HABITAT pH CHARACTERISTICS OF TREE HOLE *CULICOIDES* (DIPTERA: CERATOPOGONIDAE)

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ABSTRACT. Ten species of *Culicoides* were collected from 166 tree holes at 20 widely separated geographic locations to assess relationships with habitat pH. Wet tree holes (containing standing water) had a mean pH of 7.46 while dry tree holes (no standing water) had a mean pH of 8.60. *Culicoides arboricola, C. guttipennis* and *C. villosipennis* occurred in wet tree holes that had mean pH values of 7.66, 7.95 and 7.31, respectively. Dry tree holes, where *C. hinmani, C. elemae, C. paraensis, C. nanus, C. snowi* and *C. footei* occurred, had pH values ranging from 8.13 to 9.08. *Culicoides lahillei*, a dry tree hole species, was collected from habitats with a pH range similar to the wet tree hole species.

INTRODUCTION

Several studies have examined the relationship between species presence and the chemical characteristics of blood feeding Diptera habitats. Some studies (Knight 1965, Petersen and Chapman 1969, Hagstrum and Gunstream 1971) dealt with soil or ground water environments, while others (Petersen and Chapman 1969, Lunt and Peters 1976, Mitchell and Rockett 1981, Vrtiska and Pappas 1984, Smith and Varnell 1967) have investigated tree holes. These studies do show differences in pH when comparing the diverse habitats of ground water, containers and tree holes; but few (Smith and Varnell 1967) support a pH preference within a guild (Root 1967) of closely related species.

Most studies of habitat pH have been limited to a restricted geographic location with a limited number of faunal elements or a limited floral type distributed over a larger geographic area. To determine whether pH relationships observed in local situations extend throughout a species' distribution, we have studied the pH of tree holes that support 10 species of *Culicoides* (Diptera: Ceratopogonidae) in a range of habitats over a large geographic area.

MATERIALS AND METHODS

Tree hole samples were taken from 20 locations in the following states (counties): Florida (Liberty, Wakulla), Georgia (Butts, Clayton, Fayette), Kansas (Jackson), Missouri (Barry, Cape Girardeau, Mississippi, Montgomery, Osage), Nebraska (Brown, Dixon, Garden, Gosper, Harlan, Madison, Nemaha) and Tennessee (Coffee, Grundy). A total of 264 samples were taken, including 166 tree holes that produced *Culicoides.*

Material (standing water and/or moist organic matter) was collected from tree holes into quart jars and taken to the laboratory where pH was measured with a conventional pH meter. Distilled water was added as needed to retain original consistency. Samples were maintained under ambient conditions in the laboratory until adults stopped emerging. Following emergence, adults were aspirated into 70% ethanol and mounted on slides (Wirth and Marston 1968) for identification (Blanton and Wirth 1979, Wirth et al. 1985). Statistical analyses were performed with SYSTAT™ (Wilkinson 1988). Significance was determined with ANOVA tests and post-hoc multiple comparison contrasts. Voucher specimens have been deposited in the University of Nebraska State Museum, Lincoln, NE.

RESULTS

We categorized the *Culicoides* in our study as being either wet or dry tree hole (Snow 1949[1]) species (Table 1). A species was considered a wet tree hole species if collected primarily from tree holes with standing water (>45% of tree holes, Table 1) or if the number of individual specimens collected per tree hole was greater from the wet tree hole environment. For example, *Culicoides guttipennis* (Coquillett), *Culicoides arboricola* Root and Hoffman and *Culicoides villosipennis* Root and Hoffman were classified as wet tree hole species because they occurred in the wet tree hole habitat in more than 45% of the collections. Also, for these 3 species, the average number of specimens collected per tree hole was higher from the wet habitat (mean specimens per wet/dry habitats = 12.5/2.1, 4.7/2.0, 5.8/2.1; respectively). Those classified as dry tree hole species (Table 1) had the opposite characteristics.

The pH values recorded for the 10 *Culicoides* species collected are found in Table 1. These pH values ranged from a low 7.31 for *C. villosipennis* to a high 9.08 for *Culicoides hinmani* Khalaf.

[1] Snow, W. E. 1949. The arthropoda of wet tree holes. Ph.D. thesis. University of Illinois, Urbana, IL, 235 p.

Table 1. Mean pH values of the tree hole habitats from which 10 species of *Culicoides* were collected.

Species	No. of tree holes	Percentage of wet tree holes	pH	SE
*C. guttipennis**	75	85	7.95	0.11
*C. arboricola**	39	54	7.66	0.17
*C. villosipennis**	20	45	7.31	0.21
*C. hinmani***	7	0	9.08	0.15
*C. elemae***	19	0	8.73	0.13
*C. paraensis***	19	11	8.57	0.14
*C. nanus***	16	25	8.57	0.16
*C. snowi***	8	38	8.50	0.27
*C. footei***	8	0	8.13	0.52
*C. lahillei***	10	30	7.38	0.35

* Classified as wet tree hole species.
** Classified as dry tree hole species.

The mean pH values in Table 1 are significantly different (df = 9,211; F-ratio = 6.35; $P < 0.05$). The 3 wet tree hole species had pH values significantly less than the dry tree hole species (df = 1,211; F-ratio = 30.38; $P < 0.001$) which is not surprising as the mean pH of wet and dry tree holes was 7.46 (SE = 0.13) and 8.60 (SE = 0.11), respectively. Using a t-test procedure, these values are significantly different (df = 166; $t = 6.39$; $P < 0.001$). One of the dry tree hole species (*Culicoides lahillei* Iches) did not significantly differ from *C. arboricola* and *C. villosipennis* (df = 1,211; F-ratio = 0.71; $P > 0.001$). *Culicoides lahillei* was found in wet tree holes 30% of the time and was classified as a dry species by the ratio of specimens from wet/dry habitats (1.0/2.2). Except for *C. lahillei*, the dry tree hole species listed in Table 1 were found not to be significantly different from one another (df = 1,211; F-ratio = 1.76, $P > 0.05$).

DISCUSSION

Two independent studies, one examining a local fauna (Smith and Varnell 1967) and our research based on widely separated geographic areas, have found similar pH characteristics for tree hole *Culicoides*. These pH associations occurred despite the wide range of tree species involved, oak/beech forests of the East to the cottonwood/willow flood plain forests of the Central Plains. The present study and that of Smith and Varnell (1967) delineated 2 *Culicoides* groups based on pH. One association, comprised of *C. arboricola*, *C. guttipennis* and *C. villosipennis*, occurred in tree holes having a pH of less than 8.0. Smith and Varnell (1967) did not include *C. villosipennis*, because few specimens were collected in this group, although it occurred at pH values between 5.8 and 6.7 in their study. Additionally, both studies found *C. lahillei* in the low pH group. The second group, having pH values above 8.0 in our study, comprised *C. hinmani*, *Culicoides elemae* Pappas and Pappas, *Culicoides paraensis* (Goeldi), *Culicoides nanus* Root and Hoffman, *Culicoides snowi* Wirth and Jones and *Culicoides footei* Wirth and Jones. These pH relationships are similar to the Smith and Varnell (1967) high pH group although they did not collect *C. elemae*, only known from Nebraska and Kansas (Pappas and Pappas 1989), or *C. footei*. The pH values in our study, although associated with specific species, may be a reflection of the specific habitat (wet or dry), and the resource partitioning strategies of tree hole *Culicoides*.

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