# DISTRIBUTION OF CULICINE MOSQUITOES WITHIN THE POCOMOKE CYPRESSS SWAMP, MARYLAND

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INTRODUCTION. Little is known about the distribution of mosquito species within fresh-water river swamps. Although one swamp species, *Culiseta melanura* (Coquillett), has received considerable attention because of its role as a vector of equine encephalitis (see review in Joseph and Bickley, 1969), little work has been done to determine the optimum swamp environment for the development of larval or adult populations. Likewise, within-swamp distribution has not been described for mosquitoes of lesser economic and medical importance. Our investigation was undertaken to measure adult and larval densities of mosquitoes, including *C. melanura*, at different swamp sites, to describe the swamp environment which is favorable for each species, and thus to gain some insight into what factors determine the distribution of mosquito species within a river swamp.

MATERIALS AND METHODS. Studies were conducted in the Pocomoke Cypress Swamp, which is 2.5 miles southwest of Pocomoke City, Worcester County, Maryland. Descriptions of this swamp are given by Moussa *et al.* (1966) and by Joseph and Bickley (1969). It is a second growth, maple swamp bordering the Pocomoke River. Most of the cypress has been removed by lumbering.

Mosquitoes were collected at three sites (40Q, 20Q and 1Q) on a transect called the "Q-line," which extended from the Pocomoke River to a point 2,640 ft. into the swamp, and at a nearby upland site (Fig. 1). CDC miniature light traps placed 6 feet above the ground were operated one night each week in May and June and on two consecutive nights each week from July to December.

Mosquito larvae were sampled from three holes at each of seven sites on the "Q-line" (distance between adjacent sites was 330 ft. except from 1Q to 10Q and from 30Q to 40Q which equalled 660 ft.). The holes measured 3 to 7 square feet in area and were cut into the root-mat of the swamp floor on 5 March 1968. In addition, larvae were collected from three smaller holes (1/3 sq. ft. in area) which had been dug early in 1967 and from three pools of water (110, 225 and 600 sq. ft. in area). The pools and small holes were located between 15Q and 20Q (Fig. 1). Larvae were collected at each hole or pool with a 400 ml enamel dipper for 5 minutes. All larvae dipped were preserved, and those 3 mm or more in length were identified subsequently to species. One man sampled all sites on a date to reduce sampling errors between sites.

An experiment was conducted from August to mid-November, 1968, to determine the influence of light on developing larval populations. Four holes, each approximately one square foot in area, were established at 8-foot intervals and in a line near 15Q. Holes "A" and "C" were covered with wooden boxes having a slit cut out at the base to give mosquitoes an access to the holes, whereas "B" and "D" were uncovered. In sampling, an equal number of dips were taken at each hole, and larvae dipped were collected and identified.

Several physical and chemical parameters of larval habitats were examined. Water tables were monitored with Leupold and Stevens Type 7 recorders (Portland, Oregon) near the river (40Q) and

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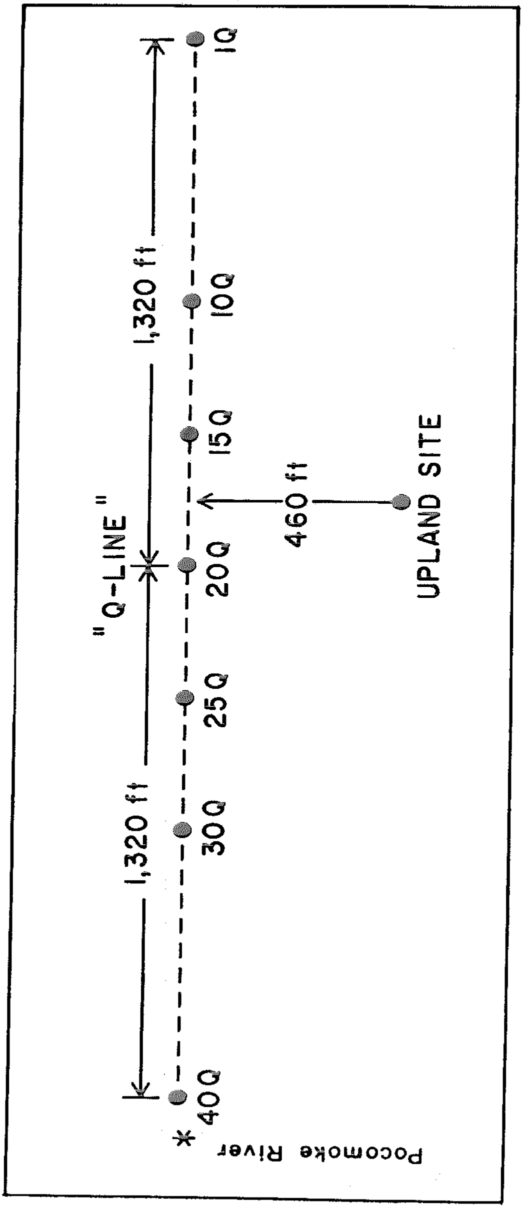


