# CHEMICAL CHARACTERISTICS OF HABITATS PRODUCING LARVAE OF *AEDES SOLLICITANS, AEDES TAENIORHYNCHUS,* AND *PSOROPHORA CONFINNIS* IN LOUISIANA [1]

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*Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann) are well-known salt-marsh mosquitoes and *Psorophora confinnis* (Lynch-Arribálzaga) is an equally well-known fresh water species. Several investigators (Chapman, 1959; Darsie and Springer, 1957; Dixon, 1957; and Cory and Crosthwait, 1939) have reported the results of chemical analyses of water samples from the larval habitats of the salt-marsh mosquitoes. However, only Micks and McNeill (1963) and Knight (1965) have reported on the chemical characteristics of the soils underlying the breeding areas of these mosquitoes. Knight (1965), in the most extensive study to date, reported that the salinity of waters in the breeding areas had little validity as an indicator of sites that would be selected by ovipositing females and that soil extracts should provide a more reliable measure of the suitability of an area. He found that the minimum level of soluble salts in soils from habitats of *A. sollicitans* and *A. taeniorhynchus* in North Carolina was that which produced an electrical conductivity of 2.6 millimhos/-cm. Since this value was only slightly above the maximum conductivity measured for habitats of *P. confinnis,* Knight concluded that the slight difference might have great biological significance in that it could separate the larval habitats of the three mosquito species. We have on many occasions observed *P. confinnis* and the *Aedes* spp. co-inhabiting breeding sites in marginal marsh habitats. Since *P. confinnis* and the *Aedes* spp. are not generally considered to co-exist in the same larval habitats, this study was undertaken at the Gulf Coast Marsh and Rice Field Mosquito Investigations Laboratory at Lake Charles, Louisiana, to determine the importance of salinity to the presence or absence of these species in these marginal habitats provided by the coastal marshes of southwestern Louisiana.

MATERIALS AND METHODS. The study was made during the summer months from July 1966 through 1968 when the three species were actively breeding. In the first phase, water samples were collected and analyzed from areas producing the three species so specific areas could be selected for soil sampling and more detailed observations. In the second phase, chemical analyses were made of soil from the selected breeding areas. In the third phase, the long-term changes in salinity in selected habitats and the resultant changes in the species of mosquitoes inhabiting them were studied. The presence of larvae in the breeding sites, determined by sampling, was considered indirect evidence that the habitats had been used by ovipositing females of that species. Larvae were also collected to determine the number of species present and the approximate ratios of the three species present.

The soil samples were collected from the selected sites between floodings by using a hollow cylindrical hand tool to take 10 cores at random (6 cm diam. x 5 cm deep). Then the cores from each site were placed together in a plastic bag and returned to the laboratory where they were prepared for analyses as in an earlier study (Petersen and Rees, 1966). The habitats were closely watched for floodings subsequent to the soil sampling since the species and ratios of species in many

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of the habitats changed from flooding to flooding.

The procedures for the chemical analysis were as follows: Electrical conductivity was measured with a Wheatstone bridge and read directly in millimhos per centimeter at 25°C. The concentration of hydrogen ion (pH) was measured with an electric pH meter. The amounts of carbonates and bicarbonates were determined by titration with 0.01 N sulfuric acid and pH meter endpoints; those of calcium and magnesium were determined by the versene procedure. Silver nitrate titration was used to measure the concentrations of chloride, and the barium sulfate turbimetric method was used for sulfates. Sodium and potassium were analyzed by flame spectrophotometry.

RESULTS AND DISCUSSION. In the first phase of the study water samples were collected from 93 habitats that produced one or more of the three species, 51 from habitats producing only *P. confinnis*, 11 from habitats producing only the *Aedes* spp., and 31 from areas producing both *P. confinnis* and the *Aedes* spp. at the time of sampling (Table 1). The salinity of the sites ranged from a low in rain water (0.1 millimhos/cm) to a high in tide water (35.0 millimhos/cm). All sites were well within the flight range of ovipositing females of all three species.

The conductivity of habitats producing only *P. confinnis* (1.8 millimhos/cm) averaged less than one-ninth that of habitats producing only the *Aedes* spp. (17.5 millimhos/cm); habitats that produced both *P. confinnis* and the *Aedes* spp. had average conductivities of 5.9 millimhos/cm. All habitats producing *P. confinnis* (82 samples) had an average 3.9 millimhos/cm compared with 9.3 millimhos/cm for all those producing *A. sollicitans* (29 samples), and 11.9 millimhos/cm for all those producing *A. taeniorhynchus* (26 samples). However, the averages may be somewhat misleading; 21 of the 82 samples containing *P. confinnis* had conductivities in excess of 5.0 millimhos/cm, 7 were above 10 millimhos/cm, and 3 were above 20 millimhos/cm. In comparison, 29 of the 42 habitats producing one or both *Aedes* spp. had values less than 10 millimhos/cm and 18 were below 5 millimhos/cm.

