Lillian McRae Bunch. A POPULATION STUDY OF TOMOCERUS (COLLEMBOLA) IN A WOODLAND AREA OF PITT COUNTY, NORTH CAROLINA. (Under the direction of Clifford B. Knight) Department of Biology, August 1972.

The purpose of this study was to determine fluctuations in populations of *Tomocerus* and to acertain the environmental factors that influenced these fluctuations. Microstratification of *Tomocerus* indicated a definite preference for the litter-fermentation stratum during the warmer months while a vertical migration was observed during the fall and winter. Largest populations were removed in winter, with secondary peaks indicated in late fall and early spring. Statistical tests for correlation showed no significant predator-prey relationship between *Tomocerus* and mites or *Tomocerus* and spiders. Four environmental areas including a flood plain, a lower forest station, an upper forest station, and an ecotone were studied. Data obtained showed a preference for the lower forest area, with smallest numbers recovered from the flood plain. Analysis of variance showed a relationship between numbers of *Tomocerus* and months of the year but not between *Tomocerus* and locations. The interaction of months and locations did show a significant influence.

A POPULATION STUDY OF *TOMOCERUS* (COLLEMBOLA) IN A WOODLAND AREA OF PITT COUNTY, NORTH CAROLINA

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INTRODUCTION

A twelve months investigation of the Tomocerinae was conducted in a mixed forest in the Brook Valley area of Greenville in Pitt County, North Carolina, to follow the seasonal fluctuations in density and a possible predator-prey relationship between Tomocerus, the Acarina, and the Araneae.

The region studied was divided into four ecological areas to investigate the environmental factors which might affect collembolan populations. The areas studied included an ecotone, two forest areas of different elevations, and a flood plain. The latter area was periodically inundated. Although there have been numerous recent studies of forest environments (Knight, 1961; Ostdiek, 1961; Knight, 1963; Poole, 1964; Dowdy, 1965; Joose, 1969; Pedigo, 1970; and Usher, 1970) the literature on research in an ecotone (Knight and Read, 1969) and in flooded areas (Ostdiek, 1961; Pedigo, 1970) is sparse. Recent research on the predator-prey relationship is represented by the work of Dowdy (1965) with collembolans and mites, and by Clark and Grant (1968) with collembolans and spiders.

The areas chosen for this investigation were located on a slope with an approximate 45° elevation gradient, with the ecotone at the upper end of the slope and continuous with a cultivated field. Below the ecotone was the upper forest bordered on the lower side by a lower forest area. At the lower end of the slope was the flat flood plain area which bordered a stream that overflowed during periods of heavy rainfall, inundating this area. Parts of the flood plain were submerged at all times except during extreme drought.

In this study, the litter-fermentation and humus-soil microstrata were observed separately so that vertical distribution and density differences for Tomocerus could be determined.

The research stand was primarily a pine-gum forest having loblolly pine (Pinus taeda) and sweet gum (Liquidambar styraciflua) as the dominant flora of the overstory. The dominant species co-existed with tulip poplar (Liriodendron tulipidera), ironwood, (Carpinus caroliniana), black gum (Nyssa sylvatica), black oak (Quercus velutina), water oak (Quercus nigra), sourwood (Oxydendrum arboreum), red maple (Acer rubrum), and hickory (Carya sp.) in completing the overstory of the stand. The understory and transgressive strata were composed of flowering dogwood (Cornus florida), holly (Ilex opaca), sassafras (Sassafras albidum), persimmon (Diospyros virginiana), black cherry (Prunus serotina), and dwarf pawpaw (Asimina parviflora). Shrubs in the transgressive stratum included sweet bay (Magnolia virginiana), privet hedge (Ligustrum vulgare), wax myrtle (Myrica cerifera), St. Andrew's Cross (Hypericum hypericoides), blue haw (Viburnum rufidulum), Virginia willow (Itea virginica), and elderberry (Sambucus canadensis). The herbaceous stratum contained vines such as trumpet creeper (Campsis radicans), climbing hempweed (Mikania scandens), smilax (Smilax rotundifolia), grape (Vitis sp.), poison ivy (Rhus radicans), yellow jessamine (Gelsemium sp.), and crawling honeysuckle (Lonicera sempervirens). Other herbaceous representatives included Hercules club (Aralia spinosa), lizard's tail (Saururus cernuus) which was common in the flood plain, blueberry (Vaccinium sp.), pink lady slipper (Cypri-

pedium acaule), netted chain fern (*Woodwardia aerolata*), and some sphagnum moss.