FIG. 1.—Relative positions of sampling sites in the Pocomoke Cypress Swamp, Md.

in the center of the study area (20Q). Chemical analyses were performed on water samples taken from holes at 1Q, 20Q and 40Q. Water was collected in liter bottles and refrigerated until the chemistry was done (within 24 hours of sampling) using a Hellige Aqua Analyzer photometer. Procedures used were those described in instruction series No. 955, available from Hellige, Inc. (877 Stewart Ave., Garden City, New York), except that water samples were filtered under suction with a Büchner funnel and No. 40 Whatman paper prior to testing. Chemicals used were those supplied by Hellige, Inc.

RESULTS. The predominant mosquito collected in light traps was *Culiseta melanura* (Fig. 2), which accounted for 89 percent of the female mosquitoes caught in this study, as in the study of Moussa *et al.* (1966) of this swamp. Peak captures occurred on 14–15 July and on 2 September. *Aedes cantator* (Coq.), *A. canadensis* (Theob.) and *Culex salinarius* (Coq.) made up 9.6 percent of all female mosquitoes collected, whereas 15 other species constituted only 1.4 percent of the total catch. Most *A. cantator* (93 percent) and *A. canadensis* (77 percent) were taken between 28 May and 9 July, with peak catches of both species on 28 May. Most *Culex salinarius* (96 percent) were caught from 28 May to 19 August, with periods of abundance coinciding with those of *Culiseta melanura*. *C. melanura* was the only species collected in large numbers after 19 August. Although abundant in larval samples, *Culex restuans* (Theob.) and *C. territans* (Wlk.) were not collected by light traps. Thus, the overwhelming dominance of *Culiseta melanura* suggested by light-trap captures may be exaggerated.

Overall captures of *C. melanura* females were: 1Q=7,734; 20Q=4,408; 40Q=2,150; and upland=1,053. Differences between sites were tested with a Chi-square Sign Test (Steel and Torrie, 1960) using data from 29 nights of light trapping, where 100 or more *C. melanura* females had been taken on each night. Over the year, captures at 1Q were significantly greater than captures at 20Q ($\chi^2=6.3$, $p<.025$), captures at 20 Q were higher than those at 40Q ($\chi^2=6.3$, $p<.025$), and captures at 40Q were higher than at the upland site ($\chi^2=8.0$, $p<.005$).

Five species of mosquito larvae were collected (Table 1). *Aedes canadensis* larvae were abundant in April, as were those of *Culex restuans*. *C. restuans* larvae decreased in abundance between late August and early October, but subsequently increased in number from late October to mid-November. *C. territans* larvae were the most commonly collected species from mid-July to mid-October, although larvae

TABLE 1.—Mosquito larvae 3 mm or more in length collected in the Pocomoke Cypress Swamp, Md., on different dates in 1968.

| Date | Number collected (dipping 1¾ hrs among "Q-line" sites). | | | | |
|---|---|---|---|---|---|
| | *Aedes canadensis* | *Culex restuans* | *Culex salinarius* | *Culex territans* | *Culiseta melanura* |
| April 24 | 236 | 68 | 1 | 1 | 0 |
| 29 | 60 | 45 | 3 | 0 | 1 |
| July 16 | 12 | 38 | 52 | 65 | 11 |
| Aug. 29 | 3 | 0 | 21 | 237 | 10 |
| Sept. 6 | 1 | 6 | 29 | 197 | 3 |
| 10 | 13 | 10 | 27 | 188 | 28 |
| 17 | 5 | 22 | 34 | 248 | 19 |
| 27 | 1 | 9 | 24 | 301 | 2 |
| 30 | 0 | 8 | 25 | 165 | 6 |
| Oct. 10 | 0 | 2 | 8 | 274 | 13 |
| 16 | 1 | 39 | 0 | 174 | 13 |
| 22 | 0 | 195 | 0 | 95 | 15 |
| 29 | 0 | 192 | 0 | 13 | 12 |
| Nov. 11 | 0 | 210 | 1 | 18 | 61 |

