A SYSTEMATIC SURVEY OF THE ACARINA OF OTIS LAKE BOG, BARRY COUNTY, MICHIGAN

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A SYSTEMATIC SURVEY OF THE ACARINA OF OTIS LAKE BOG, BARRY COUNTY, MICHIGAN

By

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ABSTRACT

A SYSTEMATIC REVIEW OF THE ACARINA OF OTIS LAKE BOG, BARRY COUNTY, MICHIGAN.

By Wayne A. Yoder

Mites were collected from a sphagnum bog mat on the margin of Otis Lake, Barry County, Michigan. Oribatei were identified to genus and non-oribatids to family. An attempt was made to establish moisture preferences of the mites.

Forty-eight oribatid genera and 29 families were determined. Two families of Astigmata, 17 families of Prostigmata, and 11 families of Mesostigmata were determined.

The number of oribatid individuals found in any sample was larger than that of all non-oribatids combined.

The oribatid _Mochlozetes_ sp., not previously reported from North America, was collected in 9 samples.

Two aquatic oribatids, _Limnozetes_ sp. and _Hydrozetes_ sp., were found.

ACKNOWLEDGMENTS

I wish to express my gratitude to Dr. T. Wayne Porter for his guidance and critical review of this study, and for spurring my initial interest in the Acarina.

Sincere thanks are also expressed to Drs. Ralph A. Pax and Julius R. Hoffman for their suggestions and review of the manuscript.

Dr. George H. Lauff made available facilities at the W.K. Kellogg Gull Lake Biological Station for work during the summer of 1966.

The National Institutes of Health through the Department of Zoology and Entomology at The Ohio State University provided a traineeship to the Institute of Acarology during the summer of 1967.

Dr. Eduard Piffl's confirmation of many oribatid genera is much appreciated.

Garrett E. Crow kindly identified plant specimens.

My sincere thanks also go to Mrs. Bernadette Henderson for her assistance in providing materials and other services.

Finally, I would like to thank my wife Roveen for her patience and assistance in the final stages of this study.

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A SYSTEMATIC SURVEY OF THE ACARINA OF OTIS LAKE BOG, BARRY COUNTY, MICHIGAN

Acarina are found in a great variety of terrestrial habitats. Their requirements for a high relative humidity make the upper region of a sphagnum bog mat an ideal environment for many species. The plant variety encountered in ecological succession in a bog also adds many suitable habitats for mites.

The flora of Michigan bogs has been studied by numerous botanists. Transeau (1904) compared physical and chemical factors of bogs of the Huron River basin in Michigan with those of more northern Canadian bogs, and related differences in those factors to the differences in plant growth and numbers of species in the two areas. Davis (1906) discussed the formation, character, and distribution of peat bogs in Michigan, and emphasized economic uses of peat. He listed 247 species of plants in connection with Michigan bog descriptions.

Weld (1904) pointed out that two Michigan lakes which were one during settlement of the United States have come to possess marked differences in their floras due to different physical characteristics since their separation. It would be interesting to examine their faunas for related differences.

Reed (1902) stated that bog plants of Michigan show a predominance of northern species, undoubtedly the result of glacial invasion of recent geological times, and conditions which tend to reproduce a boreal environment. Michigan bog faunas might also contain many northern species. Gates (1942) reviewed botanical work done on bogs in the Douglas Lake region of Cheboygan County, Michigan. He described a number of bogs, and related their vegetation to succession phases. More recently Crow (1968) did an ecological and floristic survey of a bog in Calhoun County, Michigan in which he discussed 144 species of plants in terms of their general distribution and habitat.

Acarine faunal studies of Michigan bogs are apparently lacking, although other soil surveys have been done. European workers have by far led in the field of bog studies. Beier (1928) related microflora, pH and temperature to the acarine fauna of a German "Hochmoore". Sellnick (1929) and Vitzthum reviewed the mites of middle Europe. Willmann from 1928 through the 1940s published a series of papers on bog faunas. Peus (1932) discussed mire faunas both ecologically and geographically. Hammen (1952) reviewed the Oribatei of the Netherlands, including those taken from his own collections and those of Oudemans' collection. Marie Hammer published a number of faunal studies from many parts of the world from 1937 through the present time.

Strenzke (1952) grouped his German bog mites into communities according to their dependence on five environmental factors: moisture of substratum, organic substance, acidity, degree of ground cover, and salinity. Knulle (1957) in a study similar to Strenzke's listed 64 genera and some 156 species of German bog Oribatei.

Tarras-Wahlberg (1954) surveyed oribatids of a Swedish mire. In 1961 he did a more complete study, and included detailed laboratory experiments on humidity and temperature preferences and reactions to light and wind of several oribatid species. Popp (1962) related moisture to the species found in his faunal study.

The above authors represent only some of those who have published widely concerning bog fauna, especially the Oribatei. A complete review is beyond the scope of this study.

COLLECTION SITE

Collections were made on the southern bog margin of Otis Lake, Barry County, Michigan, T3N, R9W, S31, from June 22 to November 18, 1966. Otis Lake is a closed system with acid bog margins along much of the shoreline, especially on the southern and western margins. The water level of the lake fluctuates both seasonally and annually, dependent on the precipitation of the area. During the period of collection, the level dropped slightly during the relatively dry summer. However, the bog mat retained essentially the same moisture content since it had water underlying much of its surface during the entire summer, and the absorptive qualities of the rotting Sphagnum spp. maintained moisture under the living moss.

No attempt was made to determine completely the flora of the bog. Several of the most abundant species of plants in or around the sample sites were taken and found to be comparable to other Michigan bog flora as given by Transeau (1904), Davis (1906), and Crow (1968). A list of the representative plants is given in Appendix I. From this list, those species which were especially abundant in any given sample are listed in Appendix II. It is only mentioned here that peat moss, Sphagnum spp., and cranberries, Vaccinium macrocarpus Ait. were present in all samples.

Figure 1 shows a typical view of the bog mat surveyed in this study. Pond lilies (Nuphar sp.), bulrushes (Scirpus sp.), and masses of algae float in the open water. Leatherleaf (Chamaedaphne calyculata (L.) Moench.) forms islets and also invades the bog margin. Sedges (Carex spp.) and swamp loosestrife (Decodon verticullatus (L.) Ell) send out runners from the bog mat into deeper water. Rushes (Juncus brevicaudatus (Engelm.) Fernald.), Sphagnum spp., and cranberries (Vaccinium macrocarpus Ait.) follow these, and as a more solid mat takes form cat-tails (Typha sp.) and blueberries (Vaccinium corymbosum L.) invade the mat.