The concentrations of hydrogen ions (pH) were similar in the habitats of all three species; 91 percent of the 93 samples ranged in pH from 6.0 to 8.4. However, five sites had values ranging between 3.3 and 5.9 and were associated with oil drilling; two of the five possessed *A. sollicitans*, three contained *A. taeniorhynchus*, and four contained *P. confinnis*. Only two sites had values above 8.4 (8.8 and 9.2), and both contained *P. confinnis* only.

Habitats producing *Aedes* spp. characteristically had concentrations of both chlorine and sodium ions that were several times higher than those producing *P. confinnis*. The differences were greater than but varied similarly with those of conductivity, but a wide range of overlap was observed for both ions. Also, calcium and magnesium varied similarly, but the differences were not as pronounced as with chloride and sodium. Concentrations of potassium, sulphates, carbonates, and bicarbonates were generally low in all samples, and little difference was found between the habitats of the three species.

In June 1967 and again in May 1968, 30 marginal sites were selected for soil analysis from the original 93 sites. None were influenced by agricultural practices or irrigation, and all were in areas grazed by cattle. Seven samples were discarded because the habitats from which they were taken did not produce larvae when flooded or did not hold water long enough to permit larval sampling. Twenty of these 53 sites (in the two years) produced *Aedes* spp., and 10 produced *P. confinnis* exclusively (Table 2). Values of specific ions for the sites producing *Aedes* spp. only averaged three times higher for potassium and as much as seven times higher for chloride than habitats producing only *P. confinnis*.

Concentrations of sulfate, carbonates, and bicarbonates were low and little difference was evident between habitats. Also, concentrations of hydrogen ion were

TABLE 1.—Chemical analyses of water samples from larval habitats of *Aedes sollicitans*, *Aedes taeniorhynchus*, and *Psorophora confinnis*.

| Species | Number of Samples | Conductivity (millimhos per cm) | Range of pH | Range and Average (in Parentheses) Expressed as Milligram Equivalents per Liter of | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $SO_4^{=}$ |
| *P. confinnis* only | 51 | 0.10–14.5 (1.8) | 5.0–9.2 | 0.08–13.2 (2.8) | 0.08–20.4 (2.1) | 0.09–148 (12.9) | 0.05–3.1 (0.56) | 0.10–114 (14.3) | 0.04–3.0 (0.52) |
| *A. sollicitans* only | 6 | 0.80–26.5 (10.3) | 3.5–7.7 | 1.4–16.0 (10.4) | 1.2–44.8 (18.6) | 4.6–181 (82.0) | 0.51–6.9 (2.5) | 3.3–228 (91.0) | 0.21–7.2 (3.6) |
| *A. taeniorhynchus* only | 2 | 13.0–21.2 (17.2) | 4.3–8.0 | 16.0–17.6 (16.8) | 28.0–41.6 (34.8) | 117–130 (123) | 3.0–6.5 (4.7) | 166–168 (167) | 4.2 — |
| *P. confinnis* + *A. sollicitans* | 10 | 0.8–11.0 (4.0) | 3.9–7.7 | 1.1–16.0 (5.2) | 0.2–20.8 (6.9) | 0.57–91.3 (29.1) | 0.46–4.2 (1.4) | 3.0–106 (36.1) | 0.46–4.9 (2.8) |
| *P. confinnis* + *A. taeniorhynchus* | 11 | 1.9–33.0 (8.3) | 3.3–7.8 | 2.8–24.0 (10.0) | 1.2–29.6 (9.8) | 10.9–191 (57.8) | 0.51–6.9 (2.4) | 9.6–217 (70.3) | 0.20–6.7 (1.5) |
| *A. sollicitans* + *A. taeniorhynchus* | 3 | 30.0–35.0 (32.0) | 6.7–7.8 | 15.2–48.8 (30.6) | 30.4–93.6 (58.9) | 200–309 (238) | 7.4–13.0 (9.7) | 255–424 (314) | 8.0–10.0 (8.8) |
| *P. confinnis* + *A. sollicitans* + *A. taeniorhynchus* | 10 | 1.8–26.0 (8.7) | 6.7–8.1 | 1.5–29.6 (10.7) | 1.7–40.8 (12.7) | 10.9–178 (58.0) | 0.51–6.1 (2.2) | 10.6–216 (75.1) | 0.20–7.6 (2.8) |
| Total *P. confinnis* | 82 | 0.10–33.0 (3.9) | 3.3–9.2 | 0.08–29.6 (5.0) | 0.08–40.8 (5.0) | 0.09–191 (26.4) | 0.05–6.9 (1.1) | 0.10–217 (31.9) | 0.04–7.6 (1.2) |
| Total *A. sollicitans* | 29 | 0.80–35.0 (9.3) | 3.5–8.1 | 1.1–48.8 (10.8) | 0.2–93.6 (16.7) | 0.57–309 (71.9) | 0.46–13.0 (2.7) | 3.0–424 (89.4) | 0.20–10.0 (3.4) |
| Total *A. taeniorhynchus* | 26 | 1.8–35.0 (11.9) | 3.3–8.1 | 1.7–48.8 (13.1) | 1.2–93.6 (18.5) | 10.9–309 (77.8) | 0.51–13.0 (3.3) | 9.6–424 (95.3) | 0.20–10.0 (2.9) |