The ecotone, an area of transition between the open field and forest, was composed primarily of young pines and hardwood seedlings. The forest areas were similar to each other in floral composition with few pines and many large hardwoods in the overstory stratum and with a relatively thin understory. In contrast the flood plain had a very heavy overstory and understory.

Primary goals of the study were (1) to investigate seasonal fluctuations in the population size of *Tomocerus*, (2) to study environmental differences within the stand which might affect variability in population size, and (3) to determine any correlation which might exist between populations of *Tomocerus* and soil mites or between *Tomocerus* and spiders.

MATERIALS AND METHODS

Investigation of *Tomocerus* began on March 25, 1971 and was completed on February 25, 1972. The entire sampling area was subdivided into four sampling blocks, each one equal in size and measuring twenty meters in length by four meters in width. This yielded eighty quadrats one square meter in size for each sampling block. All quadrats to be used were chosen by random sampling methods at the beginning of the study. These chosen quadrats were then subsampled at the time collections were taken each month by removing a litter-fermentation and a humus-soil layer from a 20 cm square area in the center of each quadrat. Samples from two quadrats in each sample block were removed every month, placed in plastic bags, and carried to the laboratory where they were placed in a Tullgren funnel apparatus constructed with modifications recommended by Cox (1967). Twenty-five watt incandescent light bulbs were used for a forty-eight hour interval to separate the microfauna from other material in each sample. Separated material from the funnel dropped into jars containing a preservative composed of a two parts 95% ethyl alcohol and one part glycerine mixture. The microfauna was then stored in these jars for later observation. *Tomocerus*, mites, and spiders were separated, identified, and counted with the aid of a dissecting microscope, and the Tomocerinae were collected and stored in 95% ethyl alcohol, using 2 ml shell stoppered vials. Maynard's monograph of collembolans (1951) was used to identify *Tomocerus*.

Soil moisture was determined by oven drying monthly litter-fermentation and humus-soil samples at 105°C for forty-eight hours and recording moisture values in terms of percentage dry weight of the sample. Temperature and humidity readings within the sampling areas were made every week during the twelve months study. Maximum and minimum temperatures were taken using Taylor maximum-minimum thermometers in each sampling area. Humidity readings in the litter-humus layers were recorded using a psychrometer constructed to record humidity in microhabitats. This instrument contained wet and dry bulb thermometers within a glass tube with an attached suction bulb to draw air from the microstratum through the tube. Relative humidity was determined by recording wet and dry bulb temperatures and using these to determine humidity from a table of relative humidities.

RESULTS

Environmental areas studied in this investigation were an ecotone, an upper forest area, a lower forest area, and a flood plain. Maximum temperatures from March 25, 1971 through October 25, 1971 were consistently lower in the flood plain than in the other areas studied, with a range of from 23.5°C to 33.3°C in the flood plain; 29.7°C to 47.5°C in the lower forest; 29.5°C to 44.0°C in the upper forest; and 25.0°C to 35.8°C in the ecotone. From November through February, maximum temperatures in this area were equal to or higher than other temperatures taken with few exceptions. Minimum temperatures in the flood plain were comparable to the minimums in the other three areas (Appendix A). The next lowest maximum temperatures were taken in the ecotone with the greatest differences found in May, June, July, and August. With the exception of the ecotone, highest maximum temperatures were taken in July. The highest monthly temperature in the ecotone came in April. Lowest average minimum temperatures were taken in all areas in January (Table I). Minimum temperatures from November to February ranged from -6.5°C to o.6°C in the ecotone; -7.2°C to o.7°C in the upper forest; -4.8°C to 6.1°C in the lower forest; and -5.0°C to 3.0°C in the flood plain.