Figure 1. Otis Lake bog, showing part of the collecting area.

Figure 2 shows a close-up of the lighter area in the foreground of figure 1. A somewhat packed mat of Sphagnum spp. underlies the more loosely arranged heads of the moss plants. Rushes, arrowhead (Sagittaria sp.), buckbean (Menyanthes trifoliata L.), and cranberry plants can also be seen in what may be considered a typical sample site.

Figure 3 gives a closer view of the dark area on the left of figure 1. At this distance from the open lake, the bog mat is moist but is becoming drier than it is in the shorter vegetation. The most prominent

Figure 2. Close-up of a typical collecting site on the bog mat.

plant seen in figure 3 is the chain fern, Woodwardia virginica (L.) Smith. In the background a few cat-tails can be seen. Underlying all other vegetation is the Sphagnum spp. mat with intermingled cranberries and rushes.

Figure 3. Portion of collecting site where Woodwardia virginica (L.) Smith was a dominent plant.

Toward the dry edge of the mat raised hummocks develop. Typical blueberry hummocks are seen in figure 4. In between the hummocks Sphagnum spp. growth is outstanding. It continues into the hummocks where the plants are more loosely arranged. Light colored larch

(*Larix laricina* (DuRoi) Koch) branches at the top of the picture indicate that the hummocks are near the drier bog margin. Figure 4 represents the driest part of the mat sampled in this study.

Figure 4. Close-up of collecting site on the drier bog margin.

SAMPLING METHOD

Sampling was done by hand, slightly less than one cubic foot of live green moss and associated plants being taken per sample. An attempt was made not to pull up any of the rotting vegetation which underlay the entire living mat, but to take live moss down to that level. For this reason the depth of a sample varied from approximately six inches to ten inches. The temperature was taken in each sample at a depth of four inches with a standard field thermometer. Temperatures for each sample are recorded in Appendix II. Samples were placed in plastic bags and transported immediately to the Gull Lake Biological Station for extraction.

Sample sites were chosen so as to include as wide a moisture range and vegetational variety as possible on the bog mat. An arbitrary moisture scale of 1 to 5 was used as a relative index for the moisture in each sample, the scale as follows: 1 - soaked, sample taken beside standing water; 2 - moderately wet; 3 - damp; 4 - moderately dry; 5 - dry.

In order to give an ecological relationship to this moisture scale, an attempt was made to place several plant species in respect to it. _Typha_ sp. and _Nuphar_ sp. would most likely have been found in a moisture rating of 1-2; _Carex_ spp., _Juncus_ sp., _Scirpus_ spp., _Woodwardia virginica_, _Decodon verticullatus_, and _Rhus vernix_ in 1-3; _Vaccinium corymbosium_ in 2-5; _Larix_ *laricina* in 3-5; and *Sphagnum* spp. and *Vaccinium macrocarpus* in 1-5.

Brief notes on weather conditions taken for each sampling date are included in Appendix II.

EXTRACTION METHODS

Extraction was done with Berlese funnels. Extraction was 11 to 16 days, depending upon time required for material to become thoroughly dried. The funnel size was 15 inches in diameter at the top, tapering uniformly to 7/8 inch at the bottom with a height of 13 1/2 inches. The 9 1/2 inch high lid contained a sixty-watt light bulb which served as the heat source.

A check was made of the temperature within the 10 funnels used to determine whether a good temperature gradient was being maintained between the top and bottom. On a day when room temperature was 68 degrees F, the bottom temperatures was 68 to 69 degrees F. The temperature on top of the samples varied from 100 to 123 degrees F, with an average temperature of 113 degrees F at the top of the funnels. This was a slightly larger gradient than was reported by Macfadyen (1953) to be adequate for good extraction, but seemed to do well enough for extracting all suborders of mites.

Animals were collected at the bottom of the funnels in jars containing ethylene glycol. At the end of the extraction period the jars were filled with 95% ethyl alcohol so that mites were stored in approximately 75% alcohol until examined later.

PREPARATION AND DETERMINATION OF MITES

Sorting samples for determination was done with an American Optical dissecting microscope, mostly at 27X magnification. Two different methods were evaluated for sorting samples. The first method and least successful, involved placing a sample in alcohol into the smaller half of a Petri dish. A graph paper grid was placed under the sample in the larger half of the dish, making it possible to scan the sample in an orderly way to sort out the different mites. The main objection to this sorting method was found to be in the length of time required to remove the mites from the alcohol for determination. Neither a camel hair brush nor a very small wire loop could lift specimens through the surface of the alcohol without frequently dropping them back into the dish. Nor was a finely drawn pipette found to be efficient in lifting them out because of the time and steadiness required to carefully control the pipette bulb.

Because of the inefficiency of the Petri dish sorting method, a plate method of sorting was tried and found to be effective. Alcohol was drained from the sample by filtering it through number 2 filter paper. The mites were brushed from the filter paper onto a white glass plate, and the filter was examined under dissecting microscope to be sure all mites were removed. Several drops of glycerin or lactic acid were then added to the mites to keep them from drying and air bubbles from entering their bodies. Lactic acid was used most of the time since clearing of the mites for examination under compound microscope was desired. Otherwise, glycerin served as well. The mites were arranged in a straight line across the plate making it easy to sort through the line and to separate the specimens to be determined with a camel hair brush. The mites stuck to the brush as they were pushed over the edge of the plate, making transfers to slides easy. The brush had to be trimmed to about 8 or 10 bristles to make it most effective for sorting and lifting the mites from the plate.

For determination specimens were transferred to concavity slides and cleared with lactic acid, following the method given in detail by Balogh (1959) and more briefly by Evans, Sheals, and Macfarlane (1961). The method was as follows: Two or three drops of lactic acid were placed in a cavity slide and a square coverslip was placed over the cavity so that slightly less than one-half of the cavity was covered. The lactic acid did not cover the open cavity beyond the edge of the coverslip, and it was drawn up against the coverslip. Fifty to 100% lactic acid was used, dependent upon the degree of clearing needed to see the morphological characteristics necessary to identify the mites. For oribatids and more heavily sclerotized Mesostigmata 100% lactic acid was used, while for Prostigmata, Astigmata, and more weakly sclerotized Mesostigmata 50 to 75% was used. Higher concentrations of lactic acid caused weakly sclerotized mites to swell from their normal size and shape and sometimes even to burst.