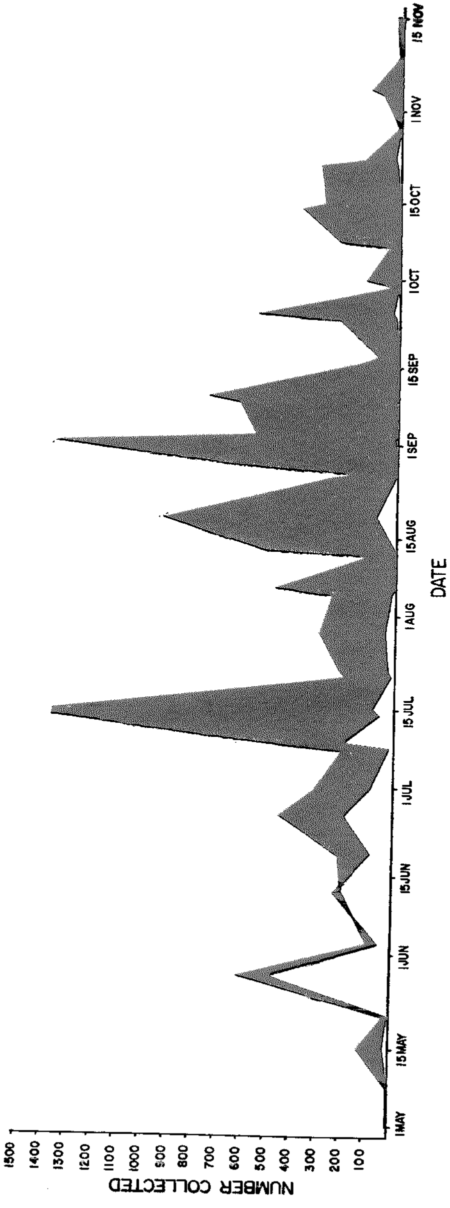


FIG. 2.—Females of *C. melanura* (black graph) and of other mosquito species (white graph) captured in light traps.

of *C. salinarius* were abundant from mid-July to September. Larvae of *Culiseta melanura* were absent in April and somewhat more plentiful in mid-November than at other times.

Overall abundance of larvae differed at sites. Statistical analysis of 13,848 larvae collected from 3–7 square foot holes on the "Q-line" on 10 days between 6 September and 11 November showed ($F=2.96$, $df=6$ and $54$, $.025>p>.01$) that greater numbers of larvae were collected in the center of the study area (20Q=2,986 larvae) than deeper in the swamp (1Q=1,475) or at the river (40Q=1,678). Intermediate numbers of larvae were collected at other "Q-line" sites. *Culex territans* was the most characteristic larval species of larger holes and pools between 1Q and 30Q (Table 2). The larval population at the river (40Q) included *C. restuans, C. salinarius* and *C. territans*, but either larvae of *C. restuans* or of *C. salinarius* predominated, depending upon the time of year (Table 1). *C. salinarius* larvae were restricted to sites near the river, whereas larvae of *C. restuans* were found deep in the swamp (1Q) in October. *Culiseta melanura* larvae were common in the deeper parts of the swamp, where it was the characteristic species of small holes.

Larger numbers of *C. melanura* larvae were found in holes covered with wooden boxes than in adjacent open sites (Table 3). Three species of *Culex* larvae were present in about equal abundance at covered and open sites but represented a greater proportion of the larval population at open sites due to the small numbers of *Culiseta melanura* present.

Larval habitats deep in the swamp were more stable than those near the river. The water table 1,320 feet from the river (20Q) changed noticeably only when there was a rainfall. Each of the 23 water table fluctuations of ½ inch or more, which occurred at 20Q during rains from May to November, showed a gradual increase and decline in water level over several days. In contrast, numerous and rapid fluctuations in water level occurred at the river (40Q) during rainfalls (51 fluctuations of ½ inch or more, May to November, 1968) and at other times (39 fluctuations not associated with rainfall, May to November) which probably reflected small changes in river discharge or a small tidal influence from the Chesapeake Bay (Hulme, 1955). Water tables increased an average of 2.7 inches per inch of rain, but increases at 40Q were consistently greater than those at 20Q by 1.5 inches. Thus, there were fewer fluctuations in water level deep in the swamp, and fluctuations that occurred in the swamp were reduced in intensity.