TABLE I

AVERAGE MONTHLY TEMPERATURES FOR ALL SAMPLING LOCATIONS IN DEGREES CENTIGRADE

MONTHS	MAXIMUM	MINIMUM
March	27.0	-1.7
April	35.9	2.9
May	36.3	12.4
June	37.0	16.2
July	40.2	18.1
August	33.9	18.0
September	30.8	17.2
October	31.5	10.5
November	23.7	2.6
December	22.6	0.1
January	24.3	-5.9
February	22.8	-3.9

Highest soil moisture expressed as per cent dry weight in the litter-fermentation level were obtained from March through July (Table II). However, this trend was reversed in the months from August through February with highest moisture values in the humus-soil microstratum. The greatest differences between soil moisture values in the litter-fermentation and humus-soil layers were from the last of October through February. During these months moisture in the litter-fermentation level was minimal as opposed to a relatively high value in the humus-soil microstratum. In all areas soil moisture exhibited less fluctuation in the humus-soil layer than in the litter-fermentation microenvironment. Highest soil moisture values in both layers were found in March when the first collections were made. Soil moisture values for the four research areas can be found in Appendix B.

TABLE II

AVERAGE MONTHLY PERCENTAGES OF SOIL MOISTURE FOR ALL SAMPLING LOCATIONS BASED ON DRY WEIGHT

MONTHS	LITTER	HUMUS	DIFFERENCE
March	89	86	3
April	26	20	6
May	28	26	2
June	22	26	4
July	16	14	2
August	12	20	8
September	16	23	7
October	22	43	21
November	18	28	10
December	4	28	24
January	16	28	12
February	1	31	30

Relative humidity was higher and fluctuated less in the flood plain than in the other three environmental areas for the most part. Readings stayed high in all areas except in the month of April when a low humidity of 57 was recorded. The average relative humidity for April was 78 while averages for the other months ranged from 89 to 100. Table III shows the monthly averages and ranges for each of the months studied.

TABLE III

RELATIVE HUMIDITY

MONTHS	RANGE	AVERAGE
March	100	100
April	57 to 100	78
May	82 to 100	91
June	78 to 100	89
July	84 to 100	92
August	100	100
September	86 to 100	93
October	89 to 100	94.5
November	80 to 100	90
December	89 to 100	94.5
January	88 to 100	94
February	89 to 100	94.5

In each of the environmental areas, populations of Tomocerus with few exceptions were higher in the L-F layer in the months from March through November. During this period there were peaks in population size in October, November, and March with smaller peaks in September and July (Table IV). In the months between and including December and February, larger populations were found in the H-S level with peaks in January and February. In the ecotone the largest population was found in the L-F microstratum in March and in the H-S layer in December. The upper forest area had large L-F populations in November and H-S populations in February. Greatest density was found in the lower forest environment in the L-F layer during March and July and in the H-S layer in January and February, while the Tomocerinae were more numerous in the L-F level of the flood plain during September and February and in the H-S layer in January. Overall population density was greatest in the lower forest area (74 Tomocerus counted) and was lowest in the flood plain (43) during the period studied. The ecotone with 51 Tomocerus and the bordering upper forest area with 52 Tomocerus were nearly equal in numbers of tomocerids collected. Throughout the twelve months study, the total number of Tomocerinae counted in the litter-fermentation level was nearly equal to the number collected from the humus-soil level with 115 in the L-F and 105 in the H-S layers. Numbers of mites which were counted during this investigation are shown in Table IV also. In general population density was higher in the L-F layer during the months of April through September and in the H-S level from October through March. Largest total numbers of mites were found in November with 279, October with 262, and February with 251. The ecotone supported the largest population (664 mites) while the smallest number was found in the flood plain with only 207 mites collected. In the upper and lower forest areas, the number of mites counted were 609 and 579. Appendix D shows the litter-fermentation and humus-soil collections of mites per environmental area per month. Total numbers of mites counted from the litter-fermentation samples was 1044 while humus-soil counts equaled 1015. In comparison to numbers of mites, spider populations were relatively small. Microstratification and monthly totals of spiders are shown in Table IV.

TABLE IV

MONTHLY TOTALS OF *TOMOCERUS*, MITES, AND SPIDERS COLLECTED

MONTHS		*TOMOCERUS*	MITES	SPIDERS
March	L-F	18	48	41
	H-S	2	104	11
April	L-F	0	19	2
	H-S	1	19	2
May	L-F	10	56	1
	H-S	0	9	0
June	L-F	7	54	7
	H-S	4	14	4
July	L-F	12	184	16
	H-S	4	57	19
August	L-F	4	118	56
	H-S	3	32	10
Sept.	L-F	12	122	62
	H-S	5	105	25
Oct.	L-F	13	114	14
	H-S	8	148	14
Nov.	L-F	12	122	4
	H-S	8	157	7
Dec.	L-F	6	49	15
	H-S	16	141	22
Jan.	L-F	9	65	12
	H-S	27	71	16
Feb.	L-F	12	93	13
	H-S	27	158	0