After the slide was ready, the mite to be examined was transferred to it and allowed to clear sufficiently for determination with a compound microscope. Gently warming the slide in an oven or on a warming plate speeded the clearing process. The length of time required varied from several minutes to several hours depending on the degree of sclerotization of the mite. Sorting on the plate in lactic acid reduced the time required for clearing on the slide.

An alternative to clearing the mites on slides is to extract them from Berlese funnels into 50% lactic acid rather than some other liquid. They can not, however, be stored in lactic acid for a long period of time because of its corrosive action on membranes of the appendages, setae, etc., and must be determined soon after extraction and stored in alcohol.

Regardless of the clearing method used, it is advantageous to determine the mites with temporary concavity preparations rather than with a permanent mount. The chief advantage lies in the fact that in the temporary mount the mite may be oriented in any position desired for examination, either by moving the coverslip or by reaching under the open edge of the coverslip with a fine needle to move the specimen. Permanent mounts of oribatids and other large mites in a standard acarine mountant such as Hoyer's solution are undesirable also because of the great tendency for the mites to be crushed as the mountant loses water in drying. The temporary mounting and alcohol storage of oribatid mites is recommended by Dr. D.E. Johnston, curator of the collection at the Institute of Acarology at Ohio State University.

Determinations of mites following clearing were made with a Zeiss phase-contrast microscope. Both phase-contrast and normal light were used, depending on structures being observed. In determining heavily sclerotized mites normal lighting was used except for examining setae and other fine structures. Both normal and phase-contrast light were used more or less equally in examining lightly sclerotized mites.

Balogh (1965) was used for determining oribatids. Dr. Eduard Piffl confirmed many of the determinations. Krantz (1966) was used to determine non-oribatids to family. Also helpful were Baker and Wharton (1952), Baker et. al. (1958), Sellnick (1929), Vitzthum (1929), and Willmann (1931).

Following identification, mites were removed from the lactic acid mounts and stored in small cotton-plugged vials in 85% ethyl alcohol. A synoptic collection of the various taxa found will be deposited in the Entomology Museum of Michigan State University together with the samples examined. Specimens of *Mochlozetes* sp. are being retained by the author for further study.

SYSTEMATIC REVIEW OF ACARINA FOUND

Primary emphasis of this study was placed on the Oribatei which were determined to genus. A total of 48 oribatid genera representing 29 families were found. Systematics was from Balogh (1965). Non-oribatid mites were determined to family. Two families of Astigmata, 17 families of Prostigmata, and 11 families of Mesostigmata were found. In addition, 2 specimens of Hydracarina were found. Systematics of non-oribatids was from Baker and Wharton (1952) except in cases of families described since 1952. Appendix III contains a complete systematic list of the taxa found, and Appendix IV contains a tabulation of the taxa found in individual samples.

DISCUSSION OF RESULTS

Twenty-nine of the 48 genera of Oribatei found in this study were found in at least three-fourths of the 36 samples. Exact quantification of the data was impossible due to the sampling method used. However, numbers of individuals ranged in the order of 50 to several hundred for the more common genera. Only two, Eupelops sp. and Rostrozetes sp., were found in all samples. Those genera found in one-fourth or less samples usually numbered eight or less specimens per sample. This suggests that they might not necessarily be considered a part of the bog mat fauna. One example worth noting is Steganacarus sp. which was found in only two samples. In one sample only one specimen was found. The other sample taken under a larch tree contained a few mushrooms. The number of Steganacarus sp. in that sample was over 100. Although such a high number might be considered normal for any of the genera occurring in at least three-fourths of the samples, it is an unusual number for a genus occurring in only two samples. The mushrooms may have been the habitat of the Steganacarus sp. found, or their presence under a larch might indicate that the sample could contain specimens from outside the bog margin.

Another example, found in only nine samples, was Mochlozetes sp. Its maximum number in any sample was six, and it was not found from any sample date until August 17. Thereafter it was found in nine of the following twenty samples. Perhaps its occurrence was seasonal. The bog margin may have been drying up somewhat so that Mochlozetes sp. was driven inward to seek more moisture, though no other genera suggest this. Neither temperature nor moisture index of the samples give any indication as to why it was not found before August 17. With its relatively large size and distinctive appearance it is unlikely that it had been overlooked in previous samples. Perhaps the low number of specimens of Mochlozetes sp. alone was the reason it did not appear in previous samples.

Mochlozetes sp. apparently has not been reported in the literature from North America. Hammer (1961) reported its possible occurrence from wet moss in the Andes Mountains of Peru. She stated that as the only specimen found was completely crushed before the figure of it had been finished, it would not be described until more material had been found. Grandjean (1930) described three species of Mochlozetes sp. from the Caribbean region.

Belba sp. was found in only two samples with a total of four specimens. Both samples were given a moisture index of 4 (moderately dry). It is quite likely that Belba sp. would have been found more often if more sampling had been done on the drier bog margin. Phthiracarus sp., Ceratoppia sp., Camisia sp., Damaeus sp., and Liochthonius sp. were also found only in samples with a moisture of 3 or 4 and may also have been marginal representatives of the fauna.

Only one specimen each of _Carabodoides_ sp., _Eobrachychthonius_ sp., _Gehypochthonius_ sp., and _Protokalumma_ sp. was found in the entire 36 samples, and their occurrence could be considered "accidental".

For the remaining Oribatei which occurred in low numbers, it is difficult to draw any conclusions as to why they were so seldom found. Most were found over a wide moisture range, and it is possible that as normal faunal representatives they are never found in very large numbers. Or they also may be marginal mat representatives.

