligned fairly well, but Collembola populations continued to show little basis for similarity. Only in 1973, was there a good alignment of the two Collembola population curves.

3. New Hazleton - Close correspondence between test and control populations is evident (Figure 4). This is especially true of exposed Mesostigmata, Prostigmata, and Collembola which parallel their counterparts with striking fidelity, considering that this is not a laboratory-controlled study and that field conditions were unusual this year. In 1975 and 1976, test and control Cryptostigmata were more numerous than before and crashed later. Four-year arthropod totals were 30,138 in the test plot and 25,467 in the control plot, a difference of 15-1/2%.

4. Old Hazleton - It has been possible to follow the ratio of Cryptostigmata to Collembola in this plot since July, 1969, before the antenna was energized (Figure 9). It is interesting to note that the pre-treatment ratio in the test plot was approximated in 4 years - 1970, 1972, 1973, and 1975 - with 1974 being a year in which no sampling was done. In the control plot this ratio was approximated in 3 years - 1971, 1972, and 1973. In 1976, the unusual burst of Cryptostigmata, occurring in almost all plots and possibly a consequence of the weather, produced a higher than usual ratio, although less in the exposed than in the control animals.

Predator-prey proportions in paired test and control plots are tested annually to obtain a comparative measure of population structure and stability. In summer of 1976 5 of the 9 pairs did not show significant differences (Table 8) corresponding to 1972 and 1975 data. Pooling the results from 1972, 1973, 1975, and 1976 indicates that 22 of 36 (61%) paired populations do not differ significantly in predator-prey proportions on an annual basis. Three have never varied significantly (Main, New Clover, and Hardwoods); GG has differed 1 year; and the New Hazleton, Old Clover, and South Roadside have differed in 2 of the 4 years. Thus, of the 9 pairs only 2 have differed significantly more than 50% of the time; the Old Hazleton pair has always differed while the North Leg has differed 3 of the 4 years. It has been previously noted that the Old Hazleton test was originally poorly matched with its control by the previous researchers while the North Leg has deviated from its control along with differences in plant succession as revealed by the floral survey in 1975. This may be due to periodic flooding.

When each of the 19 plots and subplots are tested over the 4 years, 12 of them show significant variability in predator-prey ratios (Table 10). Of the 5 which now show differences in 1976 and did not in 1975, 4 of them (A10, B2, A3, and A7) have increased predator proportions. This is mainly due to substantial increases in the Prostigmata populations. The percentages of plots differing over the years were the same (63%) for both tests and controls indicating that this is not correlated with an ELF effect but apparently with other environmental factors. In spite of these differences, when testing over several years the predator

proportions show statistical predictability on a monthly basis with 64% of the plots not differing significantly.

Over the 4 years the predator-prey proportions of the exposed populations exhibit a slightly smaller average range (.075) than the average control range (.087) (Table 10). Fifteen of the 19 plots have ranges smaller than .10 which is an indicator of stability. Of the 4 plots with ranges larger than .10, 2 of these are tests (A1a and A9) and 2 are controls (B1a and B1c). The similarities and small magnitude of these population fluctuations do not reveal any evidence of the exposed populations being subjected to additional stress imposed by the electromagnetic field.

Following are the salient features of our 1976 soil arthropod monitoring program.

1. We sought multiple stress effects from an unusually hot, dry summer coupled with the ELF electromagnetic environment, but found none. Control and exposed soil arthropods generally had similar population densities which developed in a normal manner during the course of the summer. The proportions of each arthropod group were also very close to what they were in the previous wet summers.
2. The productivities of the most numerous arthropods - Collembola and Cryptostigmata - have been practically identical in test and control plots for the last four years.
3. A comparison of predator-prey proportions in paired plots from 1972 to 1976 indicates 22 of 36 do not differ in a statistically significant way. Among those that do, only two have differed significantly in more than two out of four years.

4. The predator-prey proportion is as stable, from year to year, in the test plots as it is in the control plots. The same percentage (63%) of test plots as control plots differed since 1972, suggesting a correlation with an environmental factor other than ELF.

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Data are presented of the 1976 soil arthropod monitoring program. The program is designed to disclose small, subtle populational changes after long term exposure. The data support a conclusion that seven years of ELF operation has had no demonstratable effect on soil arthropod populations.

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