DISCUSSION

In this study samples were taken of the litter-fermentation layer which contained undecayed and partially decaying plant material and the lower humus-soil level which was composed of unidentifiable organic matter, (humus), as well as the first few centimeters of soil. A review of the literature indicates that the Tomocerinae are most extensively found in these layers (Knight, 1961; Christiansen, 1964; and Dowdy, 1965) and that a second major habitat is vegetation above ground (Christensen, 1964). Dowdy took summer samples from the vegetation in an oak-hickory forest near Jefferson City, Missouri and found aggregations of collembolans and Acarina in the herbaceous flora. According to Dhillon and Gibson (1962), the distribution of soil arthropods in the upper layers is due to a greater abundance of plant remains near the surface of the soil layer. Knight and Angel (1967) have shown that leaf material and fungal hyphae compose the bulk of the diet of most tomocerids with visible gut contents in their study. Christensen (1964) further points this out and states that bacteria, fungal spores and pollen grains contribute to the collembolan diet. According to Alexander (1961), the filamentous fungi as a group are strict aerobes for the most part and are therefore restricted to the surface few inches of soil. Larger Collembola (i.e., Tomocerinae) are also restricted to the upper portions of the soil profile because they lack structures that would enable them to burrow, and their size prevents utilization of minute soil channels (Knight and Read, 1969).

Environmental conditions greatly influence populations of collembolans. Factors responsible for variations in population size include temperature, humidity, soil moisture, soil humus, surface vegetation, and presence or absence of shade (Ashraf, 1970). Poole (1962) observed that a deep, moist organic layer generally supported the largest number of Collembola and that there was a positive correlation between numbers of Collembola and weight of organic matter. He also found a positive correlation between population size and depth of organic matter as well as its moisture content (1961). Pedigo (1970a) cited a significant association between collembolan population density and a complex of environmental factors involving tree canopy cover, light intensity, and herbaceous vegetation. According to Pedigo, this environmental complex is controlled by the canopy cover. The degree of overhead closure is a controlling factor governing the quality and quantity of light reaching the forest floor. This influences density and composition of herbaceous vegetation which in turn modifies the surface microclimate and collembolan food supply. Pedigo observed that the stations with the higher light intensity tended to have greater collembolan populations. He also found that there was no statistical correlation between collembolan population density and species composition of communities, (1970a and 1970b). In the present investigation, the controlling environmental factors studied were temperature, soil moisture content, and relative humidity. Collected data shows a definite relationship between population density of Tomocerus, temperature, and soil moisture percentages determined at the time collections were made (Fig. 1). Largest populations of Tomocerus were found in the