For the larger group of Oribatei which were present in at least three-fourths of the samples, several generalizations can be made. They were found over a wide moisture range. Usually they inhabited at least three numbers on the arbitrary moisture scale. The number of specimens of most oribatid genera was large as compared to the number of specimens of non-oribatid families. Though the study was not meant to be quantitative, it was quite easy to get a rough estimate of numbers. Whereas each non-oribatid family would have numbers of 100 or less per sample, most often 50 or less, oribatid genera would commonly have 100 to several hundred specimens per sample. There were oribatid genera which had lower numbers, but in general their numbers were higher than non-oribatids. The heavier sclerotization of oribatids probably allows them to tolerate a wider range of moisture conditions than other less sclerotized mites, increasing their numbers. Also, considering their role as primary consumers of algae and fungus in their community, one would expect their numbers to be greater than that of non-oribatids, many of which are predatory.

Only two families of Astigmata, the Acaridae and Anoetidae, were found. Acarid adults were found in one sample and anoetid adults were found in two samples. The reason for this is uncertain. Hypopi of the two families were found in 10 and 15 samples respectively. Hypopi are normally associated with insects, often specifically, and for this reason it is not surprising that in most cases their number was ten or less. In three samples, however, acarid hypopi numbered 62, 366, and more than 200. No explanation was found for such large numbers. No hypopi were found attached to insects in the sample, and no unusual occurrence of insects was noted from which hypopi might have become detached. In one sample where anoetid hypopi numbered 101, a plausible explanation was found. A pitcher plant (Sarracenia sp.) had been taken as part of that sample, and likely the hypopi had come from it. Hunter (1964) reported a new species of anoetid mite from pitcher plants in Georgia and North Carolina. He suggested that the mites were transferred from one pitcher to another by hypopi attaching to insects which visited the pitchers. The mites were thought to live on insect debris in the pitchers or the microorganisms associated with it, and to reproduce there. It is possible that the same was true for the hypopi taken here.

Representatives of the Prostigmata and Mesostigmata were not found to occur so regularly as the Oribatei. Of the Prostigmata only the Cunaxidae, Scutacaridae, and Stigmaeidae were found in at least three-fourths of the samples, and of the Mesostigmata only the Ascidae and Ologamasidae. As mentioned previously, the lightly sclerotized bodies and predatory habits of many would make their frequent occurrence less likely. The less sclerotized mites also may be extracted less efficiently from moss by Berlese funnels since dessication is more likely to occur too rapidly for all of them to escape than for the Oribatei. By using a light bulb as low as sixty watts in the funnels, their extraction should have been increased, however.

Of those families of Prostigmata and Mesostigmata which are phytophagous, the Scutacaridae and Tarsonemidae occurred quite regularly and in some samples in large numbers. Perhaps their food plants are somewhat specific and large numbers were found only when those plants were sampled. Insufficient data was available to be certain, however. Phytoseiids were found less regularly in 16 samples, but also showed larger numbers in several samples. Only two pyemotids were found, both of which were very small specimens measuring less than 0.1 mm. in length. Their small size would have made them somewhat easier to overlook in sorting samples, and their very light sclerotization may have made it difficult for them to escape the Berlese funnels.

Only one specimen each was found of the Prostigmata Terpnacaridae and the Mesostigmata Ameroseiidae and Rhodacaridae. All came from samples with a mositure of 4 and likely were from the marginal fauna of the mat. Four specimens of Penthalodidae in a single sample with a moisture of 3 may have been also.

Single specimens of unidentified Hydracarina were found in two samples. These, along with the oribatids <u>Limnozetes</u> sp. and <u>Hydrozetes</u> sp. are probably the only truly aquatic mites taken from the samples. Both Limnozetes sp. and Hydrozetes sp. were more intimately related to the vegetation of the solid bog mat than would be expected of the Hydracarina. No sampling was done along the open lake edge of the thin mat where Hydracarina would be expected in larger numbers.

FACTORS AFFECTING BOG POPULATIONS

The ecological succession of bog plants with their accompanying fauna is a complex process, and factors controlling the process are many. Though most such factors were completely uninvestigated in this study, it would not be complete without mentioning briefly their importance and the need for their investigation to increase the understanding of bog populations.

Maintenance of proper moisture is vital to arthropods. Even those mites with a well chitinized exoskeleton may die soon if the relative humidity is improper. In the bog environment, relative humidity may cause migration of mites both horizontally and vertically as they seek an optium. This may be a daily or seasonal occurrence.

Temperature may act not only directly on mites in causing a similar migration, but also indirectly as it changes the relative humidity. Chemical factors such as oxygen availability, pH, salinity and decomposition products may make a bog suitable for certain species and unsuitable for others.

The floral succession of a bog adds variety to the community. Feeding specificity shown among forest soil Oribatei by Hartenstein (1962) likely could be found in bogs also. The number of species and individuals of mites is likely affected by the number of species and individuals of plants present. Plant cover also affects the light reaching the spaces in the bog mat where Acarina are found, and remains to be investigated.

These are only some of the physical factors which by their interaction determine the flora and fauna to be found in a given environment. The previously mentioned studies of Tarras-Wahlberg show that by an isolation of factors, an increased understanding of bog populations can be obtained.

CONCLUSIONS

1. Forty-eight oribatid genera representing 29 families were found. *Eupelops* sp. and *Rostrozetes* sp. were found in all 36 samples examined. Two families of Astigmata, 17 families of Prostigmata, and 11 families of Mesostigmata were found.

2. *Mochlozetes* sp., an oribatid not previously reported from North America, was collected in 9 samples.

3. Two aquatic oribatids, *Limnozetes* sp. and *Hydrozetes* sp., were found.

4. Moisture preferences were postulated for several taxa. Further experiments with more refined methods could add much knowledge in this area.

5. A possible association of *Steganacarus* sp. with mushrooms was noted.

6. Anoetid hypopi found in large number from one sample probably were from a pitcher plant.

7. In general, the number of oribatid individuals found in any sample was much larger than that of all non-oribatids combined.

LITERATURE CITED

LITERATURE CITED

Baker, E.W. and G.W. Wharton. 1952. An introduction to acarology. New York: The Macmillan Co., 465 pp.

Baker, E.W., J.H. Camin, F. Cunliffe, T.A. Woolley, and C.E. Yunker. 1958. Guide to the families of mites. Contribution No. 3, The Institute of Acarology, Univ. of Maryland, College Park, Md., 231 pp.

Balogh, J. 1959. On the preparation and observation of oribatids. Acta Zool. Hung. 5: 241-253.

Balogh, J. 1965. A synopsis of the world oribatid (Acari) genera. Acta Zool. Hung. 9(1-2): 5-99.