TABLE 2.—Chemical analyses of soils from breeding sites of larvae of *P. confinnis*, *A. sollicitans*, and *A. taeniorhynchus*.

| Percentage of Given Species Present | | Total Number of Samples | Conductivity of Sample (millimhos/cm) | Range and Average (in Parenthesis) Expressed as Milligram Equivalents per Liter of | | | |
|---|---|---|---|---|---|---|---|
| *P. confinnis* | *A. sollicitans* + *A. taeniorhynchus* | | | $Ca^{++}+Mg^{++}$ | $Na^+$ | $K^+$ | $Cl^-$ |
| 100 | 0 | 10 | 0.13–1.3 (0.39) | 1.1– 6.6 (2.92) | 0.52–15.6 (4.12) | 0.18–0.87 (0.40) | 0.6–19.9 (4.09) |
| 76–99 | 1–25 | 5 | 0.15–1.4 (0.46) | 1.2–12.6 (3.89) | 0.83–13.0 (4.71) | 0.20–1.2 (0.45) | 0.6–13.3 (4.00) |
| 51–75 | 26–50 | 3 | 0.35–0.70 (0.50) | 2.2– 6.0 (3.79) | 2.9 – 8.1 (5.57) | 0.20–0.87 (0.50) | 4.8– 6.3 (5.60) |
| 26–50 | 51–75 | 3 | 1.1 –1.3 (1.37) | 10.3–12.3 (11.1) | 7.0 –19.1 (13.5) | 1.0 –1.3 (1.15) | 8.1–21.5 (15.6) |
| 1–25 | 76–99 | 12 | 0.3 –2.2 (1.67) | 3.0–14.3 (7.73) | 2.7 –29.1 (14.8) | 0.35–1.3 (0.95) | 2.2–37.4 (19.4) |
| 0 | 100 | 20 | 0.70–4.0 (1.88) | 2.0–30.4 (9.86) | 6.2 –52.2 (24.6) | 0.51–2.1 (1.24) | 7.6–73.0 (28.9) |

similar in all samples. The average salinity increased as the ratio of *Aedes* spp. to *P. confinnis* increased. (However, as with the samples of water, a large overlap was found in the ranges of salinity.) Two soil samples from habitats producing *P. confinnis* had conductivities of 2.1 and 2.25 millimhos/cm; the five samples with conductivities above 2.25 (2.4–4.0) produced *Aedes* spp. only (Table 3). Moreover, the percentage of habitats that produced *P. confinnis* decreased steadily as salinity increased (to 2.25 millimhos/cm), but some *A. sollicitans* and *A. taeniorhynchus* were found breeding at sites with all levels of conductivity. Also, *Aedes sollicitans* were collected in essentially all habitats that had conductivities in excess of 0.6 millimhos/cm but only in one-third of the habitats with conductivities below 0.6 millimhos/cm though they were present in the samples with the lowest salinity (0.15 millimhos/cm). The number of samples containing *A. taeniorhynchus* was low, but the same general trend was evident as with *A. sollicitans.*

Table 3.—Percentage of larval collections containing *Psorophora confinnis, Aedes sollicitans,* and *Aedes taeniorhynchus* at various conductivities from soil analyses.