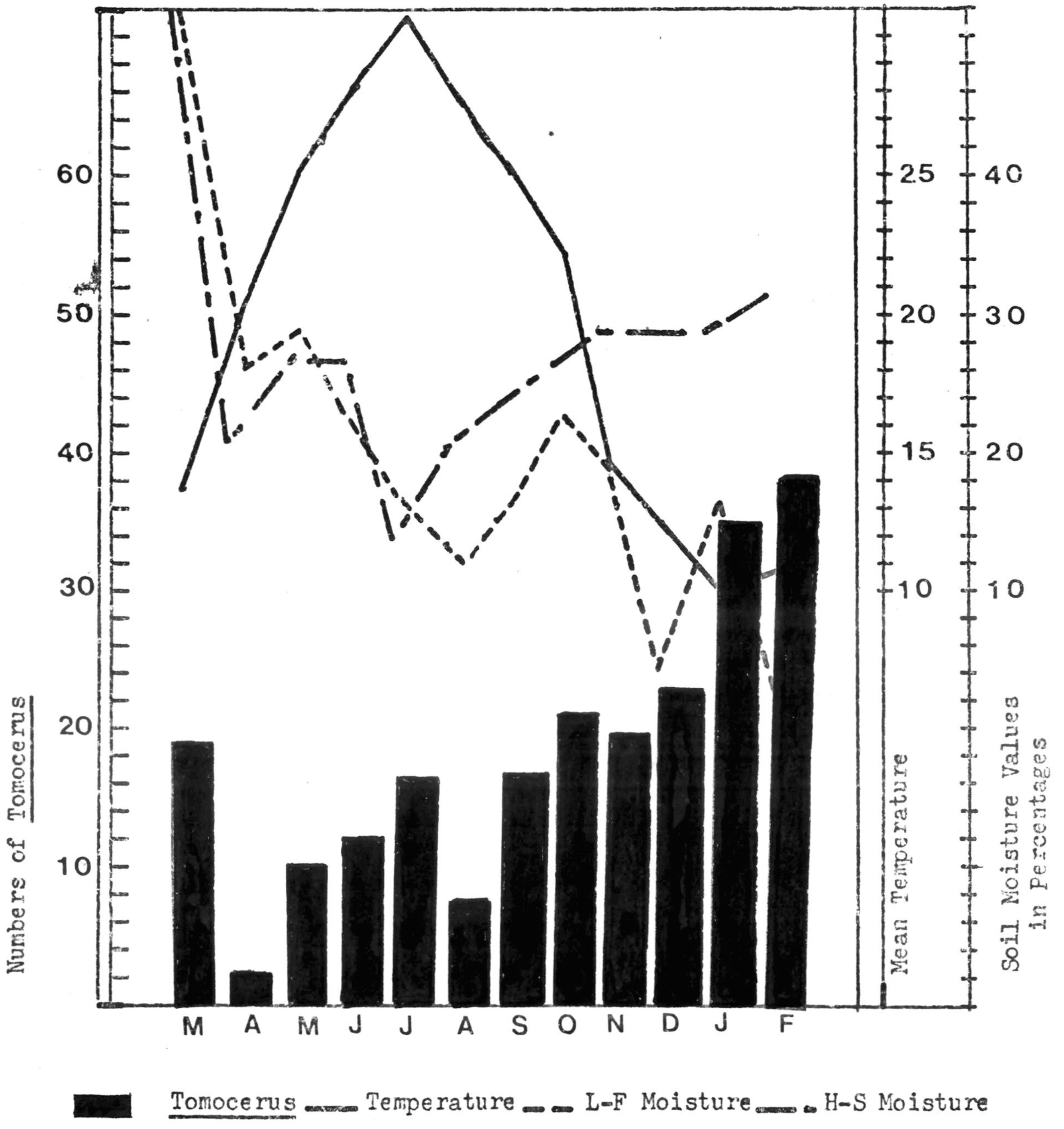

Fig. 1. - Monthly numbers of Tomocerus collected, mean monthly temperatures in degrees centigrade, and monthly soil moisture in percentage of dry weight.

months when mean temperatures were lowest and percent moisture in the soil was relatively high. During these months relative humidity was high, ranging from 90 to 100 percent (Table III). This data is supported by Knight (1961) who found that populations of Tomocerus maintained a relatively high density over a weekly temperature range of -3°C to 27°C but decreased rapidly as temperatures increased above 21°C. Christensen (1964) states that Collembola are relatively resistent to low temperatures and are rarely injured by extreme cold except where this is accompanied by desiccation. In another investigation, Choudhuri (1961b) discovered that abrupt exposure to low temperatures brought about injurious effects but that the gradual approach of low temperatures increased the resistance of collembolans and enabled them to withstand low temperatures of the same degree for a greater period. Soil fungi will grow between 0°C and 35°C and the ability of fungi to withstand extremely low temperatures has been demonstrated (Alexopoulos, 1962).

The literature concerning soil moisture content is contradictory. Knight and Read (1969) found optimum soil moisture values to be between 10 and 20 percent dry weight in the humus-soil layer, and this is further supported by findings in the present investigation. Heatwole (1961) states that moisture and temperature profoundly affect the process of decay and mineralization of plant material, and this in turn affects the microenvironment and food supply of Tomocerus. According to Alexander (1961) population density of soil fungi is positively correlated with moisture except where moisture is excessive. Ostdiek (1961) also found that lack of moisture indirectly limited collembolan populations by limiting the food supply. In contrast to these findings, Dowdy (1965) did a study of Collembola and mites in an oak-hickory community as well as in a pine community and found that moisture was not an important factor in the abundance and variation of Collembola. In January and in February with less than four inches rainfall, Dowdy collected over 3000 collembolans per month. In March with more than four inches of rain, less than 100 collembolans were taken. In both communities, very small populations of Collembola were collected during the months with the greatest amount of rainfall. Dhillon and Gibson (1962) studied the Acarina and Collembola of agricultural soils in India and found that there was no significant correlation between monthly populations and soil moisture content. They stated that although temperatures were favorable to collembolans and mites, neither moisture, humus level, or pH appeared to influence the size of populations.