Beier, Max. 1928. Die Milben in den Bioconosen der Lunzer Hochmoore. Zeitsch. Morph. Okol. d. Tiere 11: 161-181.

Crow, Garrett Eugene. 1968. An ecological, floristic and phytogeographic analysis of a southern Michigan bog. Thesis (M.S.), Mich. State Univ.

Davis, Charles Albert. 1906. Peat; essays on its origin, uses and distribution in Michigan. Michigan Geological Survey. Report, 1906.

Evans, G. Owen, J.G. Sheals, and D. Macfarlane. 1961. The terrestrial Acari of the British Isles. London: Bartholomew Press, 219 pp.

Gates, F.C. 1942. The bogs of northern lower Michigan. Ecol. Monographs 12: 214-254.

Grandjean, Francois. 1930. Oribates nouveaux de la region Caraibe. Bull. Soc. Zool. Fr. 55: 262-284.

Hammen, L. van der. 1952. The Oribatei of the Netherlands. Zool. Verhand., Leiden, No. 17: 1-139.

Hammer, Marie. 1961. Investigations on the oribatid fauna of the Andes Mountains. II. Peru. Biol. Skr. Dan. Selsk. 13(1): 1-157.

Hartenstein, Roy. 1962. Soil Oribatei. I. Feeding specificity among soil Oribatei (Acarina). Ann. Ent. Soc. Amer. 55(2): 202-206.

Hunter, Preston E., and C.A. Hunter. 1964. A new Anoetus mite from pitcher plants. Proc. Ent. Soc. Wash. 66(1): 39-46.

Knülle, Willi. 1957. Die Verteilung der Acari: Oribatei im Boden. Zeitschr. Morph. Ok. d. Tiere 46: 397-432.

Krantz, G.W. 1966. A laboratory manual for acarology. Oregon State Univ., unpublished, 170 pp.

Macfadyen, N. 1953. Notes on methods for the extraction of small arthropods. Journ. Anim. Ecol. 22: 65-77.

Peus, F. 1932. Die Tierwelt der Moore unter besonderer Berücksichtigung der europäischen Hochmoore. Handbuch der Moorekunde, 3.

Popp, Egon. 1962. Semiaquatile Lebensräume (Bulten) in Hoch- und Niedermooren. Int. Revue ges. Hydrobiol. 47(4): 533-579.

Reed, H.S. 1902. A botanical survey of the Huron River Valley. I. The ecology of a glacial lake. Bot. Gaz. 34: 125-139.

Sellnick, Max. 1929. Oribatei. Die Tierwelt Mitteleuropas 3, No. 9: 1-42.

Strenzke, K. 1952. Untersuchungen über die Tiergemeinschaften des Bodens; die Oribatiden und ihre Synusien in den Boden Norddeutschlands. Zoologica 104.

Tarras-Wahlberg, Nils. 1954. Oribatids from the Akhult-Mire. Oikos 4(2): 166-171.

Tarras-Wahlberg, Nils. 1961. The Oribatei of a central Swedish bog and their environment. Oikos suppl. 4: 1-56.

Transeau, Edgar Nelson. 1904-06. The bogs and bog flora of the Huron River Valley. Thesis (Ph. D.), Univ. of Michigan. Reprinted in Bot. Gaz. 40: 351-375, 418-448; 41: 17-42, 1906.

Vitzthum, H.G. 1929. Acari. Die Tierwelt Mitteleuropas 3, No. 7: 1-112.

Weld, L.H. 1904. Botanical survey of the Huron River Valley. II. A peat bog and morainal lake. Bot. Gaz. 37: 36-52.

Willmann, C. 1931. Spinnentiere oder Arachnoidea V: Moosmilben oder Oribatiden (Cryptostigmata). Die Tierwelt Deutschlands 22: 79-200.

APPENDICES

APPENDIX I

PLANT SPECIES COMMON IN OR AROUND SAMPLING SITES OF OTIS LAKE BOG, BARRY COUNTY, MICHIGAN

Carex spp. - sedge

Chamaedaphne calyculata (L.) Moench. - leatherleaf

Decodon verticullatus (L.) Ell. - swamp loosestrife

Eriophorum virginicum L. - cotton grass

Juncus brevicaudatus (Engelm.) Fernald. - rush

Larix laricina (DuRoi) Koch - larch or tamarack

Leersia oryzoides (L.) Sw. - cut grass

Menyanthes trifoliata L. - buckbean

Nuphar sp. - yellow water lily

Peltandra virginica (L.) Kunth. - arrow arum

Rhus vernix L. - poison sumac

Sagittaria sp. - arrowhead

Sarracenia sp. - pitcher plant

Scirpus sp. - bulrush

Sphagnum spp. - peat moss

Typha sp. - cat-tail

Vaccinium corymbosum L. - high bush blueberry

Vaccinium macrocarpus Ait. - cranberry

Woodwardia virginica (L.) Smith - chain fern

APPENDIX II

WEATHER DATA FOR SAMPLING DATES. PROMINENT VEGETATION, TEMPERATURE AND MOISTURE FOR SAMPLES.

d = degrees F, m = moisture index

June 22, 9-11 A.M.; cloudless sky, 78d.

Sample 2. Cranberry. 71d, m2.

Sample 6. Cranberry. 71d, m2.

Sample 7. Under blueberry. 70d, m1.

Sample 8. Rush. 70d, m1.

June 29, 9-11 A.M.; cloudless sky, 90d.

Sample 12. Cranberry, pitcher plant. 73d, m3.

Sample 13. Under blueberry. 78d, m3.

Sample 17. Cranberry. 89d, m1.

Sample 19. Pitcher plant. 86d, m3.

July 27, 2-3 P.M.; light fog and drizzling rain, 74d.

Sample 21. Under larch. 76d, m4.

Sample 23. Under larch and blueberry, few cranberry. 75d, m3.

Sample 26. Rush, chain fern, blueberry. 82d, m3.

Sample 30. Under larch and blueberry. 74d, m4.

August 3, 9-11 A.M.; cloudless sky, 90d.

Sample 31. Rush, cranberry. 70d, m2.

Sample 34. Under blueberry. 63d, m2.

Sample 36. Under blueberry. 64d, m3.

Sample 37. Cranberry, under blueberry. 62d, m3.

August 17, 9-11 A.M.; cloudless sky, high relative humidity, 82d.