| Range of Conductivity (millimhos/cm) | Number of Samples | Percentage of Collections Containing | | |
|---|---|---|---|---|
| | | *P. confinnis* | *A. sollicitans* | *A. taeniorhynchus* |
| 0–0.5 | 16 | 100 | 31 | 25 |
| 0.6–1.0 | 7 | 71 | 100 | 57 |
| 1.1–1.5 | 13 | 61 | 92 | 54 |
| 1.6–2.0 | 7 | 43 | 100 | 71 |
| 2.1–2.5 | 7 | 29 | 100 | 86 |
| 2.6 and up | 3 | 0 | 100 | 33 |

We observed that most habitats changed continuously and could not be classified as producers of any one particular species. Therefore, 17 sites within three marginal marsh areas were observed continuously during the summer of 1968. Also, whenever possible, the conductivity of the water was tested once a month for each site (no samples were obtained in August because of unusual dryness). Larval collections were made during May and September. All 17 sites were subject to both rain and tidal floodings but some were more subject to tidal floodings than others because of elevation. The salinity generally increased during May over that in April in the three areas, but substantial rains and no tidal action caused a gradual leaching away of salt through June and July. Then tidal action in September and October raised the salinity to the levels prevailing in April and May.

During May, in the Texaco area, *P. confinnis* was the most abundant species in sites with conductivities below 4.2 millimhos/cm, was less abundant in habitats with conductivities as high as 5.3 millimhos/cm, and was absent in those with conductivities above 5.3 millimhos/cm. In contrast, *P. confinnis* tended to comprise a large percentage of the larvae produced by all the Texaco sites in September when no site exceeded a conductivity of 4.0 millimhos/cm. At the Grand Lake area, little change was noted in the breeding of *P. confinnis* in individual sites, but the only site to produce *P. confinnis* in both May (4.8 millimhos/cm) and September (2.0 millimhos/cm) was the site with the lowest salinity. Also, little change was observed in breeding at the Hackberry site during May and September. However, two of these sites were generally much lower in salinity than the others and were the only ones to produce larvae of *P. confinnis.* The heavy rainfall in June and July did not permit meaningful sampling of larval populations; only three samples collected in October contained *P. confinnis,* primarily because of the lateness of the season and the cool weather that apparently activated winter diapause in this species.

Salinity therefore appears to be a major factor in restricting the breeding of *P. confinnis* in salt marshes, but the exact concentration of salts necessary to prevent breeding by this species is difficult to define. As mentioned, the chemistry of the water from habitats producing *P. confinnis* and the *Aedes* spp. is generally quite different, but habitats producing *P. confinnis* had salinities ranging as high as 33.0 millimhos/cm. However, such habitats probably resulted because the eggs were oviposited while the sites had low salinities and were then flooded with tide water or with a combination of rain and brine water from oil drilling operations.

The salinity of the soil in sites having or not having *P. confinnis* had a narrower range of conductivities but it was also subject to variation, perhaps because eggs from an earlier oviposition hatched or because changes in the habitats occurred between the time of soil sampling and the collection of the larval samples. No attempt was made during the soil analyses to determine the actual salinity in the natural soils but only to determine whether there were differences in salinity. Therefore, direct comparisons cannot be made between the salinity of the water and the much lower readings obtained from the soil analyses.

In the laboratory, *P. confinnis* has avoided concentrations of sodium chloride above 0.06M, and eggs of this species are killed when oviposited on concentrations of 0.15M NaCl (Petersen, 1969). This preference of the ovipositing females appears to be the main reason why the species is restricted to sites with low salinity. However, lack of tolerance of the freshly laid eggs may also play a role.

Little difference was observed between habitats producing *A. sollicitans* and *A. taeniorhynchus*. Both species were found breeding over the entire range of salinity. Also, in the laboratory, both species readily oviposited on salt-free sites (Petersen, 1969). Therefore, salinity may not be the only factor attracting and/or restricting these *Aedes* spp. to salt-marsh type habitats.

SUMMARY. Marginal salt marsh habitats in southwestern Louisiana that regularly produce *P. confinnis, A. sollicitans,* and/or *A. taeniorhynchus* were studied. Samples of the water and the soil samples from these sites were analyzed, and selected breeding sites were observed continuously. The salinity of both water and soil averaged several times higher for habitats producing the *Aedes* spp. than for habitats producing *P. confinnis;* the differences were most evident with chloride and sodium ions. The *Aedes* spp. were collected over the entire range of salinity.

Salinity appears to be the major factor restricting the breeding of *P. confinnis* in the salt-marsh areas, but it may not be the only factor attracting and/or restricting the *Aedes* spp. to salt-marsh type habitats.

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