Christensen (1964) stated that all forms of collembolans studied required 89% relative humidity to survive for functional periods. This conclusion was dramatically supported by the almost nonexistent populations of Tomocerus found in April by this investigator when relative humidity dropped to a low of 78% (Table III and Fig. 1).

In the present investigation the greatest increase in population density was found in January and February with secondary peaks in December, October, November, and March. These findings correspond to the data collected by Usher (1970) in a Scots pine forest in Scotland. He found population peaks for three species of Tomocerus in the months between December and March, and this is further supported by Dowdy (1965) and Ashraf (1970) who observed greatest population density during the colder months. In contrast, Knight (1963) found largest populations of Tomocerus flavescens separatus as well as T. lamelliferus in March, April, and May with secondary peaks in October and November, while Poole (1961) discovered the greatest populations peak in five species of Collembola to be in August with a smaller January peak. Because of the complex of factors that interact to produce optimal environmental conditions such as predation pressure, type of organic material present, type of food available, etc. peaks can and do appear in different studies at different seasons of the year.

Studies of the vertical distribution of Collembola are contradictory also. This investigator found nearly equal numbers of Tomocerus in the litter-fermentation and humus-soil layers, while Dowdy (1965) collected more collembolans from the litter-fermentation stratum. Choudhuri (1961a) observed that some species of Collembola show distinct vertical migration as a response to surface drying, and Dowdy collected collembolans in depths of 5" to 10" in January and February but not in summer. According to Knight and Read (1969), the lower microstratum is less variable in terms of humidity and percent moisture, requires less physiological adjustment, and supports an increase in the growth rate and reproductive potential of fungal colonies. In their investigation, humus-soil populations were significantly larger than litter-fermentation aggregates.

Dowdy (1965) removed greater numbers of collembolans at lower levels in winter than in summer. In the present investigation greater numbers of *Tomocerus* were also taken from the litter-fermentation level in the warmer months while greater density was observed in the humus-soil microstratum during the colder months. This population trend was probably due to a higher percent of soil moisture in the humus-soil level during the hiemal interval of the year. During the winter months the litter-fermentation layer was principally composed of dry leaf matter which had not yet begun to decompose. This plant material held very little moisture, and the percent soil moisture was lowest during this period of the year.

The relationship between *Tomocerus* and mites was studied to determine the influence of mite populations on *Tomocerus* populations. In his paper on the bionomics of collembolans, Christensen (1964) cites references stating that mites may be a major factor in governing the size of collembolan populations. Wallwork (1958) observed that for some species of mites, carrion composed of dead mites and collembolans was preferred to plant material, while Knight and Read (1969) stated that mites compete with Collembola for food, preventing increases in the density of *Tomocerus* at certain seasons of the year. A statistical test for the correlation between *Tomocerus* and mites collected in the present study gave a correlation coefficient of .54 which proved to be statistically insignificant when using the t-distribution. Because the null hypothesis H_0: p=0 could not be rejected, it was concluded that the sample data provided no statistical evidence that a true correlation existed between *Tomocerus* and mites in this study.

Spiders are also predators of collembolans (Clarke and Grant, 1968), and this microfauna was counted from the samples taken to determine correlation. In contrast to the number of mites observed, populations of spiders were very small and the correlation coefficient was determined to be .008. This implied that there was a lack of true correlation between Tomocerus and spiders in the several areas studied.

During the twelve month study period, samples were taken in four different environmental areas to determine whether location had an influence on populations of Tomocerus. The greatest differences in density and environmental factors were found in the flood plain area which was subjected to flooding during periods of heavy rainfall. This area had the lowest density of Tomocerus of all the areas studied. Although Christensen (1964) mentions that floods of short duration are not severe in their effect on many collembolans, Knight and Read (1969) state that a reduction in population density in inumdated areas is due mostly to reduction in food supply. Ostdiek (1961) found, as did this investigator, that in flood plain areas, the fresh litter and fermentation layers were poorly developed because of frequent floods. The intensity of sunlight striking the forest floor in this area was minimized by a dense canopy of trees in the transgressive stratum, and this contributed to a thin herbaceous stratum which further limited the food supply.