Sample 43. Under larch. 67d, m3.

Sample 45. Under blueberry. 66d, m4.

Sample 46. Under blueberry; cat-tail. 68d, m3.

Sample 50. Under blueberry, few cranberry. 67d, m2.

August 30, 2-3 P.M.; clear sky, 84d.

Sample 52. Chain fern, cat-tail, arrowhead. 72d, m2.

Sample 55. Rush, loosestrife, cranberry, under blueberry. 72d, m1.

Sample 58. Chain fern, cranberry, under blueberry. 67d, m3.

Sample 60. Cranberry, under blueberry. 68d, m3.

September 9, 9-11 A.M.; partly cloudy sky, 82d.

Sample 62. Chain fern, under larch and blueberry. 63d, m3.

Sample 63. Chain fern, cat-tail, few rushes, under blueberries. 63d, m3.

Sample 64. Rush. 72d, m2.

Sample 67. Rush, cranberry. 68d, m2.

October 13, 2-3 P.M.; foggy, light drizzle, 56d.

Sample 71. Under larch, mushrooms; hummock elevated 1 foot above mat. 54d, m4.

Sample 74. Chain fern, under blueberry. 54d, m2.

Sample 76. Chain fern, under larch and blueberry; hummock elevated 6 inches above mat. 54d, m2.

Sample 78. Chain fern, dead cat-tails, under blueberry. 54d, m3.

November 18, 2-3 P.M.; cloudy sky, 46d.

Sample 79. Chain fern, under blueberry and poison sumac. 44d, m3.

Sample 81. Pitcher plant, under blueberry and larch. 40d, m3.

Sample 82. Rush, cranberry. 44d, m2.

Sample 83. Rush, under blueberry. 44d, ml.

APPENDIX III. SYSTEMATIC LIST OF ACARINA FROM OTIS LAKE BOG, BARRY COUNTY, MICHIGAN.

ORIBATEI

Parhypochthoniidae Grandjean, 1932

Gehypochthonius Jacot, 1936

Hypochthoniidae Berlese, 1910

Hypochthonius C.L. Koch, 1836

Eniochthoniidae Grandjean, 1933

Hypochthoniella Berlese, 1910

Brachychthoniidae Balogh, 1943

Brachychthonius Berlese, 1910

Eobrachychthonius Jacot, 1936

Liochthonius van der Hammen, 1959

Phthiracaridae Perty, 1841

Phthiracarus Perty, 1841

Hoplophthiracarus Jacot, 1933

Steganacarus Ewing, 1917

Euphthiracaridae Jacot, 1830

Euphthiracarus Ewing, 1917

Rhysotritia Markel & Meyer, 1959

Nothridae Berlese, 1896

Nothrus C.L. Koch, 1836

Camisiidae Oudemans, 1900

Camisia von Heyden, 1826

Platynothrus Berlese, 1913

Trhypochthoniidae Willmann, 1931

Trhypochthonius Berlese, 1904

Malaconothridae Berlese, 1916

Malaconothrus Berlese, 1904

Trimalaconothrus Berlese, 1916

Nanhermanniidae Sellnick, 1928

Nanhermannia Berlese, 1913

Damaeidae Berlese, 1896

Damaeus C.L. Koch, 1836

Belba von Heyden, 1826

Epidamaeus Bulanova-Zakhvatkina, 1957

Metrioppiidae Balogh, 1943

Ceratoppia Berlese, 1908

Astegistidae Balogh, 1961

Cultoribula Berlese, 1908

Carabodidae Dubinin, 1954

Carabodes C.L. Koch, 1836

Tectocepheidae Grandjean, 1954

Tectocepheus Berlese, 1913

Tegeocranellus Berlese, 1913

Oppiidae Grandjean, 1954

Oppia C.L. Koch, 1836

Carabodoides Jacot, 1937

Suctobelbidae Grandjean, 1954

Suctobelba Paoli, 1908

Hydrozetidae Grandjean, 1954

Hydrozetes Berlese, 1902

Limnozetidae Grandjean, 1954

Limnozetes Hull, 1916

Pelopidae Ewing, 1917

Eupelops Ewing, 1917

Achipteriidae Thor, 1929

Anachipteria Grandjean, 1935

Ceratozetidae Jacot, 1925

Ceratozetes Berlese, 1908

Heterozetes Willmann, 1917

Trichoribates Berlese, 1910

Mycobatidae Grandjean, 1960

Punctoribates Berlese, 1908

Mochlozetidae Grandjean, 1960

Mochlozetes Grandjean, 1930

Parakalummidae Grandjean, 1936

Protokalumma Jacot, 1929

Galumnidae Jacot, 1925

Galumna von Heyden, 1826

Pergalumna Grandjean, 1936

Trichogalumna Balogh, 1960

Oribatulidae Thor, 1929

Dometorina Grandjean, 1951

Lucoppia Berlese, 1908

Scheloribates Berlese, 1908

Zygoribatula Berlese, 1917

Haplozetidae Grandjean, 1936

Rostrozetes Sellnick, 1925

Xylobates Jacot, 1929

ASTIGMATA (Sarcoptiformes - Acaridiae)

Anoetidae Oudemans, 1904

Acaridae Oudemans, 1904

PROSTIGMATA (Trombidiformes)

Scutacaridae Oudemans, 1916

Pyemotidae Oudemans, 1937

Tarsonemidae Kramer, 1877

Eupodidae Koch, 1842

Penthalodidae Thor, 1933

Bdellidae Duges, 1834

Rhagidiidae Oudemans, 1922

Ereynetidae Oudemans, 1931

Tydeidae Kramer, 1877

Cunaxidae Thor, 1902

Nanorchestidae Grandjean, 1937

Pachygnathidae Kramer, 1877

Terpnacaridae Grandjean, 1939

Raphignathidae Kramer, 1877

Stigmaeidae Oudemans, 1931

Smarididae Kramer, 1878

Trombidiidae Leach, 1815

HYDRACARINA (Hydrachnellae)

Two specimens, undetermined

MESOSTIGMATA

Rhodacaridae Oudemans, 1902

Ascidae Oudemans, 1915

Veigaiidae Oudemans, 1939

Parasitidae Oudemans, 1901

Parholaspidae Krantz, 1960

Ologamasinae Ryke, 1962

Ameroseiidae Evans, 1961

Phytoseiidae Berlese, 1916

Laelaptidae Berlese, 1892

Zerconidae Berlese, 1892

Uropodidae Berlese, 1917

APPENDIX IV
TABULATION OF ACARINE TAXA FOUND IN SAMPLES.