Larval habitats also differed in certain

TABLE 2.—The composition of mosquito larval populations at sites in the Pocomoke Cypress Swamp, Md., 1968.

| | Percent of all larvae 3 or more mm in length * | | | | |
|---|---|---|---|---|---|
| Site | *Aedes canadensis* | *Culex restuans* | *Culex salinarius* | *Culex territans* | *Culiseta melanura* |
| 1Q | 0 (1) | 20 (66) | 0 (0) | 71 (235) | 9 (30) |
| 10Q | 1 (5) | 0 (0) | 0 (0) | 86 (315) | 13 (46) |
| 15Q | 2 (7) | 0 (0) | 4 (17) | 91 (355) | 3 (13) |
| 20Q | 1 (8) | 34 (276) | 0 (2) | 52 (421) | 12 (99) |
| 25Q | 1 (3) | 28 (142) | 14 (72) | 56 (279) | 0 (2) |
| 30Q | 3 (12) | 8 (28) | 4 (15) | 84 (295) | 1 (3) |
| 40Q | 0 (0) | 54 (219) | 28 (115) | 18 (75) | 0 (0) |
| Small holes | 12 (18) | 2 (3) | 0 (1) | 3 (4) | 83 (124) |
| Pools | 0 (0) | 0 (0) | 1 (1) | 97 (104) | 2 (2) |

* Parentheses give the numbers collected in 3 hrs dipping from IQ to 40Q between 16 July–11 November or in 1½ hrs dipping at small holes and pools between 16 July–27 September.

chemical parameters (Table 4). Sulfates were most abundant near the river (40Q), where concentrations were also larger than expected river concentrations (ppm $SO_4$=15, at Pocomoke City; Hulme, 1955). Dissolved irons were most abundant near the river, whereas suspended irons (total irons of Table 4 minus dis-

TABLE 3.—Mosquito larvae collected from box-covered and uncovered holes between 15 August and 14 November, 1968. Sites dug 8 August 1968.

| | Species of larvae | | | |
|---|---|---|---|---|
| Number collected | *Culex restuans* | *Culex salinarius* | *Culex territans* | *Culiseta melanura* |
| Box-covered site "A" | 0 | 21 | 31 | 131 |
| "C" | 23 | 16 | 44 | 101 |
| Open site "B" | 0 | 3 | 5 | 21 |
| "D" | 4 | 28 | 70 | 1 |
| Sum: box-covered sites | 23 | 37 | 75 | 232 |
| Sum: open sites | 4 | 31 | 75 | 22 |
| Species composition (%) | | | | |
| Box-covered sites | 6.3 | 10.1 | 20.4 | 63.2 |
| Open sites | 3.0 | 23.5 | 56.8 | 16.7 |

TABLE 4.—Chemical analysis of waters in the Pocomoke Cypress Swamp, Md. Samples taken on four days between 15 August and 26 November, 1968.

| | Average ppm (range observed) at site | | |
|---|---|---|---|
| | 1Q | 20Q | 40Q |
| Sulfate (ppm $SO_4$): | 1.8 (1.0–2.0) | 29.4 (1.5–74.0) | >96.0 (54.0–>110) |
| Sulfite (ppm $SO_3$): | 15.5 (13.7–17.0) | 7.0 (5.6–9.8) | 6.2 (3.3–9.8) |
| Dissolved iron (ppm Fe): | 0.3 (0.2–0.5) | 1.1 (0.9–1.6) | 1.3 (0.5–2.2) |
| Total iron (ppm Fe): | 1.3 (0.3–3.0) | 1.2 (1.0–1.7) | 1.4 (0.7–2.2) |
| Turbidity: | 71.3 (44–84) | 27.3 (11–48) | 35.0 (14–74) |
| Silica (ppm $SiO_2$): | 2.8 (1.0–3.9) | 4.8 (1.0–9.3) | >8.8 (2.1–>12) |
| pH: | 4.2 (4.1–4.4) | 3.8 (3.6–4.0) | 4.3 (4.0–4.6) |
| Total phosphates (ppm $PO_4$): | 1.1 (0.5–2.2) | 0.5 (0.2–0.7) | 0.7 (0.1–1.4) |
| Orthophosphates (ppm $PO_4$): | 0.6 (0.1–1.6) | 0.3 (0.2–0.3) | 0.4 (0.1–0.7) |
| Nitrates (ppm $NO_3$): | 2.5 (0.5–5.5) | 1.8 (0.5–3.5) | 1.9 (0.5–4.0) |

solved irons) were frequently more abundant deep in the swamp (1Q). The concentrations of total irons were not different in the swamp from those measured previously in the Pocomoke River at Pocomoke City by Hulme (1955; ppm Fe=1.4).

Sites were similar in acidity of water (pH 4.6 or less), and phosphate and nitrate concentrations were similar at sampling sites. Thus, these parameters showed no influence on larval distribution.

DISCUSSION. Probably adult mosquitoes easily dispersed over the short distances that separated our light-trapping sites, as no differences in species composition were evident. Significant differences in abundance between sites were found only for *Culiseta melanura*, which reached highest densities in the deep swamp (1Q) where *C. melanura* larvae were abundant.