The lower forest area supported the largest populations of Tomocerus and represented the most favorable environment for this genus. The canopy cover was relatively open, allowing the growth of a thick herbaceous stratum. Soil moisture and relative humidity in this area came within the optimum range for survival of Tomocerus. Although the highest temperatures were recorded at this station, the detrimental effects of these high temperatures were offset by more optimum conditions for growth of the food supply.

The ecotone and upper forest areas were comparable in numbers of Tomocerus collected, canopy cover, thickness of the herbaceous growth, temperature, soil moisture, and relative humidity. According to the data collected in this investigation, the principle factor effecting population density of Tomocerus in the four areas studied was that of the food supply available in each sampling area.

An analysis of variance comparing the four basic locations studied, the individual monthly collections and the interaction between area and month yielded the following results. Population differences based on locations yielded a value which was not statistically significant. However 'F' values based on months and the interaction between location and months were highly significant (P, less than .01).

TABLE V

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	PROBABILITY
Location	3	11.04	3.68	1.98	$>$ .05
Months	11	82.78	7.52	4.04	$<$ .01
Interaction	33	208.67	6.32	3.40	$<$ .01
Error	144	267.43	1.86		
Total	191	569.92			

The small 'F' value obtained for locations was possibly due to the lack of any critical differences in the four environmental areas. Temperature, soil moisture, relative humidity, and amount of herbaceous growth were relatively similar in each area; and the population density of *Tomocerus* supported by each area was also comparable. Fluctuations in temperature caused by seasonal changes were much more critical to populations of *Tomocerus*, yielding a highly significant 'F' value for months. These fluctuations helped to create environmental conditions that were favorable or unfavorable to *Tomocerus*. Although the differences within the four environmental areas were not significant when analyzed alone, the interaction between these differences and the fluctuations caused by seasonal changes was found to be important to the population density of *Tomocerus*. The high 'F' value for interaction shows that a complex of factors work together to create the optimal environment for tomocerids.

SUMMARY

1. Fluctuations in the population density of *Tomocerus* were investigated in a woodland area of Pitt County throughout the various seasons of an annual cycle using four types of environmental communities as research areas. These communities included a flood plain, a lower forest station, an upper forest station, and an ecotone.

2. Random 20 cm square quadrats were subdivided into litter-fermentation and humus-soil levels which were sampled every month. Specimens of *Tomocerus*, mites, and spiders were separated from the stratal samples using a modified Tullgren funnel. Recorded environmental data included weekly records of maximum-minimum temperatures, relative humidity, and soil moisture percentage values.

3. Highest population density of *Tomocerus* was found in the winter months with secondary peaks in March, October, and November. Although numerical totals of *Tomocerus* in the L-F and H-S layers were nearly equal for the entire period studied, the litter-fermentation layer supported a larger population in the warmer months while the humus-soil level had greater numbers in the fall and winter months.

4. The highest density of *Tomocerus* was found in the lower forest area, while smallest numbers were recovered from the flood plain. This difference in density in these two areas may possibly be explained by environmental conditions which affected the food supply. In the lower forest station, high temperatures and open canopy cover favored an abundant food supply in the form of herbaceous vegetation while a relatively closed canopy cover and frequent

flooding caused a decrease in the herbaceous stratum and the litter-fermentation layer in the flood plain.

5. Statistical tests of correlation indicated that the mite population as well as the spider population were not significant in limiting total numbers of Tomocerus in the study areas. Mites and collembolans do compete for the same food supply, and there is a predator-prey relationship.

6. Tests for analysis of variance indicated that the fluctuations in environmental conditions caused by seasonal changes had significant effect on population changes of Tomocerus, but the four environmental stations within the forest had no significant influence alone. The interaction caused by seasonal changes and environmental conditions within the four areas did show significant effect on fluctuation of Tomocerus populations.