+ = more than 10 specimens in sample.
* = a proportionately large number were present.
Numbers are given only where less than 11 specimens occurred, except for hypopi

ORIBATEI	June 22				June 29				July 27			
Sample number	2	6	7	8	12	13	17	19	21	23	26	30
Anachipteria		*	+	+	+		+					
Belba												1
Brachychthonius	+		+	+	1	1				+		*
Camisa						1						
Carabodes									+			
Carabodoides												
Ceratozetes	+	*	+	+	+		+	+	+		+	+
Ceratoppia												
Cultoribula	+		+			+		+	+	+	+	+
Damaeus												
Dometorina									+			
Eobrachychthonius	1											
Epidamaeus	2	2	+	+				+		*		*
Eupelops	+	+	+	+	+	+	+	+	+	+	+	+
Euphthiracarus	+		+			+			+	2		+
Galumna												
Gehypochthonius												
Heterozetes		+										
Hoplophthiracarus	*	+	+	+	+	*	+	+	+	+	+	+
Hypochthoniella	+		+			+		+	+	*		+
Hypochthonius			+	+		+		+	1	+		
Hydrozetes		+		+	3		+					
Limnozetes		+		+	+		+	+			+	
Liochthonius						1		2	+			
Lucoppia				+								
Malaconothrus	+	+	+	+	+	+	+	+	+	+	+	+
Mochlozetes												
Nanhermannia	+	+	+	+	+	+	+	+	+	+	+	+
Nothrus	*	+	+	+	+	+	+	+	+	+	+	+
Oppia	+	+	+	+	+	+			+	*	+	+
Pergalumna	+	+							+	+		+
Phthiracarus			3							+		+
Platynothrus				+	+			+				
Protokalumma												
Punctoribates						+				+	2	+
Rhysotritia	3	+	+	+		+	+	+	+	+	1	+
Rostrozetes	+	+	+	+	+	+	+	+	+	+	+	+
Scheloribates		+	+	+	+	+		+	+	+	+	+
Steganacarus												
Suctobelba	+	+	+	+		+	+	+	+	*		+
Tectocephaeus	+	+	+	+	+	+	+	+	+	+	2	+
Tegeocranellus				+				*			+	
Trhypochthonius	+	+	+	+	+	+	+	+	+	+	+	
Trichogalumna	+	+	+			+	+		+	+	+	+
Trichoribates									+			2
Trimalaconothrus		+	+	+	+		+	+			+	
Xylobates	+		+	+	+	+		+	+	+		
Zygoribatula						1						

ORIBATEI	August 3				August 17				August 30			
Sample number	31	34	36	37	43	45	46	50	52	55	58	60
Anachipteria	+	*	+						+	+		+
Belba						3						
Brachychthonius		+	+	+	+	+	+	+	+		+	+
Camisia						1						
Carabodes			1					1				
Carabodoides												
Ceratozetes	+	+	+		+	+	*	+	*	+		+
Ceratoppia				1	2	1						
Cultoribula	1		+	+		+	*	*	+		+	+
Damaeus											1	
Dometorina							2	9	1		1	1
Eobrachythonius												
Epidamaeus		+	+	+	+	+		+		+	+	+
Eupelops	+	+	+	+	+	+	+	+	+	+	+	+
Euphthiracarus	+		+	+		+		*				+
Galumna												1
Gehypochthonius												
Heterozetes	1	2					1		1	+	+	
Hoplophthiracarus		+	+	*	+	+	+	+	+	+	+	+
Hypochthoniella	3		+	+	+	+		*			+	+
Hypochthonius		+	+	+		+		+			+	+
Hydrozetes	+	+								1		
Limnozetes	+	+								+		
Liochthonius												
Lucoppia												
Malaconothrus	+	+	+	+	+	+	+	+	+	+		+
Mochlozetes					6	3		1			4	1
Nanhermannia	+	+	+	+	+	+	+	+	+	+	+	+
Nothrus	+	+	+	+	+	+	+	+	+	+	+	+
Oppia	+	+	+	+	*	+	+	+	+	+	+	+
Pergalumna			+	+	+	+		+			1	+
Phthiracarus			6	1		+						1
Platynothrus	2	2				+						
Protokalumma					1							
Punctoribates		+	+	+	+	+		+			+	+
Rhysotritia		+	+	+	+	+		+	+	1	+	
Rostrozetes	+	+	+	*	+	+	*	+	*	+	+	+
Scheloribates	+	+	+	+	+	+		+	+	+	+	+
Steganacarus												
Suctobelba			+	+	*	+	+	*	+	+	+	+
Tectocephaeus	2	+	+	+	+	+	+	+	+	+	+	+
Tegeocranellus	1									1		
Trhypochthonius	+	+	+	+	+	+	+	+	*	+		
Trichogalumna		+	+	+	+		1	+			+	+
Trichoribates					1	3						
Trimalaconothrus	+	+		+			+		+	+	+	
Xylobates				+	+	+	+	+	+	+		+
Zygoribatula		1										