The distribution and abundance of mosquito larvae varied with time of year and spatially along a gradient extending from the Pocomoke River into the swamp. Larvae of *Aedes canadensis* were abundant from spring to early summer, as were adults, but larvae were seldom found later in the season except in small, leaf-choked holes with larvae of *Culiseta melanura*. The seasonal appearance and disappearance of *A. canadensis* larvae probably was a result of physiological requirements of eggs prior to hatching (chilling: Mallack *et al.*, 1964; low dissolved oxygen concentrations: Gjullin *et al.*, 1941).

Larvae of *Culiseta melanura* and *Culex territans* dominated habitats characterized by stable water levels, and low concentrations of dissolved solids but high turbidity, which could not be attributed to dissolved solids since silica and dissolved iron were more abundant at the river. High turbidities probably resulted from an abundance of humic acids, tannins, lignins or other decomposition products. Habitats deep in the swamp were somewhat similar to a fresh-water pond and to a cranberry bog in New Jersey studied by Bast (1963; pH=4.1–4.8, sulfates=8.5–0.4 mg/1 $SO_4$, total iron=0.8–1.4 mg/1), who encountered the same species of larvae as those reported herein with the additions of *Culex pipiens* larvae and *Aedes vexans* larvae.

Larvae of *C. territans* occupied larger sized bodies of water, whereas *Culiseta melanura* larvae preferred smaller and darker holes. In the experiment conducted to determine the effect of light on the species composition of developing larval populations, greater numbers of *C. melanura* larvae developed in box-covered sites. The distribution of these species may have been a result of phototropic responses of egg-laying females, where *C. territans* was photo-positive and where *Culiseta melanura* was photo-negative.

Larvae of *Culex salinarius* were abundant near the river, where frequent flushing by river water probably resulted in higher dissolved oxygen concentrations compared to elsewhere in the swamp. Low dissolved oxygen concentrations possibly limit the development of *Culex salinarius* larvae in the deep swamp (Chapman and Barr, 1969). However, concentrations of dissolved solids (silica, iron and sulfur) also were higher at the river than in habitats of the deep swamp, where larvae of *C. territans* and *Culiseta melanura* predominated. Petersen and Chapman (1969) similarly found that salt concentrations (Ca, Mg, Na, K, Cl) were consistently higher in tree holes and ground cavities where larvae of *C. salinarius* occurred, compared to those where *C. territans* occurred. Thus the distributions of these *Culex* larvae can be related to concentrations of dissolved substances, and the same may be true for larvae of *Culiseta melanura*. Different concentrations of dissolved substances may result in dissimilar bacterial and plankton populations among sites, either in species composition (food quality) or in quantities available to larvae as food. Thus, the distribution of larvae of *C. melanura, Culex salinarius* or *C. territans* may depend upon the availability of suitable food supplies. Conclusions must await further study of larval food supplies and of the effects obtained on larval populations by changing quantity or quality of natural larval food supplies.

Larvae of *C. restuans* were found both deep in the swamp and near the river, although more often at the river. Petersen and Chapman (1969) found this species over a wider range of salt concentrations than larvae of either *C. territans* or *C. salinarius*. Larvae of *C. restuans* have been reported from habitats with high concentrations of inorganic salts (Rapp, 1960). The presence of *C. restuans* larvae in the Pocomoke Cypress Swamp, where inorganic salts were present in relatively meager concentrations, indicates that the distribution of this species probably cannot be correlated with concentrations of dissolved substances.

SUMMARY. *Culiseta melanura* made up 89 percent of female mosquitoes collected in light-traps; *Aedes cantator*, *A. canadensis* and *Culex salinarius* composed 9.6 percent; and 15 other species made up the remaining 1.4 percent. Density of *Culiseta melanura* mosquitoes was greatest deep in the swamp, where *C. melanura* larvae were plentiful, and least on an upland site bordering the swamp. Larvae of *C. melanura, Culex territans, C. salinarius, C. restuans* and *Aedes canadensis* were collected; abundance varied with time of year, location and type of habitat. Larvae of *C. territans* and *Culiseta melanura* were characteristic of stable habitats with low concentrations of dissolved solids. Larvae of *C. melanura* were most plentiful in small leaf-choked holes, whereas *Culex territans* larvae were abundant in larger bodies of water. Larvae of *C. salinarius* and *C. restuans* were characteristic of sites near the river with higher concentrations of dissolved solids and where frequent water fluctuations occurred. Larvae of *A. canadensis* were abundant in the spring everywhere but near the river. Factors which possibly determine the distribution of these species are discussed. Food supplies may determine the larval distribution of some species.

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