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APPENDIX A

MONTHLY TEMPERATURES IN DEGREES CENTIGRADE

MONTHS		I	II	III	IV
March	Max.	25.0	29.5	31.0	23.5
	Min.	-2.5	-2.2	-0.6	-1.5
April	Max.	36.5	41.0	36.8	29.4
	Min.	3.0	2.8	3.3	2.5
May	Max.	34.2	43.0	40.0	28.0
	Min.	12.5	12.5	13.0	11.7
June	Max.	33.4	40.0	42.5	32.0
	Min.	16.2	16.4	16.4	16.0
July	Max.	35.8	44.0	47.5	33.3
	Min.	18.3	18.3	18.1	17.8
August	Max.	33.9	37.5	37.2	27.0
	Min.	18.3	18.3	17.7	17.7
Sept.	Max.	34.4	33.3	31.7	23.9
	Min.	17.2	17.2	17.2	17.3
Oct.	Max.	32.4	34.4	29.7	29.4
	Min.	9.4	10.5	10.2	11.8
Nov.	Max.	25.6	24.0	22.0	23.2
	Min.	0.6	0.7	6.1	3.0
Dec.	Max.	22.9	23.4	22.3	21.7
	Min.	-2.0	-2.0	2.2	2.0
Jan.	Max.	24.5	26.7	22.5	23.4
	Min.	-6.5	-7.2	-4.8	-5.0
Feb.	Max.	23.9		22.2	22.8
	Min.	-4.4		-3.9	-3.3

Note: I is the ecotone; II, the upper forest area; III, the lower forest area; and IV, the flood plain. Max. is maximum temperature and min. is minimum temperatures. These are averages for the month.

The space for II in February is blank due to the disappearance of the thermometer after the last reading in January.

APPENDIX B

SOIL MOISTURE PERCENTAGES BASED ON DRY WEIGHT

MONTHS		I	II	III	IV
March	L-F	88	84	91	93
	H-S	84	82	90	88
April	L-F	11	39	24	31
	H-S	9	18	42	10
May	L-F	17	31	24	38
	H-S	15	23	25	43
June	L-F	34	14	20	22
	H-S	19	21	40	23
July	L-F	18	18	20	9
	H-S	8	17	24	9
August	L-F	8	8	14	17
	H-S	12	12	29	28
Sept.	L-F	8	12	12	32
	H-S	31	19	14	29
Oct.	L-F	6	11	16	57
	H-S	21	36	33	83
Nov.	L-F	14	18	24	17
	H-S	24	29	39	21
Dec.	L-F	4	2	4	8
	H-S	15	22	31	45
Jan.	L-F	17	20	17	8
	H-S	30	1	43	37
Feb.	L-F	1	1	1	2
	H-S	13	38	57	16

Note: I is the ecotone; II, the upper forest; III, the lower forest; and IV, the flood plain.

L-F is the litter-fermentation layer and H-S is humus-soil.

APPENDIX C

NUMBERS OF TOMOCERUS COLLECTED

MONTHS		I	II	III	IV
March	L-F	6	3	9	0
	H-S	1	1	0	0
April	L-F	0	0	0	0
	H-S	0	0	1	0
May	L-F	1	1	3	5
	H-S	0	0	0	0
June	L-F	0	1	1	5
	H-S	0	2	2	0
July	L-F	1	2	9	0
	H-S	2	2	0	0
August	L-F	2	0	1	1
	H-S	1	0	2	0
Sept.	L-F	2	3	1	6
	H-S	2	1	1	1
Oct.	L-F	2	3	8	0
	H-S	6	0	1	1
Nov.	L-F	2	6	3	1
	H-S	2	4	1	1
Dec.	L-F	0	2	0	4
	H-S	10	4	1	1
Jan.	L-F	1	2	4	2
	H-S	7	2	12	6
Feb.	L-F	1	2	3	6
	H-S	2	11	11	3

Note: I is the ecotone; II, the upper forest; III, the lower forest; and IV, the flood plain.

L-F is the litter-fermentation layer and H-S is humus-soil.

APPENDIX D

NUMBER OF MITES COUNTED

MONTHS		I	II	III	IV
March	L	9	11	22	6
	H	37	21	40	6
April	L	5	3	11	0
	H	1	14	4	0
May	L	12	15	18	11
	H	4	3	2	0
June	L	15	12	21	6
	H	2	2	10	0
July	L	100	35	48	1
	H	27	18	12	0
August	L	18	25	62	13
	H	4	10	9	9
Sept.	L	55	21	43	3
	H	58	14	25	8
Oct.	L	42	32	15	25
	H	40	80	11	17
Nov.	L	34	50	28	10
	H	75	43	28	11
Dec.	L	6	27	23	9
	H	26	19	15	11
Jan.	L	6	22	11	10
	H	25	60	40	16
Feb.	L	3	15	60	15
	H	60	57	21	20

Note: I is the ecotone; II, the upper forest; III, the lower forest; and IV, the flood plain.

L is litter-fermentation and H is the humus-soil layer.