ORIBATEI	September 9				October 13				November 18			
Sample number	62	63	64	67	71	74	76	78	79	81	82	83
Anachipteria			+	+			+		+		+	+
Belba												
Brachychthonius	+	+			+	+				+	+	+
Camisia					2				2			
Carabodes					1		1					
Carabodoides							1					
Ceratozetes	+	+	+	+				+	+		+	+
Ceratoppia					10							
Cultoribula	+	*	+	+	+	+	1		+	+	+	
Damaeus	1				2							
Dometorina		1				2			**	2	1	3
Eobrachychthonius												
Epidamaeus				1	+		+			+		
Eupelops	+	+	*	+	+	+	+	+	+	+	+	+
Euphthiracarus		+		+	+	+				+		
Galumna			1		*		+	2				
Gehypochthonius							1					
Heterozetes									1		+	+
Hoplophthiracarus	+	+	*	+	+		+	+	+	+	+	+
Hypochthoniella	+			+	*	+	+			+		
Hypochthonius	+		+	+	+	+	+			1	1	
Hydrozetes								3			+	+
Limnozetes		+	+				+	2			+	*
Liochthonius							+					
Lucoppia								1				
Malaconothrus	+	+	+	+		+	+	+	+	+	+	+
Mochlozetes					3	1			4	3		
Nanhermannia	*	+	+	+		+	+	+	+	+	+	2
Nothrus	+	+	*	+	+	+	+	+	+	+	+	
Oppia	+	+	+	+	*	+	+	+	+	*	+	+
Pergalumna					*					+		
Phthiracarus					1							
Platynothrus							+	1				
Protokalumma												
Punctoribates	+		+		+		+		+	+	+	+
Rhysotritia			+	+	+	1		+	+	+	+	1
Rostrozetes	*	**	*	+	+	+	+	+	+	*	+	+
Scheloribates		+	+	+	+	+		+	+	+	2	+
Steganacarus					*				1			
Suctobelba	+	+	+	+	+	+	+	+	+	+	+	+
Tectocephaeus	+	+	+	+	+	+	+	+	+	+	+	
Tegeocranellus			3					*	3			1
Trhypochthonius	+	+	+	+	+	+	+	+	+	+	+	*
Trichogalumna	+			+	+	+	+		+		+	
Trichoribates			1		5	1				1		
Trimalaconothrus		+	+	+			+		+		+	+
Xylobates	+	+	+		+	+		+	+	+	+	+
Zygoribatula												

	June 22				June 29				July 27			
Sample number	2	6	7	8	12	13	17	19	21	23	26	30
ASTIGMATA												
Acaridae												
hypopi					1							
adults						2						
Anoetidae												
hypopi			6	2	8		1	101			2	
adults							1					
PROSTIGMATA												
Bdellidae	+								+		+	+
Cunaxidae	+	+	+	+	+	+	+	+	+		*	+
Ereynetidae									+			
Eupodidae						+						
Nanorchestidae			+		+	+			+	+		+
Pachygnathidae												
Penthalodidae												
Pyemotidae											1	
Raphignathidae		1		+								
Rhagidiidae			+			+			+	+		+
Scutacaridae	+	1		+	+	+		+	+	+	2	+
Smaridiidae							+					
Stigmaeidae		*	+	+	+	+		+	+	+	+	+
Tarsonemidae				+	2	1		+	+	+	3	*
Terpnacaridae								1				
Trombidiidae				+						1		1
Tydeidae												
MESOSTIGMATA												
Ameroseiidae												1
Ascidae	+		+	+	+	+	+	+	+	+	+	+
Laelaptidae	+	+	+	+	+	+		+		+	+	+
Ologamasidae	+	+	+	+	+	+		+	+	+	+	+
Parasitidae	+		+			+			+	+		+
Parholaspidae									+	+		+
Phytoseiidae	+				+				+	+		*
Rhodacaridae												
Uropodidae				+						+		
Veigaiidae			+			+			+	1		+
Zerconidae			+		+	+			+		1	+
HYDRACARINA		1						1				

	August 3				August 17				August 30			
Sample number	31	34	36	37	43	45	46	50	52	55	58	60
ASTIGMATA												
Acaridae												
hypopi			1	4	200	4		1			11	
adults												
Anoetidae												
hypopi	3		1	1					3	1		1
adults	2											
PROSTIGMATA												
Bdellidae		+	+	+		+	+	3				+
Cunaxidae	+	+	+	+	+	+	+	+	+	+	+	3
Ereynetidae												
Eupodidae							2			3		
Nanorchestidae			+	+	+	+	+	+	+		+	
Pachygnathidae								1	+			
Penthalodidae							4					
Pyemotidae								1				
Raphignathidae		+					+		2	+		
Rhagidiidae		+		+	+	+	+	+	+	+		+
Scutacaridae	+	+	+	1	*	+	*	+		+	*	+
Smaridiidae							1		7			
Stigmaeidae	+	+		+	*	+	+	+	+	+		
Tarsonemidae	1		+	+		+		1	+			+
Terpnacaridae												
Trombidiidae			*	2	1	2		8	1	1	2	1
Tydeidae							1	*				
MESOSTIGMATA												
Ameroseiidae												
Ascidae	+	+	+	+	+	+	+	+	+	+	+	+
Laelaptidae	+		+	+		+	+	+	+	+	+	+
Ologamasidae	+	+	+	+	+	+	+	+	+	+	+	+
Parasitidae			+			+		1				
Parholaspidae			+	1	+	+		+			+	+
Phytoseiidae	+			+		+				1		+
Rhodacaridae												
Uropodidae												1
Veigaiidae			+	+	+	+		+			+	+
Zerconidae			+	+	+	+		+			+	+

	September 9				October 13				November 18			
Sample number	62	63	64	67	71	74	76	78	79	81	82	83
<u>ASTIGMATA</u>												
Acaridae												
hypopi	366				62	+						
adults												
Anoetidae												
hypopi		1	1					3				
adults												
<u>PROSTIGMATA</u>												
Bdellidae					+	+			+			
Cunaxidae	+	+	+		+	+	+	+	+	+	+	+
Ereynetidae							+					
Eupodidae								3			+	
Nanorchestidae	+	+	+		+	+	+		+	+	+	
Pachygnathidae		+					+					
Penthalodidae												
Pyemotidae												
Raphignathidae		1	2	1				1				
Rhagidiidae	*	+		+	+	+	+	+	+	+	+	+
Scutacaridae	1	+		+	+	+	+		+	+		+
Smarididae												
Stigmaeidae	*	+	*	+	+	+	+	+	+	+	+	+
Tarsonemidae	+	+	+	+				+		+		+
Terpnacaridae												
Trombidiidae		1	1							1		
Tydeidae		+			+		+					+
<u>MESOSTIGMATA</u>												
Ameroseiidae												
Ascidae	+	+	+	+	+	+	+	+	+	+	+	+
Laelaptidae		+	+	+	+		+		+		+	
Ologamasidae	+	+	+	+	+	+	+	+	+	+	+	+
Parasitidae				1	+	3	+		3	+	+	
Parholaspidae	+		+		+	+	+		+		+	1
Phytoseiidae		+			+		+	+	+	+		
Rhodacaridae					1							
Uropodidae										1		
Veigaiidae	+				+	+	+		+	+		
Zerconidae	+	+			+	+				+		